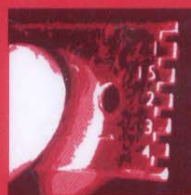


The INSPECTION of COATINGS and LININGS

**A Handbook
of Basic Practice
for Inspectors,
Owners,
and Specifiers**

SSPC 97-07

 **SSPC**
the society for protective coatings



The Inspection of Coatings and Linings:

A Handbook of Basic Practice for Inspectors, Owners, and Specifiers

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The techniques, procedures, regulations, and other information presented in this volume have been reviewed by experts in each field and are believed to represent good current practice. They will be monitored and revised as practices improve, and suggestions for revision are welcome.

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Acknowledgement

Several years ago, SSPC undertook the task of preparing a broad-scope handbook, covering all aspects of coatings inspection. To accomplish this, an SSPC Inspection Manual Committee was formed with Dean Berger as chairman and Richard Drisko as co-chairman. Starting in 1984, this committee met each year at the annual SSPC meeting. Drafts of some chapters were prepared as early as 1986.

At the 1989 SSPC Annual Meeting, a new strategy was adopted to produce a quality handbook in a more timely manner. The format of the handbook was changed and several sections were eliminated, most notably, surveying of existing coated structures, economics of inspection, failure analysis, and inspection of coated non-ferrous metals.

SSPC extends its sincere appreciation and congratulations to the following individuals who have been instrumental in the completion of this major task:

- Dean Berger - As chairman of the Inspection Manual Committee, he has served as technical reviewer for the entire book.
- Richard W. Drisko - As co-chairman of the Inspection Manual Committee and Senior Writer/Editor for SSPC, he has served as technical reviewer for the entire book. He has also provided many of the photos for the book and authored several sections.
- Jack Delahunt - As coordinator of Chapter 6 (Inspection of Facilities), he has served as technical reviewer for the many sections of this chapter.
- Al Hendricks - As coordinator of Chapter 5 (Inspection of Specific Coating Materials), he has served as technical reviewer for the many sections of this chapter.
- Harold Hower - As publisher of JPCL and former Director of Publications for SSPC, he provided many of the original ideas for the handbook, and extensive information for the Glossary and list of Inspection Equipment Suppliers.
- Stephen G. Pinney - As main author of Chapter 4 (Basic Inspection Practice), he has served as technical reviewer for a large part of the book. He and his firm, S.G. Pinney & Associates, Inc., have also provided many of the photos for the book.
- Kenneth B. Tator - As author of Chapter 2 (Inspection Personnel) and Chapter 6.4 (Bridges) he has served as technical reviewer for a large part of the book. He and his firm, KTA-Tator, Inc., have also provided many of the photos for the book.

SSPC would also like to thank the following:

- The numerous committee members, expert authors, and technical reviewers who have contributed to this book. A biographical sketch of each author, as well as a list of technical reviewers, is included at the end of each chapter.
- The numerous individuals and companies who provided photos for this book. Photo credits are listed at the end of each photo caption. SSPC also gratefully acknowledges the support of its members who, over the years, provided the photos marked "SSPC file photo," initially for use in various publications, training courses, and presentations.

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Chapter 1

Introduction to the Handbook

by SSPC Staff

OUTLINE

- I. What this Handbook Is
- II. Scope and Intended Audience
- III. The Need for Quality Inspection
- IV. The Cost of Inspection
- V. The Value of Inspection
- VI. Organization - Summary of Each Chapter
- VII. Use of this Handbook
- VIII. Summary
- IX. References

I. WHAT THIS HANDBOOK IS

This handbook is a comprehensive compilation of information, procedures, standards, techniques, and practices needed for effective inspection of coatings and linings applied to industrial structures. Its primary purpose is to provide coatings inspectors with the resources and guidance to effectively perform the work of inspection. This forms an important part of SSPC's larger mission to advance the technology and promote the use of coatings to preserve industrial structures.

This handbook brings "under one cover," the body of materials that may be needed to define, understand, and conduct a coatings inspection. It builds on the material covered in other documents, standards, and books relating to inspection. Standard procedures and practices from ASTM, NACE, and SSPC are heavily referenced, along with other documents that provide additional detail or insight into the inspection process. While primarily

intended for coatings inspectors, the information in this handbook is also applicable to specifiers, applicators, suppliers, and others associated with the use and application of protective coatings for industrial structures.

II. SCOPE AND INTENDED AUDIENCE

This handbook focuses on the inspection of coating and lining work on industrial steel and concrete structures (Figure 1-1). It includes procedures for the inspection of surface preparation, coating application, and associated work, as well as procedures for examining and testing newly-applied coatings and linings (Figure 1-2).

The coatings inspection addressed in this handbook involves independent checking or testing of various aspects of coating work to determine whether the standards established in the job specification are met, i.e., the type of inspection typically performed by a professional coatings inspector employed by the owner, the applicator, or an independent inspection firm. It does not address "informal" inspection done by the worker, the supervisor, or others involved directly in the operations. It also does not include procedures for surveying existing coated structures or conducting coating failure analyses, since these are more the responsibilities of specially trained scientists or engineers. However, laboratory analyses are briefly mentioned to advise the inspector as to what laboratory tests are available should problems occur.

FIGURE 1-1. Industrial structures on which coatings inspections may be performed. Top - Bridge. Courtesy of KTA-Tator, Inc. Bottom - Tank. Courtesy of Tank Industry Consultants, Inc.



The intended audience of this handbook includes:

- Coatings inspectors. They can consult the handbook for guidance on inspection procedures for both standard cleaning/coating operations and those for specialty coatings and structures
- Specification writers. They can use the handbook to identify standards and special industrial inspection practices to be referenced in job specifications
- Owners. They can derive from the handbook a basic understanding of what inspection practices are available, how these practices are suited to particular needs, and how they are properly utilized.

- Project engineers, supervisors, and structural and maintenance engineers involved in coating work. They can obtain from the handbook general knowledge about the importance of the inspection process and how to utilize it most effectively
- Applicators. They can use the handbook to get an understanding of the basic procedures and criteria they must conform to when undertaking protective coatings work.

III. THE NEED FOR QUALITY INSPECTION

Most coating contracts involve the investment of significant sums of time and money, and the inspector plays a critical role in ensuring that the owner receives a return on this investment. With a well-written job specification in hand, the owner requires a thorough inspection to establish that the requirements of the specification are met and that work is completed in a timely and satisfactory manner (Figure 1-3). Inadequate or improperly conducted inspections can result in:

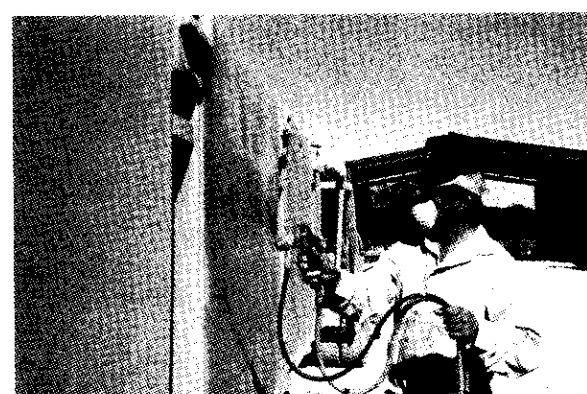
- Costly delays in completion of the work
- Less quality or quantity of work than specified
- Contractual disputes and years of litigation
- Costly replacement of inadequately protected structures and/or equipment
- Costly maintenance of inadequate coatings
- Environmental contamination
- Accidents

IV. THE COST OF INSPECTION

Inspection should be considered an essential component of a coatings project and of its cost. Inspection costs may be direct or indirect, and will reflect items such as training and company overhead.

Direct costs include the cost of the inspector's time, travel, and materials. Other direct costs are the costs for the applicator to provide access to the structure and for the applicator's time in meetings and discussions regarding the inspection procedure and results. Pre-job meetings with the applicator, inspector and owner must also be taken into account as a direct cost.

FIGURE 1-2. Examples of the type of work that the inspector must monitor. Top - Blast cleaning. Courtesy of Tank Industry Consultants, Inc. Center - Troweling. SSPC file photo. Bottom - Spraying. Courtesy of Inorganic Coatings, Inc.



Indirect costs to the owner include additional time that may be required to perform the inspection. Added to this is the time that the facility or process will be shut down or inaccessible. If there is rework required, it will increase the time before the job is complete and will require additional inspection time on the job.

Depending on the size of the job, the cost of coatings inspection is typically in the range of 5 -18% of the cost of the coating portion of the project (1). Generally, the more stringent the quality control and inspection requirements (e.g., nuclear facilities), the higher the percentage of the cost will be the inspection. Extensive documentation requirements will also increase the cost of inspection, sometimes unnecessarily.

V. THE VALUE OF INSPECTION

The value of coatings inspection is much more difficult to quantify (2). Inspection is a form of insurance for the owner. It greatly decreases the risk of early or catastrophic failure. Inspection also increases the likelihood that the coatings will provide the full intended service life and attributes (e.g., appearance) of the coating system over a long period of time. A large number of specifiers have come to recognize the value of inspection to the success of a coatings project. Unfortunately, it may take an expensive failure, on a program where inspection was ignored or under-utilized, to demonstrate the true value of inspection.

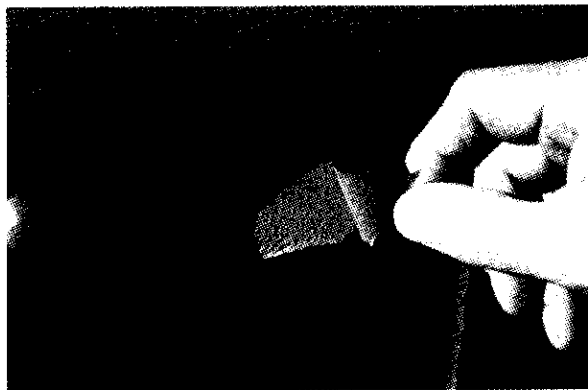
VI. ORGANIZATION - SUMMARY OF EACH CHAPTER

Chapter 2, Inspection Personnel, addresses the question, "Who is the coatings inspector?" It discusses the basic skills and qualifications required of a coatings inspector, such as:

- Physical requirements
- Training
- Communication skills
- Ethics and judgement

Typical capability levels of inspectors (based on education, training, and experience) are also described. The coatings inspector may be employed by the owner, the

FIGURE 1-3. Some of the possible consequences of omitting inspection from a job. Top - Peeling paint. SSPC file photo. Bottom - The consequences of painting over millscale. SSPC file photo.



applicator, or an independent inspection firm, but in all cases must have certain basic skills and qualifications.

Chapter 3, Reviewing and Preparing Inspection Documents, describes how the inspector uses documentation to verify that the applicator's work is in complete compliance with the specification. It presents an overview of the contents of the job specification and associated documents. It also provides suggestions for preparing inspection forms and recording observations and measurements during the inspection. The inspector's documentation and timely intervention help assure the performance of coatings, and his records can also provide an audit trail in the event of coating failure.

Chapter 4, Basic Inspection Practice, describes the basic procedures that the inspector uses to verify that the applicator's work is in complete compliance with the specification (Figure 1-4). These procedures, many of which are common to all coatings jobs, include observation, examination, and measurement. They can be classified as follows:

- Preliminary Inspection Responsibilities (e.g., inspection of jobsite conditions, materials, equipment, and ambient conditions)
- Inspection of Surface Preparation
- Inspection of Coating Application (including mixing and thinning)
- Post-Application Inspection

Chapter 5, Inspection of Specific Coating Materials, is divided into sub-chapters. The first sub-chapter covers the properties of several "conventional" coatings, i.e., those with relatively straightforward inspection requirements as described in Chapters 3 and 4. The remaining sub-chapters cover a variety of specialty coatings and linings used today to protect steel and concrete:

- Chemical-Resistant Brick and Tile Linings
- Coal Tar Coatings
- Elastomeric Polyurethanes, Thick-film
- Fiberglass-Reinforced Plastic (FRP) Linings

FIGURE 1-4. The coatings inspector in action. Courtesy of Elcometer Instruments Ltd.



- Fluoroelastomeric Coatings
- High Bake Phenolic and Epoxy Phenolic Coatings
- Powder Coatings
- Rubber Linings, Natural and Synthetic
- Shotcrete
- Tapes
- Thermal Spray Metallic Coatings for Steel
- Thermoplastic Sheet Linings
- Zinc-Rich Coatings, Inorganic

For these specialty coatings and linings, inspection requirements are presented that extend beyond the basic procedures outlined in Chapter 4.

Chapter 6, Inspection of Facilities, provides an overview of coating and lining operations in a variety of industrial facilities. The first sub-chapter covers inspection of storage tanks; the second, inspection of pipelines. The third sub-chapter covers the special topic of underwater inspection. The remaining sub-chapters of Chapter 6 cover a variety of structures and industrial facilities:

- Bridges
- Ship Hulls
- Locks, Dams, Spillways, and Their Appurtenances
- Offshore Facilities
- Refineries and Petrochemical Plants
- Food and Beverage Processing Plants
- Water and Wastewater Treatment Plants
- Pulp and Paper Mills
- Nuclear Power Plants
- Fossil Fuel Power Plants

In each sub-chapter, inspection requirements are presented that extend beyond the procedures outlined in Chapters 4 and 5. In addition, some information is provided about the exposure environments, typical coatings used, and safety precautions in each facility.

Chapter 7, Safety, presents basic safety information for the coatings inspector (Figure 1-5). The following topics are addressed:

- Safety and health regulations, and how to obtain information about them
- Hazards encountered in coatings work--divided into hazardous materials, hazardous environments, and hazardous activities
- Safety practices
- Safety monitoring equipment - Appendix

Surface preparation and coating application inherently present some dangers because of hazardous materials (e.g., solvents), hazardous conditions (e.g., working at heights), and hazardous activities (e.g., working with pressurized blast nozzles). Coatings inspectors should be familiar with all basic safety requirements and have access to the pertinent documents, codes, and standards when necessary to make decisions concerning safety.

FIGURE 1-5. Safety hazards that the inspector may encounter. Top - Lack of proper fall protection. Bottom - A potential fire hazard. Both SSPC file photos.



Chapter 8, Field Test Methods and Instruments Used by Inspectors, provides detailed procedures for the tests and measurements performed by coatings inspectors. The inspector uses instruments to determine whether dimensional requirements such as surface profile and film thickness meet the specification, and to identify pinholes in the film which are invisible to the naked eye. The inspector also routinely uses standards (e.g., for surface preparation) and tests. It is particularly important that the inspector understand the values and limitations of the instruments (principle of operation, accuracy, and calibration), standards, and tests that he uses during inspection.

Appendixes in this handbook are:

- **Abbreviations and acronyms** used in the handbook
- **Glossary** of industry and inspection terms
- **Standards referenced** in this book - The latest issue, revision, or amendment of the reference standards should be used unless otherwise specified.
- **Regulations referenced** in this book.
- **Standards-issuing organizations and regulatory agencies** - names and addresses
- **Inspection equipment** - a list of the basic equipment needed for coatings inspection
- **Inspection equipment manufacturers and suppliers** - names and addresses
- **Bibliography** - reference works and further reading on coatings inspection

VII. USE OF THIS HANDBOOK

This handbook constitutes one volume of the revamped and expanded Steel Structures Painting Manual. It can be used as a comprehensive reference source on inspection. It can also be used to guide an inspector, specifier, or applicator on the procedural technique for a specific application. Three examples are given below:

- An inspector needs a guide to a specific inspection assignment, for example, a food and beverage processing plant. To prepare himself, he could read the following chapters:
Chapter 4, Basic Inspection Practice
Chapter 7, Safety
Chapter 6.9, Food and Beverage Processing Plants

Applicable sub-chapters of Chapter 5 on specific coatings and linings

- A specification writer is writing a specification, for example, for coating of pipelines with a coal tar enamel system, and needs to know what requirements should be called out. She could find examples of requirements in Chapter 5.3, Coal Tar Coatings, and Chapter 6.2, Pipelines.
- A supervisor is preparing to apply a coating he has never worked with before, for example, a fiberglass reinforced plastic lining. To prepare himself and his workers, he could consult Chapter 5.1, Conventional Coatings (for information on polyester and vinyl ester linings), and Chapter 5.5, Fiberglass Reinforced Plastic (FRP) Linings.

VIII. SUMMARY

Coatings inspection is an important means of ensuring that the specified level of work is achieved. A coatings inspector is a professional with specific knowledge and experience, whose chief responsibility is to verify that the requirements of the specification are met. To accomplish this, the inspector uses certain standard procedures, instruments, and tests. The inspector is also responsible for preparing documentation of the inspection process. In general, all coatings inspections involve a set of basic inspection procedures; however, specific responsibilities vary from job to job, depending on the coating(s) and the facility being inspected. Like other workers, the coatings inspector may face many on-the-job hazards. The inspector must therefore be familiar with a variety of safety issues and basic safety practices.

IX. REFERENCES

1. Pinney, Steven G., "Coating Inspection: Is It Worth It?" in *The Economics of Protective Coatings*, SSPC Proceedings, Baltimore, November 1988, p. 68. [SSPC 88-03]
2. Walter W. Kaminski and J.R. Allen, "What is Inspection Worth?," JPCL, August 1984, p. 30.

ACKNOWLEDGEMENT

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Chapter 2

Inspection Personnel

by Kenneth B. Tator

OUTLINE

- I. Scope
- II. References
- III. Coatings Inspector Requirements
 - A. Physical Requirements
 - B. Training
 - C. Communication Skills
 - D. Ethics and Judgement
 - E. How Many Inspectors are Needed for a Particular Job?
- IV. Capability Levels of Coating Inspection Personnel
 - A. Level I Inspector
 - B. Level II Inspector
 - C. Level III Inspector
- V. Summary

I. SCOPE

This chapter describes the professional and personal requirements of coatings inspectors. It also identifies sources of inspector training and certification, and describes capability levels of inspectors.

II. REFERENCES

American National Standards Institute (ANSI)

ANSI/ASME N45.2.6 Qualifications of Inspection, Examination, and Testing Personnel for Nuclear Power Plants (replaced by ANSI/ASME NQA-1-1994)

ANSI/ASME NQA-1-1994 Quality Assurance Requirements for Nuclear Facility Applications (replaces ANSI/ASME N45.2.6)

American Society for Testing and Materials (ASTM)

ASTM D 4537 Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear Facilities

III. COATINGS INSPECTOR REQUIREMENTS

The coatings inspector may be employed by the owner, the applicator, or an independent inspection firm. In all cases, however, the inspector must meet certain professional and personal requirements. Although specific requirements may vary depending on the nature and purpose of the inspection job, they generally include physical ability, training, and experience, as well as verbal and written communications skills, and certain character traits. The inspector must be properly prepared to respond to all inspection needs.

FIGURE 2-1. Inspector using special equipment to access an elevated tank. Courtesy of Tank Industry Consultants, Inc.



A. PHYSICAL REQUIREMENTS

The inspector must have the physical capabilities to meet all of his work requirements. The inspector should be physically fit and be able to access the work area in which the inspection operation is conducted, using special equipment as necessary to allow the work to be conducted safely and as specified (Figure 2-1). In general, the inspector should be able to climb towers or crawl into tight spaces without fear, and to lift weights of up to 25 lbs. (11 kg). The inspector's vision must be correctable close to 20/20 and be free of such defects as color blindness. The inspector should have the dexterity to mark areas of deficient workmanship.

B. TRAINING

The inspector should be trained through formal courses in the following areas: the fundamentals of corrosion and its control by protective coatings, procedures for surface preparation and coating application, and hands-on instruction in the calibration and use of quality control instruments. Available training courses for coatings inspectors include:

- NACE International's coating inspector certification program
- SSPC tutorials, and general and specialized training courses

- Industry courses
- Community college and trade school courses

The inspector may also achieve training through prior experience, on-the-job experience, proper supervision and adequate jobsite instruction. All of these contribute toward good inspection work. On-the-job training is best obtained by working under the supervision of an experienced inspector. The supervising inspector should monitor the trainee's work regularly to ensure that the standard test procedures and practices are routinely followed and that quality documentation results.

Whether through formal training or experience, the inspector should also be knowledgeable in all the applicable standards required by the project's coating specification. There are numerous standards relating to coating work. Many of these are listed in Chapter 4.

Once trained, the inspector should keep abreast of new technical developments in his field (e.g., new techniques, equipment, and regulations) through membership in SSPC and other technical associations, and by reading technical journals and attending seminars and conferences.

C. COMMUNICATION SKILLS

The inspector must be able to communicate verbally in a concise, professional, impartial manner. The inspector should be patient and calm at all times, and not be excitable, arrogant, or rude. Inspection should not be a demeaning, confrontational process. Deficient work should be identified and, if necessary, marked and documented. The worker (and, if appropriate, the supervisor), and all involved inspectors should discuss and/or agree what corrections may be required to meet the job specification requirements.

The inspector must also have good writing skills, and be able to provide clear documentation to establish whether the specification requirements have been met. Written documentation may be of great value in the event of a dispute, a future coating problem, or a change in personnel (Figure 2-2).

In the event of a dispute, the inspector should attempt to resolve all differences of opinion as rapidly as possible in accordance with established procedures. Any unclear areas in the specification should be resolved at the pre-construction



FIGURE 2-2. Inspector filling out inspection documentation. Photo by Richard W. Drisko, SSPC.

tion conference; or through clarification by the owner's representative, the project engineer. Any apparent specification deviations detected by the inspector in the work should be immediately discussed with the applicator's representative at the jobsite. If the discrepancy cannot be resolved at that level, the inspector should report it both verbally and in writing to the project engineer. The inspector does not normally have the authority to stop the work or to lower the specification requirements to meet the quality of the work performed. Only the owner or his representative has this authority.

D. ETHICS AND JUDGEMENT

The inspector must have high personal integrity and a strong work ethic to provide quality monitoring and be fair to all parties in the contract. This requires documentation that is clear, impartial and sufficiently detailed, such that it can stand up to any challenge (Figure 2-3). The inspector should not impose personal standards of quality or workmanship, and must remain constantly aware that the criteria for work acceptance are the job specification requirements, not some preconceived personal viewpoint as to "what will give the best performance," "what the boss would like," or "what will work."

It must be understood during the conduct of any coating work project that the specification, even if comprehensive

and well-written, cannot cover all possible problems that might arise. Accordingly, some knowledgeable judgement on the part of the applicator and the inspector will occasionally be required. However, the inspector should make no decisions that modify or interpret job specification requirements that are not approved by the owner's representative.

The inspector should support the applicator by advising him as early as possible when surface preparation or coating application techniques must be modified to meet job specification requirements. This will save the applicator additional work and money that would otherwise be spent to take corrective actions. This will also serve the owner by accelerating the work. The inspector should try to anticipate problems that may arise and have them addressed before they result in delays. In other cases, inspection may identify an area where clarification of the specification requirement may be necessary.

The "Coating Inspector's Attestation," reproduced on Page 11, further illustrates how the inspector must continuously strive to maintain high personal integrity and a strong work ethic. NACE International uses this attestation in its inspection training courses and peer reviews. Each course attendee and peer review (certification) candidate is required to sign the attestation. It then becomes a part of their permanent record.

FIGURE 2-3. Inspection documentation may be used as legal evidence. Illustration by Jerry Sweeney. Courtesy of the *Journal of Protective Coatings and Linings*.



E. HOW MANY INSPECTORS ARE NEEDED FOR A PARTICULAR JOB?

The amount and type of inspection will vary according to the size of the project and the type of application contract. A general rule is that one inspector can monitor no more than 20 journeymen.

IV. CAPABILITY LEVELS OF COATING INSPECTION PERSONNEL

Coatings inspectors can be categorized by experience and education into capability levels. A typical categorization groups inspectors into three levels, Level I, II, or III (see ASTM D 4537 and ANSI/ASME N45.2.6). Candidates for certification as coatings inspectors should have sufficient education, experience, and training to ensure an understanding of the principles and procedures in those areas of inspection for which they are being considered for certification. A typical summary of requirements for the three levels follows.

A. LEVEL I INSPECTOR

1. Education, Training, and Experience Qualifications

Level I coatings inspectors should, as a minimum, meet one or more of the following requirements:

- High school graduation plus six months of related experience in equivalent inspection activities.
- Completion of college level work leading to an associate's degree or higher, plus three months of related experience in equivalent inspection activities.

2. Responsibilities and Capabilities

- Implementing and recording all inspections required by the applicable procedures.
- Verifying instrument calibration.
- Performing hold point inspections and releasing hold points in accordance with the applicable procedures.

B. LEVEL II INSPECTOR

1. Education, Training, and Experience Qualifications

Level II coatings inspectors should, as a minimum, meet one or more of the following requirements:

- High school graduation plus one year of satisfactory performance as a Level I coatings inspector in the corresponding inspection activity.
- Completion of college level work leading to an associate's degree plus one year of related experience in equivalent inspection activities.
- Four-year college degree plus six months of related experience in equivalent inspection activities.

2. Responsibilities and Capabilities

- Performing all of the duties and responsibilities of a Level I coatings inspector.
- Planning and supervising inspections, initiating and reviewing inspection procedures, and evaluating the adequacy of activities.
- Revising, organizing, and approving results of inspections.
- Monitoring the performance of and supervising the work of Level I coatings inspectors.
- Training and verifying the qualifications of Level I coatings inspectors for certification.
- Initiating changes to quality procedures.
- Implementing the quality assurance program if assigned that authority by company policy or the quality assurance program.

C. LEVEL III INSPECTOR

1. Education, Training, and Experience Qualifications

Level III coatings inspectors should, as a minimum, meet one or more of the following requirements:

FIGURE 2-4. Coating Inspector's Attestation. Copyright 1992 by NACE International. All rights reserved by NACE; reprinted with permission.

I, (the candidate), recognize and acknowledge that:

Proper coating inspection can be critical to the safety and welfare of the general public and industrial facilities.

Coating inspection is obligatory to maximize conservation of our material resources and to reduce economic losses.

The entire field of coatings encompasses many diverse skills and disciplines and levels of technical competence, which must often be taken into consideration.

Through continual association and cooperation with others in the coatings field, the safest and most economical solutions may be found to many types of coatings problems.

The quality of work and personal conduct of each coating inspector reflect on the entire profession of coating inspection.

Therefore, I hereby agree to:

Give first consideration in my coating inspection work to safety and public welfare.

Apply myself with diligence and responsibility to my coatings inspection work.

Pursue my work with fairness, honesty, integrity, and courtesy, ever mindful of the best interest of the public, my employer, and my fellow workers.

Not represent myself to be proficient or make recommendations concerning coatings-related work for which I am not qualified by knowledge or experience.

Avoid and discourage untrue, sensational, exaggerated, or unwarranted statements regarding my work.

Treat as confidential my knowledge of the business affairs or technical processes of clients, employers, or customers.

Inform clients or employers of any affiliations, interests, or connections that might influence my judgment.

Accept no monetary gratuities of any kind nor other gratuities whose value could cause a question as to whether they may have influenced my inspection activities, decisions, or reports.

Be fair, reasonable, and objective in my work, not allowing myself to be influenced by personalities or other individual considerations.

Completely, accurately, and honestly fulfill the reporting requirements of the specifications for any coating operation I may be responsible for inspecting.

Take it upon myself to determine from my superiors the scope of my authority and work within it.

Ensure, to the best of my ability, that the terms, language, and requirements of the coatings specifications are clearly understood and agreed to by all parties involved.

Strive to obtain the best possible results under given conditions with a given coating specification.

- High school graduation plus six years of satisfactory performance as a Level II coatings inspector in the corresponding inspection activity.
- High school graduation plus ten years of related experience in equivalent inspection activities; or high school graduation plus eight years experience in equivalent inspection activities, with at least two years as a Level II coatings inspector, and with at least two years associated with industrial facilities using high technology coatings or sufficient training to be knowledgeable of the quality assurance requirements for industrial work.
- Completion of college level work leading to an associate's degree and seven years of related experience in equivalent inspection activities with at least two years of this experience associated with industrial facilities using high technology coating or sufficient training to be knowledgeable of the quality assurance requirements for industrial work.
- Four-year college degree plus five years of related experience in equivalent inspection activities, with at least two years of this experience associated with industrial facilities using high technology coating or sufficient training to be knowledgeable of the quality assurance requirements for industrial work.

2. Responsibilities and Capabilities

- Carrying out all of the duties and responsibilities of a Level II coatings inspector.
- Certifying Level I, Level II, and other Level III coatings inspectors.
- Evaluating the adequacy of programs used to train coatings inspectors.
- Authorizing Level II coatings inspectors to carry out training and examination duties.
- Approving all safety-related inspection procedures.

V. SUMMARY

Coatings inspectors should have the physical capabilities and training to meet all of their work requirements. It is also essential that they have good verbal and written communication skills, strong character, and good judgement.

Based on their experience and education, coatings inspectors can be certified at different levels. Higher levels of certification enable the inspector to assume greater respon-

sibility and authority, including the supervision and training of lower level inspectors.

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Stephen G. Pinney - S. G. Pinney & Associates, Inc.

Lafayette College and an MBA from Columbia University. He is a registered professional engineer. He is an SSPC Protective Coatings Specialist, a NACE Corrosion Specialist, and a Certified NACE International Coating Inspector.

BIOGRAPHICAL SKETCH

Kenneth B. Tator is the president of KTA-Tator, Inc., a protective coatings consulting, testing, and inspection firm.

Mr. Tator is active in SSPC. He has lectured at various SSPC educational courses. He has also been a recipient of the John D. Keane award, and was on the first Board of Governors. Mr. Tator is also active in NACE International and the International Organization for Standardization (ISO). He currently is a Director of NACE International, and has served as chairman of T6 Committee "Protective Coatings and Linings." Mr. Tator is also a member of American National Standards Institute (ANSI); American Society of Testing and Materials (ASTM); Federation of Societies for Coatings Technology (FSCT); the National Forensic Center; and the National Society of Professional Engineers.

Mr. Tator has presented technical papers or educational lectures at various meetings, and has lectured extensively at various training seminars held at KTA-Tator, Inc. Mr. Tator has presented expert witness testimony on coating failures in various states. He also holds (with Richard O. Lackey) a patent covering the KTA Envirotest®, an innovative laboratory test chamber designed to accelerate the weathering of protective coatings and linings and other materials of construction.

Mr. Tator served in the United States Navy from 1963 to 1968. He has a BS degree in Chemical Engineering from

Chapter 3

Reviewing and Preparing Inspection Documents

by Richard W. Drisko, PhD

OUTLINE

- I. Scope
- II. A Note on Terminology
- III. The Job Specification
 - A. Purpose of the Job Specification
 - B. Contents of the Job Specification
 - C. The CSI Format
- IV. Documents Associated with the Job Specification
 - A. Work Plan
 - B. Quality Control Plan
 - C. Safety Plan
 - D. Other Submittals
 - E. Pre-Job Conference Report
- V. Procedure for Reviewing Job Specification and Associated Documents
- VI. Inspector's Documentation
 - A. Purpose of Inspector's Documentation
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 - A. Pre-Job Inspection Documentation
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 - C. Completing Inspector's Daily Reports
 - D. Documenting Deviations from Specification
 - E. Documents after the Job is Completed
- VIII. Summary
- IX. References

I. SCOPE

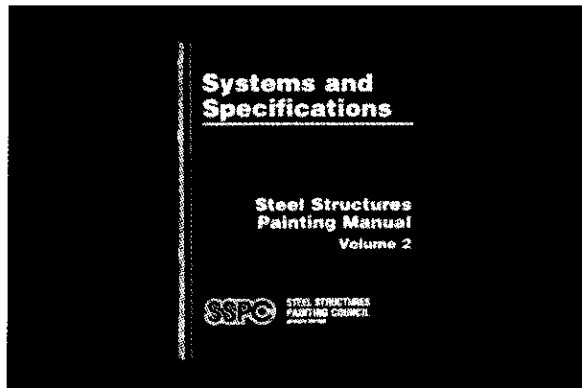
This chapter describes how documents are used by the coatings inspector. Two types of documents are described:

- Those associated with the specification detailing the work to be done by the applicator, including the inspection requirements.
- Those prepared by the inspector to document the work accomplished by the applicator.

II. A NOTE ON TERMINOLOGY

In the coatings industry, there are certain words that must be used with care because they do not have a generally agreed upon meaning in the industry or because their meaning depends on the context in which they are used. "Specification" is one of these. In this book, the term "job specification" is used to refer to the document that describes the work to be performed and expresses the owner's technical requirements for the work. (Note: Throughout the text, the word "specification" is sometimes used by itself. Unless otherwise indicated, it also refers to the job specification as defined here.) The job specification is incorporated into the legal contract, forming the legal definition of the work to which the contract relates. It should be readily distinguishable from the other types of specifications described below.

FIGURE 3-1. SSPC's Steel Structures Painting Manual, Volume 2, Systems and Specifications. Illustration by Russell Davison, SSPC.



- Many technical organizations prepare documents called specifications that describe products, procedures, or conditions. For example, SSPC's Steel Structures Painting Manual Volume 2 (Figure 3-1) includes dozens of specifications covering surface preparation, abrasives, paints and paint systems, and paint application. Military, federal, state, and other agencies also have paint specifications that are frequently referenced in job specifications.
- The Army and Navy also have documents called "guide specifications" (formerly called "type specifications"). These types of documents, which provide options for coating different types of structures, are designated "engineering standards" by corporate facilities.

III. THE JOB SPECIFICATION

A. PURPOSE OF THE JOB SPECIFICATION

One purpose of the job specification is to give a detailed description of the desired product. The job specification may also serve several other purposes, for example, it can:

- Ensure timely completion of work, without delays and disputes
- Minimize costs

- Ensure that all safety, environmental, and legal requirements are met
- Ensure that bidding is fair and widely accessible

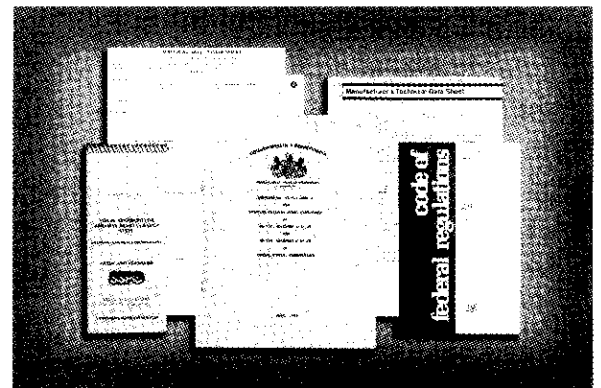
B. CONTENTS OF THE JOB SPECIFICATION

In a legal sense, the "job specification" may consist of more than just the written specification itself (Figure 3-2). Many other documents may form a legal part the job specification, such as:

- Associated and referenced drawings, photographs, plans, and video or voice recordings
- Referenced documents such as industry and government standards and specifications, pictorial standards (e.g., for surface preparation), and federal, state, and municipal regulations
- Applicator submittals such as work plan, quality control plan, safety plan, schedules, analyses, manufacturer's technical data sheets, application instructions, and Material Safety Data Sheets (MSDSs)
- Change orders and addenda
- Copies of reports (e.g., shop prime coat inspector's report, lab reports)

In order to understand all job specification requirements, the inspector must be familiar with the information in these documents, and they must be available to him at all

FIGURE 3-2. Some components of a job specification. Illustration by Russell Davison, SSPC.



times, in case he needs to verify or clarify a requirement.

These documents constitute a legal requirement between the owner and the applicator and can be changed only by them. (Note: Although the owner's representative is responsible for accepting some of these items, the inspector should be aware of them because they may define requirements that he needs to use in his work.)

Since the total contract is a legal document, it is important that it completely, clearly, and precisely defines the desired work and permits the inspector to understand his requirements. The applicator can be required to do only the work specified. Any lack of clarity can be interpreted by the applicator to his advantage. Specifications should be structured so that there are no duplications of descriptions. If descriptions are given more than once in a slightly different way each time, it could lead to different interpretations. To help ensure that a specification is easy for all involved parties to review and comprehend, it is good practice to use the format of the Construction Specification Institute (CSI).

C. THE CSI FORMAT

This format organizes any construction contract into 16 sections, according to the building trade involved. Section 9 covers finishes. Each section is divided into three parts: 1) General; 2) Products; and 3) Execution. This systematic approach permits the specification writer to avoid redundancy and misplacement of descriptions. It also allows the reader to quickly find portions of particular interest (Figure 3-3).

The three-part CSI format and some of its subsections are shown below. In this format, the inspector's responsibilities are defined in the Execution section, and fully explained usually through reference to the General and Materials sections.

Part 1. General

- 1.1 Scope
- 1.2 References
- 1.3 Definitions
- 1.4 Submittals
- 1.5 Quality Assurance
- 1.6 Delivery, Storage, and Handling
- 1.7 Project/Site Conditions

- 1.8 Sequencing and Scheduling
- 1.9 Safety and Environmental Compliance
- 1.10 Warranty
- 1.11 Maintenance (optional)

Part 2. Products

- 2.1 Manufacturers
- 2.2 Materials
- 2.3 Equipment
- 2.4 Source Quality Control

Part 3. Execution

- 3.1 Examination of ambient conditions
- 3.2 Preparation
- 3.3 Surface Preparation
- 3.4 Application
- 3.5 Quality Control
- 3.6 Site Clean-up

IV. DOCUMENTS ASSOCIATED WITH THE JOB SPECIFICATION

A. WORK PLAN

The job specification writer may require the applicator to submit a "work plan" that provides details on how the required work will be accomplished. This plan usually includes:

- Materials to be used
- Manpower and equipment to be used
- Job schedule

Most job specifications define what is to be achieved and avoid descriptions of the working methods to be used. When working methods are described in the job specification, there is a risk that the method specified will not result in the desired (required) result, leading to a dispute and potential litigation.

FIGURE 3-3. A job specification in the CSI format.

**SAMPLE PAINTING PORTION OF SPECIFICATION
FOR EXTERIOR MAINTENANCE OF A SERIES OF STEEL FUEL TANKS**

SECTION 09900

COATING STEEL WATER TANK EXTERIORS AND ATTACHED APPURTENANCES

PART 1 - General

1.1 SUMMARY

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

American Society for Testing and Materials (ASTM) Publications

D 4417-84 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

Code Of Federal Regulations (CFR)

29 CFR 1910 Occupational Safety and Health Standards - Respiratory Protection

29 CFR 1910.1000 - 1500 Subpart Z - Toxic and Hazardous Substances

29 CFR 1910.1200 Hazard Communications

Federal Standards (Fed. Std.)

Fed. Std. 313-89 Material Safety Data Sheets Preparation and Submission

Military Specifications (Mil. Spec.)

MIL-E-24635 Enamel, Silicone Alkyd Copolymer

SSPC: The Society for Protective Coatings (SSPC) Publications

SSPC-PA 1 Shop, Field, and Maintenance Painting

SSPC-PA 2 Measurement of Dry Coating Thicknesses with Magnetic Gages

SSPC-PA Guide 3 A Guide to Safety in Paint Application

SSPC-Paint 25 Red Iron Oxide, Zinc Oxide, Raw Linseed Oil and Alkyd Primer (Without Lead and Chromate Pigments)

SSPC-SP 6 Commercial Blast Cleaning

SSPC-SP 11 Power Tool Cleaning to Bare Metal

SSPC-Vis 1 Pictorial Surface Preparation Standards for Painted Steel Surfaces

1.3 SUBMITTALS:

1.3.1 Manufacturer's Certificate of Product Conformance: A certificate for each material specified, that states that a previous representative batch was tested by an independent laboratory for conformance with the referenced specification, and that the material tested, meets all of the requirements of the referenced specification. Include a list of all performance test methods, standards, etc. which are contained in the referenced material section, and required and actual test results.

1.3.2 Manufacturer's Application Instructions for All Coating Materials

1.3.3 Manufacturer's Material Safety Data Sheets: For coatings, solvents, cleaning materials, and other potentially hazardous materials, as defined in Federal Standard 313.

1.3.4 Safety Plan: Written plan of action which covers all operational requirements for safe preparation of surfaces, application of coatings, and handling, storage, and disposal of hazardous and toxic materials (including abrasive materials). Plan requirements will comply with the most stringent requirement of the following:

- (a) Manufacturer's Material Safety Data Sheets
- (b) SSPC-PA Guide 3
- (c) Toxic materials exposure limits:
 - (1) 29 CFR 1910.1000
 - (2) 29 CFR 1910.134

1.2.5 Material Samples:

1.3.5.1 Sample Size: For each batch of coating to be used, a one quart size of thoroughly mixed coating identified by contract number, manufacturer, specification number, batch number, and date of manufacture. The colors shall be those indicated on the specification drawings.

1.4 DELIVERY AND STORAGE OF MATERIALS: Deliver coating materials in properly sealed and labeled containers bearing manufacturer's name and specification number, batch number, color, date of manufacture, and all label safety requirements. Store coating materials and abrasives in accordance with manufacturer's written directions

1.5 JOB SITE REFERENCES: The Contractor shall have at least one copy of each of the referenced specifications at the job site and made available to the Contracting Officer, prior to any surface preparation or coating application work.

1.6 REMOVAL OR PROTECTION OF ITEMS NOT TO BE PAINTED: Remove or protect by covering all items not to be abrasively blasted and painted, as indicated on the specification drawings.

PART 2. MATERIALS

2.1 Abrasives. Abrasives shall be clean, dry slag, mineral grit, manufactured grit, steel shot, or steel grit which have a gradation that will produce a uniform profile of 1 mil. Abrasives shall have a free silica content of less than 5.0 percent by weight and meet local and state requirements for maximum heavy metal content for nonhazardous materials.

2.2 Coatings. The alkyd primer SSPC-Paint 25 and silicone alkyd enamel Mil. Spec. MIL-E-24635 finish shall meet all prevailing regulations.

PART 3. EXECUTION

3.1 General. Perform surface preparation and application of coating materials as specified herein and in accordance with the approved safety plan.

3.1.1 Surfaces Not to be Painted: Remove or cover all appurtenances and other areas not to be abrasive blasted or painted, as indicated on the specification drawings.

3.1.2 Abrasive and Painting Debris. Provide necessary measures and equipment to collect blasting and painting debris. Schedule and conduct blasting in such a manner as to avoid blasting dust from falling onto freshly painted surfaces.

3.1.2 Environmental Conditions. Conduct abrasive blasting and coating operations only when the following conditions are met:

- (a) Ambient air temperature is above 50 degrees F and below 95 degrees F,
- (b) The steel surface temperature is more than five degrees above the dew point of the ambient air,
- (c) The wind is no more than 10 miles per hour, when paint is to be sprayed,
- (d) Surfaces to be painted are completely dry.

3.2 Surface Preparation:

3.2.1 Repair of Metal Surfaces: Locate localized spots where rust has reduced the original thickness to a measurable extent and clean them by wire brushing to a suitable condition for welding. The total area of these spots is less than 10 square feet. Fill spots with weld material and grind smooth.

3.2.2 Abrasive Blasting:

3.2.2.1 Cleanliness: Give all areas of steel to be painted a Commercial Blast Cleaning. Verify this with the appropriate pictorial surface preparation standards for painting steel surfaces. After blasting, thoroughly remove blasting dust by brushing, blowing with oil-free and moisture-free compressed air, or vacuuming.

3.2.2.2 Surface Profile: The surface profile of the steel surfaces cleaned by abrasive blasting shall be 1 mil.

3.2.2.3 Abrasive Recycling: Recycle only manufactured grit, steel shot, or steel grit. Ensure that the recycled abrasive contains no more than 2 percent of fines, rust, mill scale, old paint, or other foreign material by weight. The recycled material must produce a uniform profile of the required thickness.

3.2.2.4 Disposal of Abrasive: Remove all blasting residue (abrasive, paint, and rust) and dispose of it in accordance with local regulations.

3.3 APPLICATION OF COATING SYSTEM:

3.3.1 General: Apply coating system in accordance with the requirements of SSPC-PA 1, except as modified by the manufacturer's instructions and this specification. Apply primer as soon as possible after abrasive blast cleaning. In no case exceed 8 hours. If any visible rust occurs, regardless of the time period, reblast the surface to the required condition prior to applying the primer. Obtain approval of Contractor before each coat is applied.

3.3.2 Coating Thickness: Apply one coat of primer and two coats of finish, each at a dry film thickness of 2 mils to obtain a total of 6 mils dry film thickness. Apply additional finish coats, if necessary to obtain the required total dry film thickness.

3.3.3 Striping: Apply by brush (stripe) a coat of primer to all edges, corners, bolts, rivets, welds, and other sharp surfaces before applying a full coat of primer. Allow striping to cure two hours before applying the full primer coat.

3.3.4 Coating Application: Apply the coating system by brush, spray, or roller, as permitted by local regulations.

3.3.5 Recoating: Follow specification requirements for times to recoat between primer and finish coat and between finish coats. Undercoats shall be free of oil, grease, dirt, dust, and other contaminants prior to application of subsequent coats.

3.3.6 Finished Surfaces: Provide finished surfaces that are free from such defects as runs, sags, laps, brush marks, and variations in shades.

3.4 INSPECTION:

3.4.1 Surface Preparation: Inspect cleaned steel surfaces for required cleanliness and profile levels before priming. Measure profile in accordance with ASTM D 4417, Method A or C.

3.4.2 Coating System: Inspect each coat of the coating system and the total system for required appearance and the required dry film thicknesses. Measure these thicknesses in accordance with SSPC-PA 2.

3.5 FINAL CLEANUP: Following completion of work, remove all debris, equipment, and materials from the site. Restore all existing facilities affected by the work to their original condition.

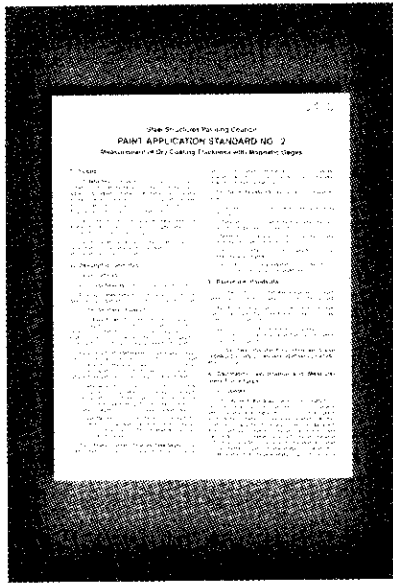


FIGURE 3-4.
SSPC-PA 2.
Measurement of
Dry Coating
Thickness with
Magnetic Gages.
Illustration by
Russell Davison,
SSPC.

B. QUALITY CONTROL PLAN

The owner may require preparation of a quality control plan showing how inspection is to be performed, including a detailed description of equipment and test methods to be used. In this plan, the main inspection points should be identified, for example:

- Examinations, measurements, or tests to be conducted
- Verification and acceptance criteria for individual tests
- Mandatory inspection surveillance points, witness points, and hold points.
- Methods for documenting inspection findings
- Methods to identify conformance or rejection of work in process (Figure 3-4)
- Methods to ensure that corrective actions are reinspected.
- Criteria for final acceptance

When the owner operates a formal quality system such as ISO 9000, the quality control plan should be more detailed and should comply with the requirements and restrictions of the quality system.

C. SAFETY PLAN

The owner may require the applicator to submit a safety plan for approval to be sure that safety requirements of the job specification adequately protect workers and conform to legal requirements. In order to meet some safety requirements, the applicator may have more than one option. As discussed further in Chapter 7, the coatings inspector does not have the responsibility to enforce the safety plan but must, by law, advise the person who has that responsibility when obvious violations are noted or observed.

D. OTHER SUBMITTALS

Documents from manufacturers and suppliers should be examined to be sure that they are completely clear and not in conflict with other portions of the specification. Any discrepancies should be resolved.

E. PRE-JOB CONFERENCE REPORT

A pre-job conference should be attended by the coatings inspector and representatives of the owner, applicator, and supplier (Figure 3-5). At this time, all uncertainties and differences of interpretation should be resolved. The inspector should make sure that he, the applicator, and the owner's representative have the same understanding of the work requirements. At this conference, the inspector should identify any missing, incomplete, unclear, or ambiguous statements and communicate this information to the owner's representative. In addition, the degree of authority of the inspector to stop work or make any other managerial decisions should be established by the owner and communicated to the applicator. The inspector must never overstep this authority.

All subsequent correspondence between the inspector and the parties present at the pre-job conference should be kept in the contract file for future reference. In addition, a pre-job conference report should be prepared. Occasionally the report becomes an amendment to the contract.

FIGURE 3-5. Sample agenda for a pre-job conference.

Preliminary

1. Introduction of attendees
2. Announcements
3. Reading of scope

Discussions

4. Mobilization and staging area
5. Cleaning and painting operations
 - Material storage
 - Equipment use
 - Surface preparation: Presence of contamination on abrasives; types and sizes; air pressure at blast nozzle; definition of degree of cleaning
 - Unconventional paint application techniques
 - Inspection requirements: Ambient conditions, surface cleanliness, blast profile, wet and dry film thickness, continuity testing
 - Patching techniques
 - Safety precautions
6. Contract administration
7. Environmental issues
 - Presence of hazardous materials
 - Disposal of waste
 - Monitoring
8. Special matters

V. PROCEDURE FOR REVIEWING JOB SPECIFICATION AND ASSOCIATED DOCUMENTS

In order to review the job specification and associated documents, the coatings inspector should:

A. Obtain from the project manager a copy of the job specification and supporting documents, and review them thoroughly.

B. Verify that the following major elements are included in the job specification:

- Work plan
- Quality control plan
- Safety plan

- List of specific materials and amounts to be used
- Manufacturer's technical data sheets, application instructions, and Materials Safety Data Sheets
- Samples, test reports, and certificates of compliance

C. Examine the quality control plan to verify that it contains forms to be completed before proceeding with additional work and that it includes the following inspection hold points:

- Inspection of materials
- Inspection of equipment
- Completion of surface preparation
- Initiation of paint application
- Completion of paint application
- Partial or final acceptance

D. Verify that all uncertainties and differences of interpretation brought up at the pre-job conference have been resolved, and that there are no inspection problems that require resolution. Also verify that the contract has been amended to include all agreements made at the pre-job conference and keep these agreements in the contract files.

VI. INSPECTOR'S DOCUMENTATION

A. PURPOSE OF INSPECTOR'S DOCUMENTATION

In order to accomplish his responsibilities satisfactorily, the inspector should prepare detailed documentation of all work done by the applicator. Data from his detailed reports may provide significant assistance in resolving disputes between the two parties. The purpose of reporting is as follows:

- In the event of premature failure of the coating, inspection records may be reviewed to aid in the analysis.
- Inspection records provide a means of ensuring that deviations from the specification are corrected prior to final acceptance of the work.
- In the event that more than one inspector inspects the work, the records provide a history of what has transpired and of the current status of the project.

B. ITEMS FOR INSPECTION DOCUMENTATION

The specific items for inspection documentation vary depending on the job specification; however, the following items generally always require documentation:

- Type and amount of work accomplished (e.g., crew size, application schedules, areas worked)
- Environmental conditions under which the work was done
- Methods of surface preparation and coating application, the equipment used, and its operating conditions
- Instrumental analyses and calibrations
- Measurements taken (e.g., film thickness)
- Amounts of materials used each day
- Deviations from contract specification requirements and their resolutions

Unless otherwise specified, the inspector may select his own documentation formatting. Several examples of different types of reporting forms can be found at the end of this chapter. Others can be found in the NACE Coating Inspector's Logbook (Figure 3-6). The inspector may use these exact forms or slight modifications--or he may prepare forms that suit his particular needs and provide adequate space to record each item. This can be done inexpensively (e.g., on a computer), and the forms can be placed in a binder for field use. Alternatively, data can be recorded directly into a computer or entered immediately after return to the office. In this way the data can be retrieved or treated mathematically much more efficiently.

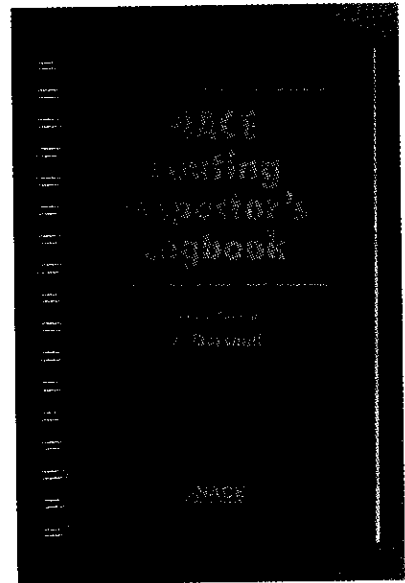
VII. PROCEDURE FOR DOCUMENTING INSPECTION

A. PRE-JOB INSPECTION DOCUMENTATION

Before the job, the inspector should:

1. Prepare or obtain standard inspection forms to be used in the coatings inspection, as well as copies of all documents.
2. Modify standard inspection forms to meet specific requirements of the job, based on examination of contract

FIGURE 3-6.
The NACE
Coating
Inspector's
Logbook. Photo
by Russell
Davison, SSPC.



documents (contracts, specifications, drawings, standards, materials specifications, written submittals).

3. Determine the frequency and times (when) and the format (how) for recording information.
4. Establish the protocol for dating and initialing or signing the copies and the number of copies to be retained. It is recommended that descriptions be prepared legibly in ink in bound books. The date of each entry should be shown, and the prevailing conditions and work done should be described as completely as is required by the inspection plan. If more than one inspector uses the book, each entry should be initialed by the inspector recording it.
5. Determine the need for physical records (e.g. replica tape, pH paper) and for diagrams.

B. INSPECTION PLAN

In order to achieve quality and timely inspection, the inspector should have an orderly inspection plan and a schedule for implementing it. The inspection process should be conducted in such a manner that workers gain a better understanding of the job specification requirements, and are assisted in completing the required work. If the job specification does not include an inspection plan, the inspector should prepare one himself. The completed plan indicates what instruments will be necessary and shows

what additional information might be needed. This might simply be a checklist or agenda of inspection items to be recorded; however, once completed for a particular coating system, the inspection plan can be used with minor or no modification on many jobs.

C. COMPLETING INSPECTOR'S DAILY REPORTS

The inspector should record observations and measurements on the coating job conditions as required, and note any hold points. This may include the following:

- Weather and site conditions
- Pre-surface preparation setup
- Surface preparation
- Surface cleanliness and roughness
- Coating material preparation
- Coating application set-up
- Coating application
- Film thickness measurement
- Film physical or appearance properties
- Other factors, conditions, or observations

Note: The inspector's daily reports are perhaps his most important documentation. Data on standard forms should be supplemented with written descriptions in the job log. These should be objective observations, not "intuition" or "guesswork." They should be independent, not reflecting bias for or against the applicator or owner. They should note calibrations of instruments and other data that substantiate credibility.

D. DOCUMENTING DEVIATIONS FROM SPECIFICATION

If the inspector finds any deviations from the specification or regulations, he should:

1. Document the deviations, based on pre-determined procedure.
2. Describe actions taken to resolve deviations satisfactorily.
3. Identify any specification deviations that were not resolved.

E. DOCUMENTS AFTER THE JOB IS COMPLETED

After the job is completed, the inspector should:

1. Verify that all required entries and supporting notes have been made, that they are legible, and that they are properly signed.
2. Deliver or retain the record log, as required.
3. Furnish any photographs (with date taken and other identification on back of photo) and other supplementary documentation.

VIII. SUMMARY

In order for an inspector to complete his work in an efficient and satisfactory manner, he must utilize several basic documents. Some of these are prepared by others, and some, by himself.

A. DOCUMENTS PREPARED BY OTHERS

1. Job Specification - The job specification defines all requirements of the contractor and all those that must be monitored by the inspector. It includes all plans, drawings, and submittals associated with the specification. It should be updated as each amendment to it or change order is made.

2. Work Plan - The work plan usually includes listings of materials to be used, manpower and equipment to be used, and the job schedule.

3. Quality Control Plan - The Quality Control Plan shows how the inspection requirements are to be met.

4. Safety Plan - The safety plan tells how the safety requirements of the job specification are to be met and who is to be the point of contact for safety items.

5. Report of Pre-Job Conference - The written report of the pre-job conference includes all clarifications and/or changes made at that time.

B. DOCUMENTS PREPARED BY INSPECTOR

1. Inspection Plan - The inspector must have a plan detailing when and with what instruments and support equipment he is to accomplish each inspection item. The plan should be modified and updated as required.

2. Daily Reports - The inspector's daily reports describe all the work done that day and the conditions under which it was done.

3. Inspection Forms - The inspector should prepare inspection forms that apply to each particular hold point or other critical point in the job.

4. Deviation Report - This is to document occurrence of and resolution of deviations from the specification.

Dr. Drisko is a member of several SSPC and NACE technical committees concerned with preparation of guidance documents. He has served in many organizational offices, chaired numerous symposia, presented numerous technical presentations, and authored more than fifty articles in technical and trade journals. He is the recipient of SSPC's John D. Keane and Honorary Life Member Awards and numerous NACE and Navy awards.

Dr. Drisko received BS, MS, and PhD degrees from Stanford University. He is a professional corrosion engineer in the state of California, an SSPC Protective Coatings Specialist, and a NACE International certificated corrosion specialist.

IX. REFERENCE

NACE Coating Inspector's Logbook, A. Marshall, NACE International, Houston, TX 1991.

ACKNOWLEDGEMENTS

The author and editors gratefully acknowledge the active participation of the following in the review process for this chapter:

David L. Carrick - Union Carbide Corporation

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Tony Cunningham - Transocean Anti-Corrosion, Inc.

Raye A. Fraser - CANAC Railroad Technologies

Curt E. Huber - Cives Steel Company

Moe Kerr - M & B Consulting

Stephen G. Pinney - S. G. Pinney & Associates, Inc.

BIOGRAPHICAL SKETCH

Dr. Richard W. Drisko has been a senior writer for SSPC since January 1995. Prior to this he was employed since 1951 at the Naval Civil Engineering Laboratory, Port Hueneme, California, where he conducted research, evaluation, and testing, and served as the Navy's center of expertise on coatings for shore structures.

Appendix

Inspection Forms

Form 1: Inspection of Materials

Form 2: Inspection of Equipment before Use

Form 3: Inspection of Coating Application

Form 4: Inspection for Partial or Final Acceptance

Sample Inspection Form: Reproduced with permission from ITI Anti-Corrosion, Inc.

Sample Inspection Form: Reproduced with permission from Standards Australia.

ACKNOWLEDGEMENTS

The author and editors gratefully acknowledge the following for providing samples of their inspection forms:

Dixon Engineering

ITI Anti-Corrosion, Inc.

KTA-Tator, Inc.

Long Painting Company

McElligott Partners Pty. Ltd.

FORM 1
INSPECTION OF MATERIALS

Coatings	Identification (supplier name/ specification no.)	Generic Type	Quantity (gallons)	Batch No.	Date Made	Condition in Can	Storage Conditions
#1							
#2							
#3							
#4							
#5							
#6							

Circle all coating numbers from which quart or other samples were taken for immediate or possible later testing.

Thinners	Identification (supplier name/ specification no.)	Quantity (gallons)	Storage Conditions
#1			
#2			
#3			

Abrasives	Identification (supplier name/ specification no.)	Quantity	Packaging	Oil Contamination	Sieve Size	Storage Conditions
#1						
#2						
#3						

Cleaners and Other Materials	Identification (supplier name/ specification no.)	Quantity	Storage Conditions
#1			
#2			
#3			

FORM 2
INSPECTION OF EQUIPMENT BEFORE USE

Inspector _____ Job Ident. _____ Date _____

Equipment for Abrasive Blasting:	Identification	Capacity	Condition
Compressor			
Pot			
Hose			
	Identification	Throat Diameter	
Nozzle			
Hand or Power Tool Cleaning Equipment: Identify all hand or power tools used for surface preparation and record type, horsepower, etc.			
Other Surface Preparation Equipment: Identify all other surface preparation equipment and record size, capacity and other important properties.			
Application Equipment: 1. Brushes. Record brand name, width, shape, and bristle type. 2. Rollers. Record width, nap height, and type of reservoir. 3. Spray equipment. Record name, type, capacity, condition, etc. of: Compressor or pump Spray gun Hoses Nozzles Other specialized equipment			

FORM 3
INSPECTION OF COATING APPLICATION

Inspector _____ Job Ident. _____ Date _____

Surface Contamination: Results of test before starting application
Thinner: Type _____ Amount _____
Ambient Conditions: Temperature _____ Dew point _____ Wind _____
Drying/Curing: Drying time between coats _____ Extent of curing _____
Wet Film Thickness (WFT): WFT, mils _____
Dry Film Thickness (DFT): DFT, mils _____ Identification of DFT gage _____ Location on structure measured _____ Calibration of gage _____
Holiday Detection: Identification of holiday detector _____ Were holidays detected? _____ Marked? _____

FORM 4
INSPECTION FOR PARTIAL OR FINAL ACCEPTANCE

Inspector _____ Job Ident. _____ Date _____

Dry Film Thickness (DFT):

Identification of DFT gage

Total DFT, mils

Location on structure

DFT gage calibration

Appearance:

Uniformity. Color _____ Gloss _____ Texture _____

Match of specified color

Other concern

Number of coats:**Holidays:**

Were holidays corrected?

Coating failures:

Found

Identified

Corrected

Adhesion:

Identification of adhesion test

Results

Cure:

Prime-component coatings

Two-component coatings

DAILY INSPECTION REPORT															CONTRACT NO REPORT NO																																																																																																																																																																									
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STANDARDS AUSTRALIA

AS 3894.12

SITE TESTING OF PROTECTIVE COATINGS

INSPECTION REPORT — COATING

PROJECT..... DATE.....

ITEM NAME		ID NUMBER			
SKETCH/LOCATION/DESCRIPTION					
SUBSTRATE MATERIAL					
COATING IDENTIFICATION		1ST COAT	2ND COAT	3RD COAT	4TH COAT
Generic Type					
Brand Name					
Batch Number Base					
Batch Number Hardener					
Colour					
Thinner Used (Reference Number)					
% Thinner Used					
APPLICATION [☐] Date Applied / Time					
Brush		[]	[]	[]	[]
Roller		[]	[]	[]	[]
Spray Conventional [] Airless [] Plural []		[]	[]	[]	[]
COATING THICKNESS					
Wet Film Thickness (µm)					
Dry Film Thickness (µm)					
Specified (µm)					
Average (µm)					
Maximum (µm)					
Minimum (µm)					
Number of Readings Taken					
ADHESION [☐] Full Cure / Dry Method		[]	[]	[]	[]
HARDNESS [☐] Full Cure / Dry Method					
CURE / FULL DRY [☐] Method AS 3894.4 []		PASS []	FAIL []		
CONTINUITY TESTING [☐] Method AS 3894.1 [] AS 3894.2 []		PASS []	FAIL []	VOLTAGE:	
OTHER TESTS					

REMARKS

Signed

On behalf of

Date

PASSED []

REJECTED []

REWORK []

COPYRIGHT

Site testing of protective coatings

INSPECTION REPORT—COATING

AS 3894.12

This Report was prepared by Subcommittee CH/3/10 as a quality control record of conditions and results when applying protective coatings.

The Report is suitable for use by paint applicators, coating suppliers, inspectors, project managers and specifiers who have undertaken work in such diverse fields as mining, energy and power, water, oil and gas, transport and food.

This Report form may also be used as a quality control document to record quality control details as required by the AS 2990 and AS 3900 Standards series.

The Report should be used in conjunction with AS 3894.10 and AS 3894.11.

Where an identification number is not applicable, a suitable sketch or location diagram should clearly designate the area under test.

For the future assessment of performance a full coating identification and application method must be recorded.

Chapter 4.0

Basic Inspection Practice: Introduction

by SSPC Staff

I. SCOPE

This chapter describes the basic procedures for coatings inspection. It covers the entire inspection process, from preliminary inspections (e.g., of materials) to final testing of the cured coating (e.g., for dry film thickness, adhesion, hardness).

In order to consider both steel and concrete substrates, as well as a variety of surface preparation and application methods, this chapter is divided as follows:

- 4.1 Preliminary Inspection Responsibilities
- 4.2 Inspection of Surface Preparation of Steel
- 4.3 Inspection of Surface Preparation of Concrete
- 4.4 Inspection of Mixing, Thinning, and Coating Application
- 4.5 Post-Application Inspection
- Appendix - Concrete Surfaces

It should be noted that this chapter is intended to be a guide to basic inspection practice. In all cases, the job specification and associated documents (e.g., Quality Control Plan) should be consulted for specific inspection requirements and inspector responsibilities. The latest issue, revision, or amendment of the reference standards should be used unless otherwise specified.

II. OVERVIEW

A. PRELIMINARY INSPECTION RESPONSIBILITIES

The coatings inspector has several pre-job responsibilities, such as familiarizing himself with the job specification and the facility to be coated (Figure 4-1), attending the pre-job conference, becoming aware of safety hazards and responsibilities, and inspecting the jobsite. The inspector should also inspect the equipment that will be used for surface preparation, mixing, and coating application; inspect all materials to be used for the job; and monitor ambient conditions.

Chapter 4.1 addresses the inspector's pre-job responsibilities. It applies to most inspection jobs, i.e., both steel and concrete substrates, and most types of coatings, surface preparation methods, and application methods. For further information on the review and preparation of inspection documents, see Chapter 3. For further information on safety for the coatings inspector, see Chapter 7.

B. INSPECTION OF SURFACE PREPARATION

Prior to surface preparation, the inspector should assess and document the initial condition of the surface and verify that all necessary preparatory work has been completed. After surface preparation is completed, the

FIGURE 4-1. Inspection of jobsite. Courtesy of KTA-Tator Inc.



inspector should verify that the specified level of surface cleanliness and surface profile are attained. The inspector may also be required to test the compressed air for cleanliness, as well as test the substrate for various types of surface contamination.

Chapters 4.2 and 4.3 cover separately surface preparation of steel and surface preparation of concrete, two topics that are quite distinct from each other. For steel, the techniques of abrasive blasting, solvent cleaning, hand- and power-tool cleaning, and water cleaning are discussed. For concrete, various surface cleaning procedures are discussed, along with abrading and acid etching.

C. INSPECTION OF MIXING, THINNING, AND COATING APPLICATION

The inspector should monitor mixing and thinning operations as follows:

- Record batch numbers
- Assure that the specified material is used
- Record time of mixing and temperature
- Observe that a homogeneous coating mixture is produced and that manufacturer's instructions are followed exactly with regard to addition of components, timing, thinning, and straining.
- Verify that pot life is not exceeded

The inspector should also verify that appropriate precautions are taken to prevent contamination of the mixed materials.

During coating application (primer, intermediate, and finish coats), the inspector should once again monitor ambient conditions and verify that they fall within the ranges required by the specification. He should also observe the coating applicator(s) at work. His main responsibility is to verify that a smooth, continuous, defect-free film applied at the specified thickness range is attained.

Chapter 4.4 addresses the inspector's responsibilities during mixing, thinning, and coating application. It covers the application of coatings to both steel and concrete substrates, by several conventional application methods. In these two sub-chapters, the differences between application techniques for steel and concrete substrates are highlighted. For further information on inspection procedures for specialty coatings, see Chapter 5.

D. POST-APPLICATION INSPECTION

Following coating application, the inspector should measure the dry film thickness of the coating and verify that it meets the specification requirements. He may also be required to test the coating for holidays, adhesion, cure, and other properties. Finally, the inspector may have some responsibilities for verifying the proper handling and disposal of waste.

Chapter 4.5 addresses post-application inspections, such as those described above, as well as other post-application responsibilities that might be assigned to the inspector. It covers the inspection of coating films on both steel and concrete substrates. In this chapter, the differences between inspection techniques for steel and concrete substrates are highlighted. For further details on field tests and the use of inspection instruments, see Chapter 8.

E. APPENDIX

The Appendix provides some general information about the components of concrete, methods of concrete construction, and the properties of concrete and other cementitious surfaces.

ACKNOWLEDGEMENTS

The author and editors gratefully acknowledge the active participation of the following in the review process for all or parts of this chapter:

David L. Carrick - Union Carbide Corporation

Harold G. Clem, Jr. - Union Carbide Corporation

Frederick S. Gelfant - Stonhard Inc.

Albert L. Hendricks - Wisconsin Protective Coatings Corporation

Harlan Kline - Ameron PCS

E. Crone Knoy - Tank Industry Consultants, Inc.

Dale Semanisin - Master Construction Service/Technical Equipment

Ronald R. Skabo - CH2M Hill

BIOGRAPHICAL SKETCH

John L. Hausfeld has been the Midwest Regional Manager for KCC Corrosion Control since 1990. He is involved in managing contracts and qualifying and training contractors in the application of corrosion resistant tank linings, secondary containment coatings, and grouts. He has also worked seven years with Baker Concrete Construction, as the Concrete Restoration Division manager, managing industrial concrete flooring installations, concrete structural repairs, and concrete surface treatments. He holds a B.S. degree in Construction Management from the University of Cincinnati.

BIOGRAPHICAL SKETCH

Stephen G. Pinney is CEO of S.G. Pinney & Associates, Inc., a firm that provides professional engineering, inspection, laboratory services, underwater inspection, and quality control instruments to users of industrial protective coatings.

Mr. Pinney is active in SSPC technical committees and training. He is the Chairman of the Education & Certification Committee and a recipient of the Coatings Education Award. Mr. Pinney is also active in NACE committees and training; and ASTM, where he was the Vice Chairman for Committee D-33, Coating for the Power Generation Industry. He has also served as director of the National Board of Registration for Nuclear Coating Engineers and Specialists, Inc. (NBR).

Mr. Pinney has a BS in Agricultural Engineering and a BS in Civil Engineering from the University of Connecticut, and an MS in Business Management from Florida State University. He is a registered professional engineer in nine states. He holds many certifications, including SSPC Protective Coatings Specialist, NACE corrosion specialist, NACE coating specialist, NACE coating inspector and instructor, and NBR nuclear coating engineer.

Chapter 4.1

Preliminary Inspection Responsibilities

by Stephen G. Pinney

OUTLINE

- I. References
- II. Reading and Understanding the Job Specification
- III. Attending the Pre-Job Conference
- IV. Becoming Aware of Safety Hazards and Responsibilities
- V. Preparing Inspection Forms and Inspection Plan
- VI. Inspection of Jobsite Conditions
- VII. Inspection of Materials
- VIII. Inspection of Equipment
- IX. Monitoring Ambient Conditions (Weather Conditions)
- X. Summary

I. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 3925, Practice for Sampling Liquid Paints and Related Pigmented Coatings

ASTM E 337, Test Method for Measuring Humidity with Psychrometer (The Measurement of Wet- and Dry-Bulb Temperatures)

US Federal Test Method Standards

FTMS 141C, Method 3011.2 Condition in Container

Naval Civil Engineering Laboratory (NCEL)

R.W. Drisko, Inspection of Contract Painting of Shore Facilities, NCEL TM No. 52-91-03, Naval Civil Engineering Laboratory, Port Hueneme, CA, December, 1990.

II. READING AND UNDERSTANDING THE JOB SPECIFICATION

As detailed in Chapter 3, the inspector should read and fully understand all items in the job specification, as well as all associated documents pertinent to the project, such as:

- Associated and referenced drawings, photographs, plans, and video or voice recordings (Figure 4-2)
- Referenced documents such as industry and government standards and specifications, pictorial standards, and federal, state, and municipal regulations
- Applicator submittals such as work plan, quality control plan, safety plan, schedules, laboratory analyses of coatings, manufacturer's technical data sheets, application instructions, and Material Safety Data Sheets (MSDSs)
- Change orders and addenda
- Reports (e.g., shop inspector's report)

The inspector should also familiarize himself with the surface preparation and coating equipment to be used, as well as the individual coating properties and application characteristics.

FIGURE 4-2. A blueprint or site plan may be included in the job specification as a submittal. Courtesy of KTA-Tator Inc.



III. ATTENDING THE PRE-JOB CONFERENCE

Through a pre-job conference, attended by the coatings inspector and representatives of the owner and the applicator (and, sometimes, the supplier), the inspector should make sure that he and the applicator have the same understanding of the specification and the work requirements. At this conference, the inspector should identify any missing, incomplete, unclear, or ambiguous statements and communicate this information to the owner's representative. Concerns such as site variations from the job specification should be resolved. In addition, the degree of authority of the inspector should be established by the owner and communicated to the applicator.

IV. BECOMING AWARE OF SAFETY HAZARDS AND RESPONSIBILITIES

By familiarizing himself with the specification and associated documents, by attending the pre-job conference, and from previous training and experience, the inspector should become aware of the potential safety hazards on the job (Figure 4-3). Before beginning work at the jobsite, the inspector should clarify his position, and the safety-related duties expected of him. He should also be prepared to recognize all safety risks, and take reasonable care to reduce the risks wherever possible. Chapter 7 of this Handbook provides further information on safety for the inspector.

V. PREPARING INSPECTION FORMS AND INSPECTION PLAN

The inspector should prepare all necessary recording forms. He should also prepare an inspection plan. Chapter 3 provides further information on inspection forms and the inspection plan.

VI. INSPECTION OF JOBSITE CONDITIONS

It is extremely beneficial for the inspector to survey the facility to be coated prior to starting work. During this survey, the following should be noted:

- Features that have the potential to directly affect the inspection process, e.g., inaccessible areas, lighting and rigging
- Areas in which compliance with the specified requirements may be impractical or impossible (Figure 4-4)
- Areas that have prematurely or catastrophically failed
- Areas that are different from the descriptions in the specification.
- Proper curing of concrete in accordance with the specification.

Noted items of concern should be brought to the attention of the owner or engineer. Corrective actions may be required prior to beginning work and entail modifying the job specification.

VII. INSPECTION OF MATERIALS

All materials to be used for the job should be inspected. This includes paints, thinners, abrasives, and cleaners. For all materials, the inspector should:

- Verify that the materials received are the materials specified.
- Assure that the quantities received match the quantities required.

FIGURE 4-3. An elevated work area in which proper means of access and fall protection are being used. Courtesy of Tank Industry Consultants, Inc.

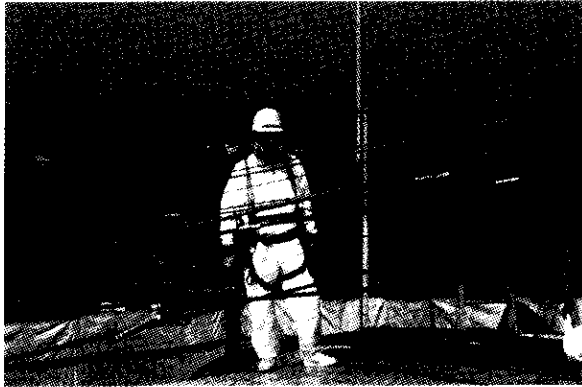
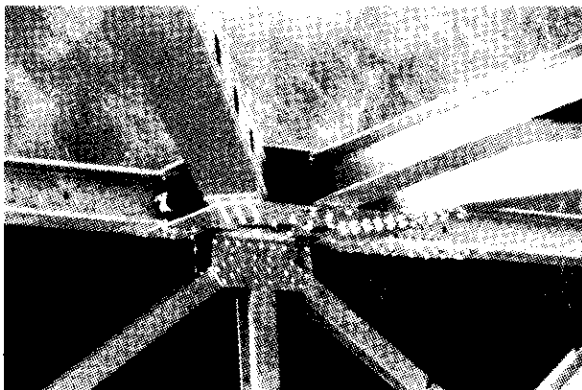


FIGURE 4-4. Intersecting beams on a bridge, showing inaccessible areas in which compliance to the specification may be difficult to achieve. SSPC file photo.



- Assure that the containers have not been damaged to the extent that contents may be adversely affected. Materials rejected because of damage should be segregated or removed from the storage facility.
- Assure that materials have not exceeded their shelf lives (Figure 4-5). The shelf life of a coating is stated on the manufacturer's technical data sheet. The application characteristics of a coating that has exceeded the

FIGURE 4-5. Storage of coating materials. SSPC file photo.

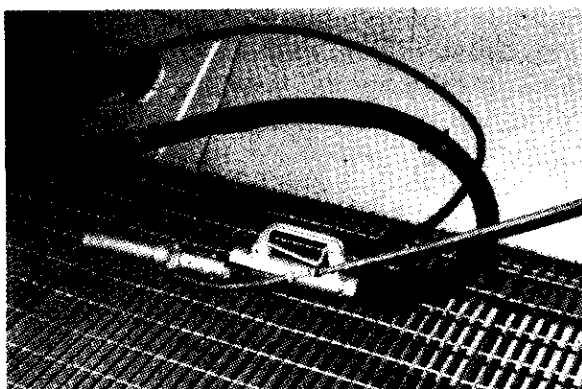
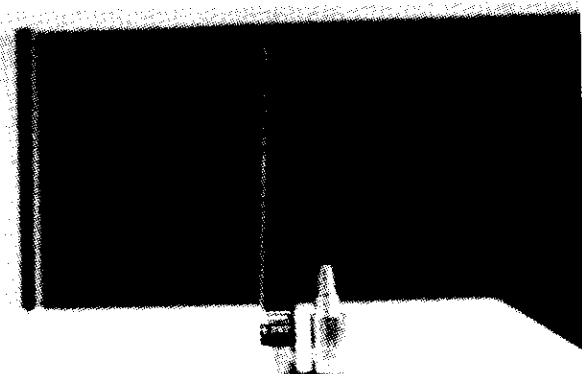


specified shelf life may be very different from those of an "in-date" material. Factors such as drying time, film build, flow out, and viscosity may be affected. Material that has exceeded its shelf life should therefore be physically segregated from in-date material, and the site engineer should be advised of this action.

- Record the batch numbers.
- Tag or otherwise mark materials as required by the job specification.
- Obtain samples for testing as required. Further information on laboratory testing of coating materials is given in Chapter 8.
- Assure that the storage facility meets the requirements of the specification. High storage temperatures may reduce a material's shelf life and should be avoided. Low storage temperatures may also have adverse effects on some coatings. For example, water-borne coatings should not be stored below freezing.
- Routinely inventory materials, and assure that the oldest acceptable material is the first material used. The date of manufacture is normally printed or coded on the label on the material container.
- Assure that Material Safety Data Sheets (MSDSs) accompany all materials

Depending on the type of coatings to be applied, the job specification may require additional materials inspections or information from the coating manufacturer. Further information on inspection of abrasives is given in Chapter

FIGURE 4-6. Top - Nozzle orifice gage for measuring blast nozzle wear. Courtesy of KTA-Tator Inc. Bottom - Proper coupling of blasting hoses. Courtesy of KTA-Tator Inc.



4.2. Further information on materials inspections for specialty coatings is given in Chapter 5.

VIII. INSPECTION OF EQUIPMENT

The inspector should observe all surface preparation, mixing, and coating application equipment before their use. The inspector should verify the identity of each piece of equipment, ensuring that specific proprietary products are present if required by the specification. The inspector should also verify that the equipment is appropriate, clean, and operational, and has the capabilities for the intended use:

- Items such as blasting hoses, couplings, and nozzles should be checked for deterioration. Hoses should be of the appropriate length. (Note: Although these inspections are not usually required by the job specification, they can be helpful in explaining why poor cleaning rates or other poor results are being achieved; Figures 4-6 and 4-7)
- Mixing equipment should be checked to see that it is cleaned at least after each day's use.
- Application equipment should be checked to see that it is clean and has the capability to apply the materials to be used.

Equipment manufacturers' operation and maintenance instructions should be available. Further information on inspection of equipment is given in Chapters 4.2 and 4.4.

The inspector should check all inspection equipment. After use, all inspection equipment should be cleaned, lubricated (where appropriate), and stored in its proper place, ready to be used again. A carrying case with a special place to hold each instrument is highly desired. Operating and calibrating instructions should also be included, so that all equipment is complete and ready for use at a moment's notice.

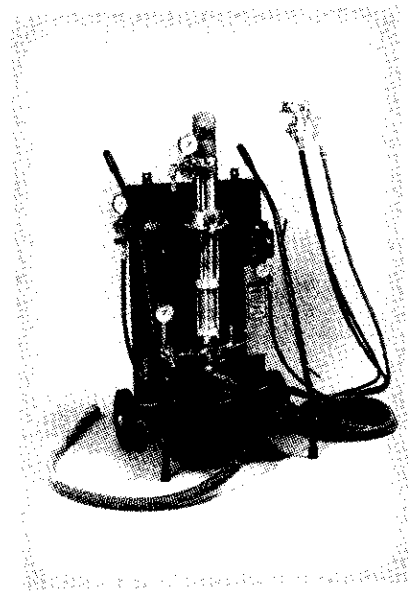
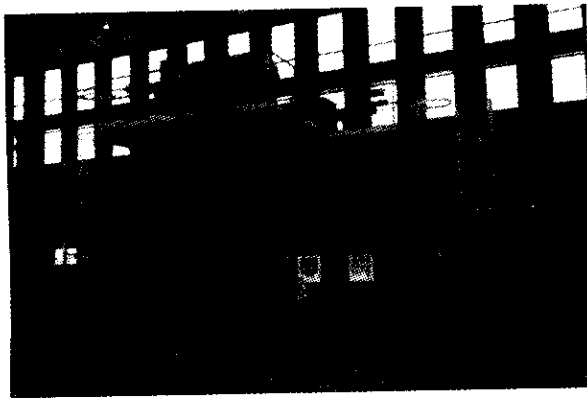
The inspector should also establish that he has the necessary equipment to inspect the cleaned surfaces to determine if cleaning requirements are met. If an SSPC-Vis 1 pictorial standard is to be used, a copy must be available at the job site. If none of the Vis 1 pictorial standards matches the appearance of the cleaned surface, then an agreement should be made about using a field standard.

It is especially important to clean and store safety equipment properly, so that there is no need to check it for readiness at the job site. Obviously, this does not include such things as respirator fit, which is always required immediately before use.

IX. MONITORING AMBIENT CONDITIONS (WEATHER CONDITIONS)

Monitoring ambient conditions (weather conditions) is an important step in the successful application of protective coatings and linings. Coatings manufacturers often give recommended air and surface temperature ranges, as well as relative humidity ranges for use of their products. Also,

FIGURE 4-7. Top - Centrifugal blast cleaning unit. Courtesy of Wheelabrator. Bottom - An airless rig. SSPC file photo.



in general, the surface temperature should be at least 5°F (3°C) above the dew point temperature, and not falling, to ensure a moisture-free surface. Applying the coating materials outside of recommended range(s) may compromise coating system performance.

The ambient conditions that should be monitored are air temperature, relative humidity (percent), dew point temperature, and surface temperature. Wind velocity and paint temperature may also be measured. The instruments and

tables used to measure and determine the ambient conditions include:

- Sling or electric psychrometers (Figure 4-8)
- U.S. Weather Bureau psychrometric tables
- Hygrothermographs (temperature/humidity recorders)
- Surface temperature thermometers
- Wind meters
- Paint temperature thermometers

A description of each of the instruments listed above, and its use and calibration procedure is given in Chapter 8.

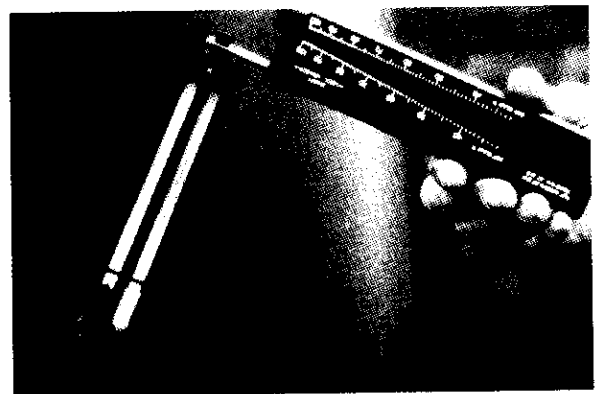
The inspector should measure ambient conditions at the actual work locations early in the morning, and often while coating work is being performed. As a rule of thumb, ambient conditions should be monitored every four hours; more often if weather conditions appear to be changing.

X. SUMMARY

The coatings inspector has a number of responsibilities before any actual work begins. The inspector should:

- Read and fully understand all items in the job specification, as well as associated documents.

FIGURE 4-8. Use of sling psychrometer. Courtesy of KTA-Tator Inc.



- Attend a pre-job conference with representatives of the owner and the applicator to solidify everyone's understanding of the work requirements
- Become aware of safety hazards and responsibilities-
Prepare inspection forms and an inspection plan

The inspector may also be required to inspect the jobsite conditions.

At the jobsite, the inspector is responsible for verifying the identity, amount, and condition of each material to be used. He should also verify that all equipment is of the type required by the specification, clean, operational, and suitable for the intended use.

Chapter 4.2

Inspection of Surface Preparation of Steel

by Stephen G. Pinney

OUTLINE

- I. References
- II. About Surface Preparation of Steel
- III. Verifying Condition of Welds and Sharp Edges
- IV. Monitoring Use of Chemical Strippers
- V. Testing for Surface Contamination - Before Surface Preparation
 - A. Soluble Salt Contamination
 - B. Grease or Oil Contamination
- VI. Inspection of Surface Preparation by Water Cleaning Methods
 - A. Terminology
 - B. Pressures for Water Cleaning/Blasting (SSPC-SP 12/NACE No. 5)
 - C. Uses and Advantages of Water Cleaning/Blasting
 - D. Inspection of Water Cleaning Equipment
 - E. Testing for Surface Cleanliness - Steel
 - F. Visual Surface Preparation Definitions for Water Jetting of Steel (SSPC-SP 12/NACE No. 5)
 - G. Nonvisual Surface Preparation Definitions (SSPC-SP 12/NACE No. 5)
- VII. Inspection of Solvent Cleaning (SSPC-SP 1)
- VIII. Inspection of Hand Tool and Power Tool Cleaning
 - A. Inspection of Hand and Power Tools
 - B. Testing for Surface Cleanliness
- IX. Inspection of Abrasive Blast Cleaning
 - A. Analysis of Blasting Abrasive (SSPC AB-1)
 - B. Inspection of Abrasive Blasting Equipment
 - C. Testing for Surface Cleanliness
- X. Inspection of Centrifugal Blast Cleaning
 - A. Inspection of Abrasives
 - B. Inspection of Blast Machines
- XI. Testing for Surface Profile (ASTM D 4417)
 - A. Replica Tape
 - B. Profile Comparator
 - C. Profile Depth Gage
- XII. Testing for Surface Contamination - After Surface Preparation
 - A. Soluble Salt Contamination
 - B. Grease or Oil Contamination
 - C. Dust
- XIII. Summary

I. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 4285 Method for Indicating Oil or Water in Compressed Air

ASTM D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

ASTM D 4940 Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives

SSPC: The Society for Protective Coatings (SSPC)

SSPC-AB 1 Mineral and Slag Abrasives

SSPC-AB 2 Specification for Cleanliness of Recycled Ferrous Metallic Abrasives

SSPC-Vis 1-89 Visual Standard for Abrasive Blast Cleaned Steel

SSPC-Vis 3 Visual Standard for Power and Hand Tool Cleaned Steel

SSPC-SP 1 Solvent Cleaning

SSPC-SP 2 Hand Tool Cleaning

SSPC-SP 3 Power Tool Cleaning

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

SSPC-SP 7 Brush-Off Blast Cleaning (NACE No. 4)

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

SSPC-SP 11 Power Tool Cleaning to Bare Metal

SSPC-SP 12 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating (NACE No. 5)

II. ABOUT SURFACE PREPARATION OF STEEL

Inspection requirements for surface preparation of steel are basically to determine if specification requirements are met concerning:

- The removal of contaminants that inhibit coating adhesion and/or induce early coating deterioration and corrosion
- Roughening of the steel surface to permit good coating adhesion

There are many methods that may be used to prepare a steel surface for coating. These include solvent cleaning, water cleaning, hand tool cleaning, power tool cleaning,

FIGURE 4-9. Sharp edges. Courtesy of KTA-Tator Inc.

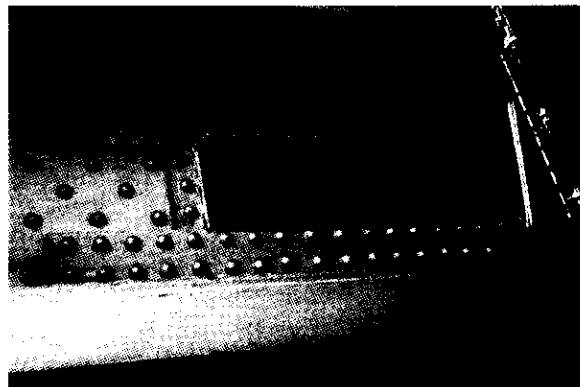


FIGURE 4-10. Weld spatter. Courtesy of KTA-Tator Inc.



abrasive blast cleaning, and centrifugal blast cleaning. The procedures for inspecting each of these methods are largely contained in the SSPC surface preparation standards, SSPC-SP 1, 2, 3, 5, 6, 7, 10, 11, and 12.

III. VERIFYING CONDITION OF WELDS AND SHARP EDGES

Prior to surface preparation, the inspector should verify that all steel work (e.g., welding, cutting, grinding of welds and sharp edges, etc.) has been completed and all

FIGURE 4-11. Use of chemical strippers to remove paint. SSPC file photo.



gross loose materials (e.g., weld spatter) have been removed (Figures 4-9 and 4-10).

IV. MONITORING USE OF CHEMICAL STRIPPERS

If the use of chemical strippers has been specified for coating removal prior to surface preparation, the inspector should verify that this is done according to the specification and manufacturer's instructions. Chemical strippers are generally alkaline or solvent-based products containing a thickener, which allows them to be spread over a surface and remain in place long enough for the alkaline or solvent component to attack the paint (Figure 4-11).

V. TESTING FOR SURFACE CONTAMINATION - BEFORE SURFACE PREPARATION

A. SOLUBLE SALT CONTAMINATION

The inspector may be required to verify that the surface is free of contamination to the extent specified. Industrial airborne chemicals and salt from a marine atmosphere or from bridge deicing can create contamination that is invisible to the unaided eye, which frequently cannot be removed by abrasive blast cleaning (Figure 4-12). Consensus standards on permissible amounts of contamination that may remain and not affect coating performance have

not yet been established. However, research and experience have shown (see Bibliography) that steps taken to remove chemical contamination will help to extend coating life. SSPC-SP 12/NACE No. 5 (see Section V. A.) contains some surface preparation definitions pertaining to surface salt levels, which may be called out in a job specification. Alternatively, the specifier, the applicator, or the coating manufacturer may provide guidelines on permissible amounts of soluble salt contamination.

Except for acidic/basic contaminants, which may be detected by measuring the pH of the surface, all other soluble contaminants on steel surfaces must be detected after extraction into an aqueous solution. To quantify salt contamination on a surface, a test area is swabbed or washed with deionized water. The extract (wash water) is collected, then test indicator strips, conductivity meters, or other instruments are used to determine ion levels. Details of how to perform these and similar tests for soluble salt contamination are given in Chapter 8.

B. GREASE OR OIL CONTAMINATION

Grease or oil contamination can be detrimental to coating performance. The inspector should therefore verify that surfaces are not contaminated by grease or oil. Three common sources of grease/oil contamination are (1) oil on the hands of the applicator or inspector (2) oils used to lubricate compressors and power tools, and (3) diesel exhaust.

FIGURE 4-12. Coating failure due to soluble salt contamination. SSPC file photo.



Several tests are available for detecting grease and oil on a steel surface. These include a "water break" test and detection with UV (black) light (see Chapter 8). If grease or oil is detected on a prepared surface, the inspector should verify that it is removed by the specified procedure, e.g., solvent cleaning, before coating application is allowed to proceed.

VI. INSPECTION OF SURFACE PREPARATION BY WATER CLEANING METHODS

A. TERMINOLOGY

Water cleaning is often used to prepare metal and concrete surfaces for coating. The water may be heated, and detergent may be added to aid in cleaning; or, abrasive may be injected into the water stream, in which case the term "water blasting" is used. Also, depending on what pressure is used, water cleaning methods may be referred to as "power washing" or "water jetting."

B. PRESSURES FOR WATER CLEANING/BLASTING (SSPC-SP 12/NACE No. 5)

- Low-pressure water cleaning - up to 5,000 psi (34 MPa)
- High-pressure water cleaning - 5,000 - 10,000 psi (34 - 70 MPa)
- High-pressure water jetting - 10,000 - 25,000 psi (70 - 170 MPa)
- Ultrahigh-pressure water jetting - above 25,000 psi (170 MPa)

C. USES AND ADVANTAGES OF WATER CLEANING/BLASTING

Water cleaning has the advantage over abrasive blasting of removing soluble salts. As with wet abrasive blasting, corrosion inhibitors may be used in the water to prevent flash rusting. Environmentally acceptable inhibitors include sodium and potassium nitrites.

Low-pressure water cleaning is effective in removing dirt and visible mildew on coated metals and is generally safe on adjacent wood and concrete/masonry (although a spot-check should always be made first). High-pressure water jetting is generally capable of removing loose rust and

most intact coatings. Ultrahigh-pressure water jetting is capable of removing tight coatings and tight rust (Figure 4-13). Water blasting cannot be used to remove mill scale and roughen the metal surface. Without abrasive injection, the surface of water-cleaned steel will not be roughened.

D. INSPECTION OF WATER CLEANING EQUIPMENT

Water cleaning equipment contains the following major components: a power source to operate the pump, a pump to pressurize the water, hose and fittings to deliver water to the nozzle, a high pressure nozzle, and a control valve system to allow the operator to start and stop water flow.

If inspection of water cleaning equipment is required by the job specification, the manufacturer should be consulted for specific instructions. In each of the major components, some of the items that may require inspection are:

- Power source and pump - should be sufficient to maintain the required pressure. Only clean water should be used, and filters should be in place and working properly (to avoid clogging the system).
- Hose and fittings - should be of the correct size and pressure rating, and free of excessive wear. The fittings should be compatible with the hose and tested as a unit.

FIGURE 4-13. Ultra high pressure water cleaning of a 1/4 inch thick, 2-part fiberglass coating from a steel tank. Courtesy of Valley Systems Inc.



- Nozzle and control valves - should be in working order. The nozzle should be appropriate for the job. Special nozzles are sometimes required for inside pipes or for floor gratings.

E. TESTING FOR SURFACE CLEANLINESS - STEEL

The inspector should verify that the specified level of surface cleanliness is attained. SSPC: The Society for Protective Coatings (SSPC) and NACE International have developed a written standard that addresses the degree of cleanliness, types of equipment, operating procedures, and safety factors associated with water jetting. The standard (SSPC-SP 12/NACE No. 5) contains visual (WJ-1, 2, 3, 4) and nonvisual (SC-1, 2, 3) definitions of the various degrees of surface cleanliness.

F. VISUAL SURFACE PREPARATION DEFINITIONS FOR WATER JETTING OF STEEL (SSPC-SP 12/NACE No. 5)

1. WJ-1

A WJ-1 surface should be free of all previously existing visible rust, coatings, mill scale, and foreign matter and have a matte metal finish.

2. WJ-2

A WJ-2 surface should be cleaned to a matte finish with at least 95% of the surface area free of all previously existing visible residues and the remaining 5% containing only randomly dispersed stains of rust, coatings, and foreign matter.

3. WJ-3

A WJ-3 surface should be cleaned to a matte finish with at least two-thirds of the surface free of all visible residues (except mill scale), and the remaining one-third containing only randomly dispersed stains of previously existing rust, coatings, and foreign matter.

4. WJ-4

A WJ-4 surface should have all loose rust, loose mill scale, and loose coatings uniformly removed.

G. NONVISUAL SURFACE PREPARATION DEFINITIONS (SSPC-SP 12/NACE No. 5)

1. SC-1

An SC-1 surface should be free of all detectable levels of contaminants as determined using available field test equipment with sensitivity approximating laboratory test

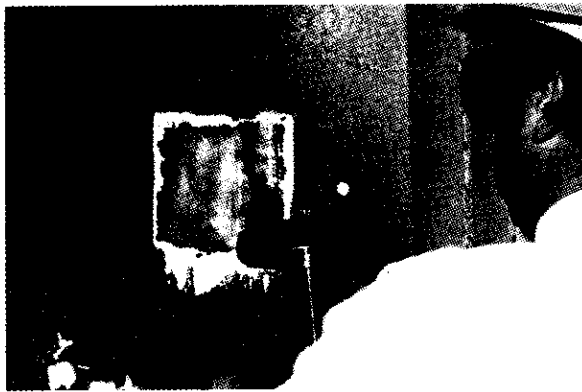
FIGURE 4-14. Swabbing surface to collect soluble salt contamination. SSPC file photo.



FIGURE 4-15. Steam cleaning, addressed in SSPC-SP 1, Solvent Cleaning. SSPC file photo.



FIGURE 4-17. Power tools. Top - Cleaning strip. SSPC file photo; Bottom - Roto-peen. Courtesy of Unique Systems Corporation.



The inspector should verify that the tools to be used are capable of providing the desired level of cleaning. The manufacturer should be consulted for the recommended operating speed of the tool. For power tools that contain an abrasive media (e.g., non-woven abrasive, rotary wire brushes, and coated abrasive discs or flap wheels), it should be verified that the tool is compatible with the size and speed rating of the abrasive media. For air-driven tools, it should be verified that the air supply is clean, dry, and adequate; and that moisture separators and filters on air lines are in place. Air-driven tools should also be properly lubricated, and should contain hoses of appropriate length and diameter for optimal operation. (Long lengths of small diameter hoses should be avoided.)

B. TESTING FOR SURFACE CLEANLINESS

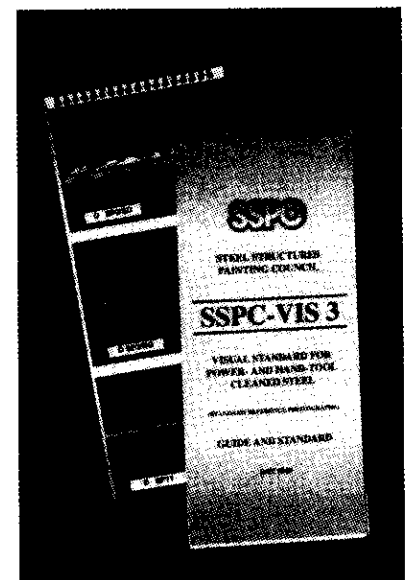
The inspector should verify that the specified level of surface cleanliness is attained. SSPC has developed written and visual standards that are used together to verify the degree of surface cleanliness by the non-abrasive blast cleaning methods "solvent cleaning," "hand-tool cleaning," and "power-tool cleaning." The written standards (SP 1, 2, 3, and 11), are descriptions of the various degrees of surface cleanliness. The visual standard (SSPC-Vis 3; Figure 4-18), is a book containing color prints illustrating the various degrees of hand- and power-tool cleaning over various rust grades of structural steel. It is intended to supplement the written descriptions. (Details on the use of SSPC-Vis 3 are given in Chapter 8.)

1. Hand Tool Cleaning (SSPC-SP 2)

Hand tool cleaning is a method of preparing steel surfaces by the use of non-powered hand tools.

Hand tool cleaning removes all loose mill scale, loose rust, loose paint and loose detrimental foreign matter. It is not intended that adherent mill scale, rust or paint be removed by this process. Mill scale, rust and paint are considered adherent if they cannot be removed by lifting with a dull putty knife.

FIGURE 4-18. SSPC-Vis 3. Photo by Russell Davison, SSPC.



equipment. For purposes of this standard, contaminants are water-soluble chlorides, iron salts, and sulfates (Figure 4-14).

2. SC-2

An SC-2 surface should have less than $7 \mu\text{g}/\text{cm}^2$ chloride contaminants, less than $10 \mu\text{g}/\text{cm}^2$ of soluble ferrous ion levels, and less than $17 \mu\text{g}/\text{cm}^2$ of sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test equipment.

3. SC-3

An SC-3 surface should have less than $50 \mu\text{g}/\text{cm}^2$ chloride and sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test equipment.

VII. INSPECTION OF SOLVENT CLEANING (SSPC-SP 1)

Solvent cleaning is a method for removing all visible oil, grease, soil, drawing and cutting compounds, and other soluble contaminants from steel surfaces. The methods of solvent cleaning included in SSPC-SP 1 are:

- Wiping or scrubbing the surface with rags or brushes wetted with solvent, then using clean solvent and rags or brushes for the final wiping
- Spraying the surface with solvent, using clean solvent for the final spraying
- Vapor degreasing using stabilized chlorinated hydrocarbon solvents
- Complete immersion in a tank or tanks of solvent. For the last immersion, solvent is used that does not contain detrimental amounts of contaminant.
- Use of emulsion or alkaline cleaners. After treatment, the surface is washed with fresh water to remove detrimental residues.
- Steam cleaning, using detergents or cleaners, followed by steam or fresh water wash to remove detrimental residues (Figure 4-15).

It is intended that solvent cleaning be used prior to the application of paint and in conjunction with surface preparation methods specified for the removal of rust, mill scale or paint, such as hand tool and power tool cleaning, and abrasive blast cleaning.

VIII. INSPECTION OF HAND TOOL AND POWER TOOL CLEANING

A. INSPECTION OF HAND AND POWER TOOLS

Hand cleaning tools include wire brushes, non-woven abrasive pads, scrapers, chisels, knives, and chipping hammers (Figure 4-16). When hand tool cleaning is specified, the inspector should verify that the tools are clean (free of grease or oil), and of the appropriate type, size, and shape to enter the area to be cleaned. Hand tool should be in such a condition that they can be used safely for effective cleaning without gouging the steel. Wire brushes with too many lost or badly bent bristles should be rejected. Scrapers should be made of tool steel, tempered, and kept sharp. Chipping hammers should have a blunt edge.

Power tools for surface cleaning are classified as impact cleaning tools, rotary cleaning tools, and rotary impact cleaning tools. They may be pneumatic or electric (Figure 4-17). When power tool cleaning is specified, the inspector should verify that the tools are appropriate for the substrate and the material to be removed, are capable of producing the specified finish without driving rust and scale into the surface (e.g., dull tools may do this), and can be safely and effectively operated in the amount of work space available. Since worker fatigue is often a problem during prolonged use of power tools, the operator's preference may also be a factor in deciding the appropriateness of a power tool.

FIGURE 4-16. Hand tools. SSPC file photo.

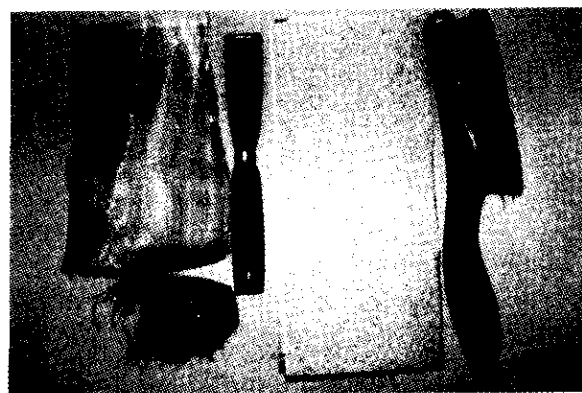
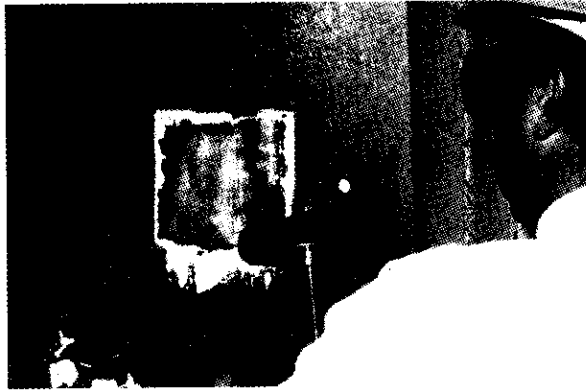


FIGURE 4-17. Power tools. Top - Cleaning strip. SSPC file photo; Bottom - Roto-peen. Courtesy of Unique Systems Corporation.



The inspector should verify that the tools to be used are capable of providing the desired level of cleaning. The manufacturer should be consulted for the recommended operating speed of the tool. For power tools that contain an abrasive media (e.g., non-woven abrasive, rotary wire brushes, and coated abrasive discs or flap wheels), it should be verified that the tool is compatible with the size and speed rating of the abrasive media. For air-driven tools, it should be verified that the air supply is clean, dry, and adequate; and that moisture separators and filters on air lines are in place. Air-driven tools should also be properly lubricated, and should contain hoses of appropriate length and diameter for optimal operation. (Long lengths of small diameter hoses should be avoided.)

B. TESTING FOR SURFACE CLEANLINESS

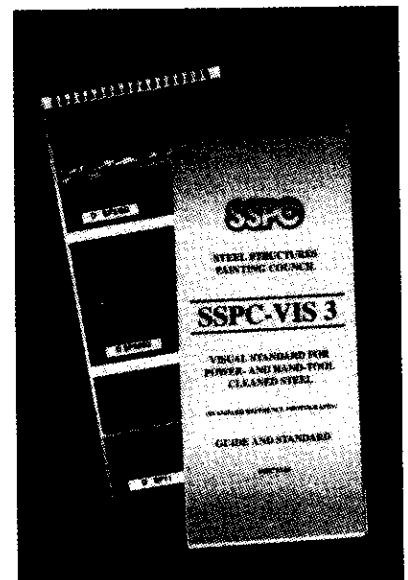
The inspector should verify that the specified level of surface cleanliness is attained. SSPC has developed written and visual standards that are used together to verify the degree of surface cleanliness by the non-abrasive blast cleaning methods "solvent cleaning," "hand-tool cleaning," and "power-tool cleaning." The written standards (SP 1, 2, 3, and 11), are descriptions of the various degrees of surface cleanliness. The visual standard (SSPC-Vis 3; Figure 4-18), is a book containing color prints illustrating the various degrees of hand- and power-tool cleaning over various rust grades of structural steel. It is intended to supplement the written descriptions. (Details on the use of SSPC-Vis 3 are given in Chapter 8.)

1. Hand Tool Cleaning (SSPC-SP 2)

Hand tool cleaning is a method of preparing steel surfaces by the use of non-powered hand tools.

Hand tool cleaning removes all loose mill scale, loose rust, loose paint and loose detrimental foreign matter. It is not intended that adherent mill scale, rust or paint be removed by this process. Mill scale, rust and paint are considered adherent if they cannot be removed by lifting with a dull putty knife.

FIGURE 4-18. SSPC-Vis 3. Photo by Russell Davison, SSPC.



2. Power Tool Cleaning (SSPC-SP 3)

Conventional power tool cleaning (SSPC-SP 3) is a method of preparing steel surfaces by the use of power-assisted hand tools.

Conventional power tool cleaning removes all loose mill scale, loose rust, loose paint and loose detrimental foreign matter. It is not intended that adherent mill scale, rust or paint be removed by the process. Mill scale, rust and paint are considered adherent if they cannot be removed by lifting with a dull putty knife.

3. Power Tool Cleaning to Bare Metal (SSPC-SP 11)

This method describes several types of power tools which provide a bare metal surface. Metallic surfaces which are prepared according to this specification, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter. Slight residues of rust and paint may be left in the lower portion of pits if the original surface is pitted.

When painting is specified, the surface shall be roughened to a degree suitable for the specified paint system. The surface profile shall not be less than 1 mil (25 micrometers). Note: This is the only surface preparation standard that designates a minimal level of profile.

IX. INSPECTION OF ABRASIVE BLAST CLEANING

A. ANALYSIS OF BLASTING ABRASIVE (SSPC AB-1)

The inspector should verify that the blasting abrasive meets all requirements of the job specification. This includes verifying that the abrasive is capable of providing the specified profile. SSPC AB-1 defines the requirements for evaluating mineral and slag abrasives. It summarizes the various tests that can be used to determine the general physical and chemical properties of abrasives. These properties include:

- Specific gravity
- Hardness
- Weight change on ignition

- Water soluble contaminants
- Moisture content
- Oil content
- Crystalline silica content
- Particle size distribution

As described in SSPC-AB 1, the blasting abrasive should be tested for water-soluble ionic contamination according to ASTM D 4940. In this test, a slurry of the abrasive is made with pure water, filtered, and the filtrate tested for acidic/basic contaminants and soluble salts (by measuring its pH and conductivity, respectively). After settling and before filtration, the water should be inspected visually for oil and dirt or fines. The test is usually conducted periodically at the discretion of the inspector. It is a good practice to retain a small sample from each delivery of abrasive. Details of how to perform these tests are given in Chapter 8.

B. INSPECTION OF ABRASIVE BLASTING EQUIPMENT

1. Hoses, coupling, and nozzles

The inspector should check blasting hoses, couplings, and nozzles for deterioration and verify that blast hoses have safety wires. Hoses should be as short a length and as large a diameter as practical to minimize loss of blasting pressure, internal friction, or restriction. To increase productivity, blast nozzles should be replaced when their throat diameters are eroded to the next larger size.

2. Testing for Oil or Water in Compressed Air (ASTM D 4285)

Oil and water in the compressed air may affect the degree of cleanliness or the performance of the coating. The inspector should check to ensure that water traps and dryers for air compressors are present and operational. The inspector should use the "blotter test," (ASTM D 4285) to determine the presence of oil or water contamination of compressed air used for abrasive blast cleaning. Blotter testing is normally conducted daily after the compressor has reached operating temperature. Any indication of oil discoloration or water contamination on the collector is cause for rejection of the compressed air. Details of how to perform this test are given in Chapter 8.

3. Verification of Blasting Pressure

A change in the blasting pressure may affect the depth of the anchor pattern. Whenever a change in blasting pressure is suspected, the inspector should measure the internal blast hose pressure at the nozzle. The test is conducted with an air pressure gage attached to a hypodermic needle (Figure 4-19). Details of how to perform this test are given in Chapter 8.

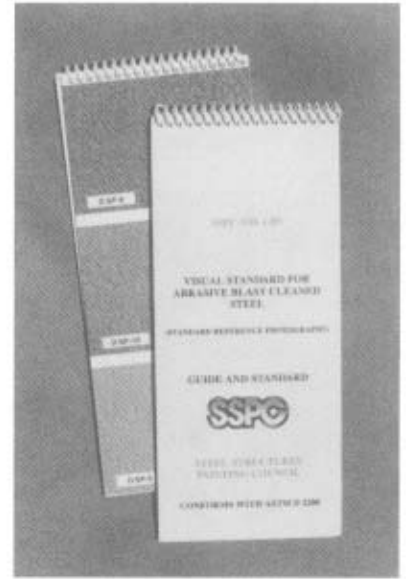
C. TESTING FOR SURFACE CLEANLINESS

The inspector should verify that the specified level of surface cleanliness is attained. SSPC: The Society for Protective Coatings (formerly the Steel Structures Painting Council) and NACE International have developed joint written standards that are used to verify the degree of surface cleanliness by abrasive blast cleaning methods. These standards SSPC-SP 5/NACE No. 1, SSPC-SP 6/NACE No. 3, SSPC-SP 7/NACE No. 4, SSPC-SP 10/NACE No. 2, are descriptions of the various degrees of surface cleanliness. In addition, SSPC has developed visual standards. SSPC-Vis 1, is a book containing color prints illustrating the various degrees of abrasive blast cleaning over various rust grades of structural steel. It is intended to supplement

FIGURE 4-19. Use of needle pressure gage. SSPC file photo.



FIGURE 4-20. SSPC-Vis 1. Photo by Russell Davison, SSPC.



the written descriptions (Figure 4-20). (Details on the use of SSPC-Vis 1 are given in Chapter 8.)

While published visual standards have proven to be extremely helpful, it is rare that the appearance of the surface condition exactly matches those in the standards. As an alternative to using published visual standards to verify the degree of surface cleanliness, a section of the structure may be selected and cleaned in the presence of the blaster and the inspector. The cleanliness is then discussed and agreed upon, and the field standard preserved as a reference. This is referred to as a jobsite standard.

1. Brush-Off Blast Cleaning (SSPC-SP 7/NACE 4)

In SSPC-SP 7/NACE 4, a Brush-Off Blast Cleaned surface is defined as follows: when viewed without magnification, [the surface] shall be free of all visible oil, grease, dirt, dust, loose mill scale (Figure 4-21), loose rust, and loose paint. Tightly adherent mill scale, rust, and paint may remain on the surface.

When Brush Off Blast cleaning is specified, the entire surface should be subjected to the abrasive blast. Mill scale, rust, and paint are considered tightly adherent if they cannot be removed by lifting with a dull putty knife.

When a Brush Off Blast cleaned surface is to be painted, the surface should comply with the specified degree of cleaning immediately prior to paint application. In addition, it must be roughened to a degree suitable for the specified paint system, i.e., the surface must also have the specified profile.

2. Commercial Blast Cleaning (SSPC-SP 6/NACE 3)

In SSPC-SP 6/NACE 3, a Commercial Blast Cleaned surface is defined as follows: when viewed without magnification, [the surface] shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter, except for staining, as noted below.

Staining shall be limited to portions no more than 33 percent of each 9 in.² (5800 mm²) of surface area and staining may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied paint. Slight residues of rust and paint may also be left in the bottoms of pits if the original surface is pitted.

Besides staining, there are other variations in appearance that do not affect surface cleanliness as defined above, and are therefore acceptable when a Commercial Blast cleaned surface is specified. These include variations caused by type of steel, original surface conditions, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat affected zones, blasting abrasive and differences in the blast pattern.

When a Commercial Blast cleaned surface is to be painted, the surface should comply with the specified degree of cleaning immediately prior to paint application. In addition, it must be roughened to a degree suitable for the specified paint system, i.e., the surface must also have the specified profile.

3. Near-White Blast Cleaning (SSPC-SP 10/NACE 2)

In SSPC-SP 10/NACE 2, a Near-White Blast Cleaned surface is defined as follows: when viewed without magnifi-

FIGURE 4-21. Mill scale. SSPC file photo.



cation, [the surface] shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter, except for staining as noted below.

Staining shall be limited to no more than 5 percent of each 9 in.² (5800 mm²) of surface area and may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied paint.

Besides staining, there are other variations in appearance that do not affect surface cleanliness as defined above, and are therefore acceptable when a Near-White Blast Cleaned surface is specified. These include variations caused by type of steel, original surface condition, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat affected zones, blasting abrasives, and differences in the blast pattern.

When a Near-White Blast cleaned surface is to be painted, the surface should comply with the specified degree of cleaning immediately prior to paint application. In addition, it must be roughened to a degree suitable for the specified paint system, i.e., the surface must also have the specified profile.

4. White Metal Blast Cleaning (SSPC-SP 5/NACE 1)

In SSPC-SP 5/NACE 1, a White Metal Blast Cleaned surface is defined as follows: when viewed without magnification, [the surface] shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter.

When White Metal Blast cleaning is specified, no stains may remain on the surface. However, there are other variations in appearance that do not affect surface cleanliness as defined above, and are therefore acceptable when a White Metal Blast Cleaned surface is specified. These include variations caused by type of steel, original surface condition, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat affected zones, blasting abrasive, and differences in the blast pattern.

When a White Metal Blast cleaned surface is to be painted, the surface should comply with the specified degree of cleaning immediately prior to paint application.

In addition, it must be roughened to a degree suitable for the specified paint system, i.e., the surface must also have the specified profile.

X. INSPECTION OF CENTRIFUGAL BLAST CLEANING

A. INSPECTION OF ABRASIVES

The abrasive used for centrifugal blast cleaning, usually cast steel shot, grit, or a combination of them should be clean, and of the appropriate size, shape, and hardness to accomplish the required surface cleaning. A properly balanced and controlled mix of particle sizes and shapes is also critical (Figure 4-22). The job specification may require pre-production trials to select the abrasive mix. In these trials, recirculating abrasive is subjected to screen analysis, and the results are used to establish procedures for maintaining the desired balance in the operating mix.

Ferrous metallic abrasive mixes that have been recycled may be tested for cleanliness according to SSPC-AB 2 before further use in blast cleaning of steel. This will ensure that significant amounts of abrasive fines and debris such as paint, rust, and mill scale are not present.

FIGURE 4-22. Work mixes for centrifugal blast cleaning. Courtesy of Ervin Industries, Inc.

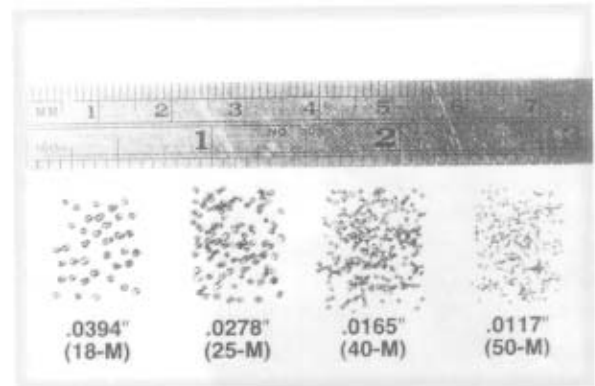
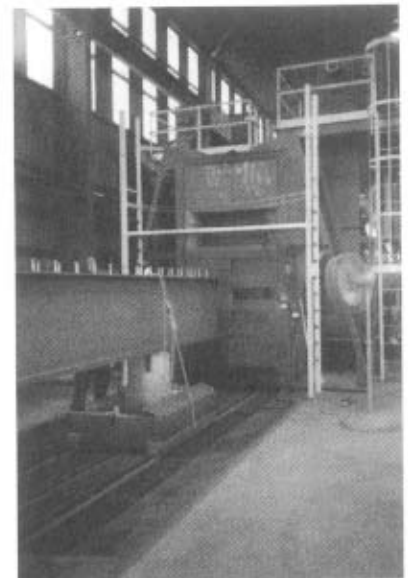


FIGURE 4-23. Centrifugal blast cleaning machine. Courtesy of Wheelabrator.



B. INSPECTION OF BLAST MACHINES

Blast machines are inherently self-destructive, and thus require regularly scheduled inspection and maintenance. A typical blast machine contains five major components: (1) the wheel unit, (2) the cabinet, (3) the work handling system, (4) the dust collector, and (5) the abrasive cleaning and recycling system (Figure 4-23). When one or more of the major components perform poorly, the blast machine

may still produce cleaned surfaces of acceptable quality; however, efficiency will decrease and costs will increase.

If inspection of machine blasting is required by the job specification, the manufacturer should be consulted for specific instructions. In each of the major components, some of the items that may require inspection are:

- **Wheel unit** - Components of the wheel unit (impeller, control cage, nozzle, blower, and blades) should be in good condition, without excessive wear. Blast wheel should be properly adjusted. Drive belts at wheel shaft should not be loose or worn. There should be a continuous, full flow of abrasive through the blast wheel.
- **Cabinet** - Entry and exit seals and interior liners should be properly maintained. There should be sufficient ventilation to maintain proper air flow into the cabinet and withdrawal of dust to the dust collector.
- **Work conveyors** - Work pieces (items to be cleaned) should be properly delivered to the blast.
- **Dust collector** - A predetermined and balanced flow of air should be maintained in the dust collector.
- **Abrasive cleaning and recycling system** - Control valve should be functioning properly. Separator should be operating properly, with proper air flow; no holes in separator housing; no foreign objects lodged within; and no warped, missing, or unevenly adjusted spreader bars or baffles.

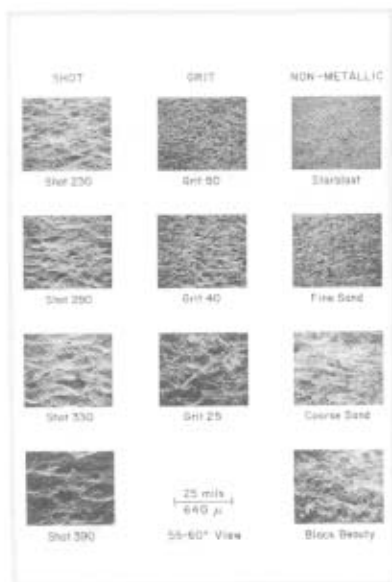


FIGURE 4-24. SEM micrographs showing qualitative features of some blast cleaned surfaces (Near White Blast Cleaning, SSPC-SP 10). SSPC file photo.

XI. TESTING FOR SURFACE PROFILE (ASTM D 4417)

The inspector should verify that the specified surface profile has been attained. Surface profile is defined as the distance (height) from the peaks to the valleys (or the roughness) created by abrasive blast cleaning (Figure 4-24). Increasing the surface profile effectively increases the surface area of the steel, promoting good coating adhesion. Too shallow of a surface profile may result in poor coating adhesion, while too deep of a profile (and insufficient coating thickness) may result in pinpoint rusting at the peaks.

Surface profile tests should be done daily and when there has been a change in abrasive or in blasting pressure or other operating parameter.

The three methods for determining surface profile described in ASTM D 4417 (see Chapter 8 for further details) are listed below in order of preference:

- Replica Tape (Method C)
- Comparators (Method A)
- Profile Depth Gage (Method B)

A. REPLICA TAPE

The use of replica tape is the most commonly used method for measuring the surface profile of prepared steel. Replica tape consists of a layer of deformable plastic bonded to a polyester backing. The deformable side of the tape is rubbed onto the blast-cleaned surface with a rigid swizzle stick to produce a reverse replica of the profile (Figure 4-25). The tape profile is then measured with a spring micrometer. After measurements, the tapes can be stored as permanent records of profile heights.

B. PROFILE COMPARATOR

A profile comparator consists of a number of areas or "leaves," each with a different profile depth. Each leaf (approximately 1 in.² [645 mm²] in area) has the nominal profile depth marked in mils or micrometers (Figure 4-26). To use a profile comparator, it is placed on the surface whose profile is to be determined. The appearance of the surface is then visually compared to the leaves of the comparator, with or without magnification, depending on the manufacturer's instructions. Comparator surfaces are pre-

FIGURE 4-25. Use of a micrometer to measure reverse replica of surface profile on replica tape. Courtesy of KTA-Tator Inc.

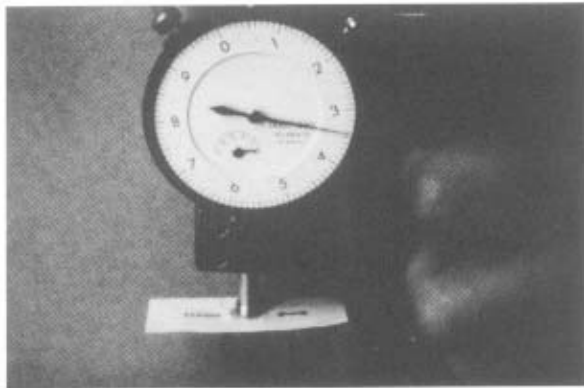
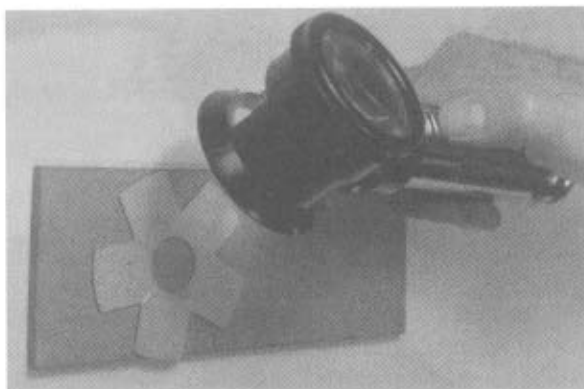


FIGURE 4-27. Surface profile depth gage. Courtesy of Elcometer Inc.



FIGURE 4-26. Profile comparator. SSPC file photo.



pared with steel shot, steel grit, or sand or other nonmetallic abrasive, as the appearance of the profile created by these abrasives may differ. (Note: Instead of visual comparators, tactile comparators are sometimes used. To use these, the "feel" of the surface is compared to the leaves of the comparator. When using tactile comparators, care should be taken to avoid contaminating the steel surface with oil or moisture from the fingers.)

C. PROFILE DEPTH GAGE

A profile depth gage (or "depth micrometer") consists of a dial gage and a stylus (pointer) which protrudes from the base of the gage. The base of the gage rests on profile peaks, while the stylus protrudes into valleys of a blasted steel surface (Figure 4-27). The profile is therefore determined from the relative position of the tip of the stylus and the base of the gage. Several readings must be taken to ensure that the stylus is not resting on the tops or sides of peaks rather than fully penetrating the valleys. (Note: The profile depth gage is seldom used today, but it is mentioned here because it may be required by a particular job specification.)

XII. TESTING FOR SURFACE CONTAMINATION - AFTER SURFACE PREPARATION

A. SOLUBLE SALT CONTAMINATION

After surface preparation, the inspector may again be required to verify that the surface is free of soluble salt contamination as described in Section V A of this subchapter. This test is normally performed after the steel has been prepared by blast cleaning. However, if a long interval occurs between coating layers (e.g., full topcoating a

shop-applied primer), it may be advisable to check for contaminants on the existing coating to be overcoated.

B. GREASE OR OIL CONTAMINATION

After surface preparation, the inspector may again be required to verify that the surface is free of grease and oil contamination as described in Section V B of this subchapter.

C. DUST

Dust collected on cleaned surfaces can interfere with coating adhesion. The inspector should therefore verify that prepared surfaces are free of dust. Abrasive blasting and other sources at the jobsite can leave dust on a cleaned surface.

Several simple tests are available for detecting dust on a steel surface. These involve wiping the surface with a clean rag or contacting the surface with the sticky side of some clear tape. The rag or tape is visually examined for particulates. If dust is detected on a prepared surface, the inspector should verify that it is removed before coating application is allowed to proceed. Dust should be removed by vacuuming if possible. It may also be removed by "blowing down" with compressed air; however, care must be taken to ensure that the air is clean and dry (see Blotter test, Chapter 8).

XIII. SUMMARY

Surface preparation of steel is essential to obtain good coating performance. The proper degree of surface cleanliness and profile are necessary for coating adhesion. Steel surfaces are usually prepared for coating by mechanical means, such as abrasive blast cleaning, centrifugal blast cleaning, hand-tool cleaning, and power tool cleaning. Solvent cleaning is also used in conjunction with these mechanical means. A newer method of surface preparation called water cleaning is also sometimes used on steel surfaces.

For all types of surface preparation methods, the inspector should inspect surface preparation materials. It should be verified that abrasives are appropriate and clean. The inspector should also verify that the surface preparation equipment is appropriate and operating properly. Air sup-

plies should be checked for cleanliness, and it should be verified that necessary filters and traps are in place.

To ensure proper surface preparation, the inspector should verify the following:

- That the specified level of surface cleanliness is attained. For this he may use visual and/or written standards and jobsite standards.
- That the specified surface profile is attained. For this he may use one or more methods, such as replica tape, comparators, and depth gages. That the level of surface contamination is within the range allowed by the specification. This may involve testing for soluble salts, grease and oil, and dust.

Chapter 4.3

Inspection of Surface Preparation of Concrete

by Stephen G. Pinney and John L. Hausfeld

OUTLINE

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- II. About Surface Preparation of Concrete
- III. Verifying Degree of Curing
- IV. Verifying Soundness of Surface
- V. Verifying Removal of Protrusions and Spatter, and Filling of Surface Indentations
- VI. Testing for Surface Contamination - Before Surface Preparation
 - A. Grease, Oil, and Form Release Agents
- VII. Inspection of Surface Cleaning of Concrete - Methods Not Intended to Alter Surface Profile
 - A. Broom, Vacuum, and Air Blast Cleaning
 - B. Wire Brushing
 - C. Water, Detergent, and Steam Cleaning
- VIII. Inspection of Surface Preparation of Concrete - Methods that Alter Surface Profile
 - A. Abrading
 - B. Acid Etching
- IX. Testing for Surface Contamination - After Surface Preparation
 - A. Incompletely Neutralized Residual Chemicals
 - B. Grease or Oil
 - C. Dust
- X. Testing for Concrete Surface Profile (CSP) - After Surface Preparation
- XI. Testing for Retained Moisture (ASTM D 4263)
 - A. Plastic Sheet Method (ASTM D 4263)
 - B. Moisture Meter

- C. Calcium Chloride Dome Test
- XII. Summary

I. REFERENCES

American Concrete Institute (ACI)

ACI 503R Use of Epoxy Compounds with Concrete

ACI 515.1R Guide to the Use of Waterproofing, Damp-proofing, Protective and Decorative Barrier Systems for Concrete

American Society for Testing and Materials (ASTM)

ASTM D 4258 Practice for Surface Cleaning Concrete for Coating

ASTM D 4259 Practice for Abrading Concrete

ASTM D 4260 Practice for Acid Etching Concrete

ASTM D 4261 Practice for Surface Cleaning Concrete Unit Masonry for Coating

ASTM D 4262 Test Method for Determining pH of Chemically Cleaned or Etched Concrete Surfaces

ASTM D 4263 Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method

ASTM D 4285 Method for Indicating Oil or Water in Compressed Air

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ASTM D 4263 Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method

ASTM D 4285 Method for Indicating Oil or Water in Compressed Air

ASTM D 4541 Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers

International Concrete Repair Institute (ICRI)

Technical Guideline No. 03732 Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays

SSPC: The Society for Protective Coatings (SSPC)

SSPC-SP 12 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating (NACE No. 5)

II. ABOUT SURFACE PREPARATION OF CONCRETE

Inspection requirements for surface preparation of concrete are basically to determine whether specification requirements are met concerning:

- The removal of contaminants that inhibit coating adhesion or induce early coating deterioration
- Roughening of smooth surfaces to improve coating adhesion
- The removal of any weak surface layer to establish a strong base required for many coating systems.

There are many methods that may be used to prepare a concrete surface for coating. These include broom, vacuum, and air blast cleaning; water, detergent, and steam cleaning; mechanical abrasion with hand or power tools; water blast cleaning; abrasive blast cleaning; and acid etching (Figure 4-28).

III. VERIFYING DEGREE OF CURING

Prior to surface preparation of new concrete the inspector may be required to verify that the concrete is fully cured. The proper curing time (with sufficient moisture and temperatures) before coating is normally stated in the specification (Figure 4-29).

FIGURE 4-28. Surface preparation of concrete. Top - A machine for preparing concrete floors for coating. Courtesy of KTA-Tator Inc. Bottom - Abrasive blasting to remove coating from a concrete surface. SSPC file photo.



FIGURE 4-29. Freshly-poured concrete. Courtesy of Sauereisen.

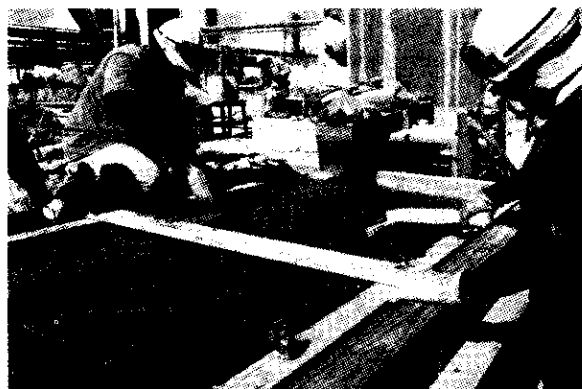
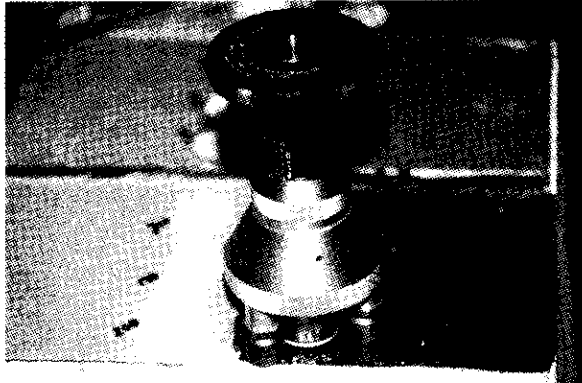


FIGURE 4-30. Testing surface tensile strength of concrete. Courtesy of Stonhard, Inc.



IV. VERIFYING SOUNDNESS OF SURFACE

Prior to surface preparation of new and older concrete, the inspector may be required to verify that the concrete is sound. The soundness of a concrete surface can be determined by measuring the surface tensile strength with an adhesion tester. ASTM D 4541 and ACI 503R, Appendix A have been used for this purpose (see Chapter 8; Figure 4-30). SSPC and NACE are currently considering a standard test method for determining the soundness of concrete and the adhesion of coatings to concrete. Both of the above standard test methods would be included in the joint standard.

V. VERIFYING REMOVAL OF PROTRUSIONS AND SPATTER, AND FILLING OF SURFACE INDENTATIONS

On new concrete, protrusions and concrete spatter should be removed by power grinding or stoning (scouring of surfaces with a carborundum or other abrasive brick). Tie-rod holes, bug holes, and other surface indentations should be filled prior to surface preparation (Figure 4-31). ACI 515.1R describes procedures for repairing defects in the concrete. In a chemical environment, it is particularly important that bug holes are filled and fins ground flush to allow for good film integrity.

It should be noted that the above repairs are normally the responsibility of the concrete personnel. However, the

inspector should verify that manufacturer's recommendations are followed when repairs are made. Otherwise, problems may arise due to low tensile strength or bond of the cement repair materials.

VI. TESTING FOR SURFACE CONTAMINATION - BEFORE SURFACE PREPARATION

A. GREASE, OIL, AND FORM RELEASE AGENTS

The inspector should verify that surfaces are not contaminated by grease, oil, or form release agents. These contaminants must be removed to permit good adhesion of coatings to concrete. Three common sources of grease/oil contamination are: (1) oil on the hands of the applicator or inspector, (2) oils used to lubricate compressors and power tools, and (3) diesel exhaust.

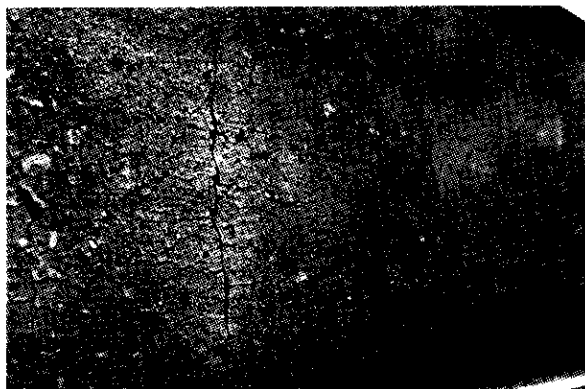
Grease and oil can sometimes be detected when not visually apparent by spraying the concrete surface with a fine mist of water (Figure 4-32). If the concrete surface is clean, the water will wet and darken the surface and spread well. If the surface is contaminated by grease, oil, or form release agents, it will resist wetting, i.e., it will not darken and/or the water will form beads or droplets on the surface (see Water Break Test, Section XIII.A. in Chapter 8).

If grease, oil, or form release agents are detected on a prepared surface, the inspector should verify that they are removed by the specified procedure, e.g., solvent cleaning, before coating application is allowed to proceed.

VII. INSPECTION OF SURFACE CLEANING OF CONCRETE - METHODS NOT INTENDED TO ALTER SURFACE PROFILE

If surface cleaning is specified, the inspector should verify it is done according to the job specification and referenced standards. ASTM D 4258 and ASTM D 4262 describe basic procedures for cleaning concrete and concrete unit masonry surfaces, respectively, to remove dust, oil, grease, dirt, and loose material prior to coating. These cleaning procedures include: broom cleaning, vacuum cleaning, air blast cleaning, water cleaning, detergent water cleaning,

FIGURE 4-31. Cracks and bugholes in a concrete surface. SSPC file photo.



steam cleaning, and mechanical tool cleaning. They are not intended to alter the surface profile. While visual standards are not available for cleaned concrete surfaces, a "field standard" may be prepared, as described for steel in Chapter 4.2.

A. BROOM, VACUUM, AND AIR BLAST CLEANING

Surface dirt, dust and other loose solid materials can be removed by broom, vacuum cleaning, or a stream of clean compressed air (ASTM D 4285). These methods will not remove grease, oil, or laitance (a weak brittle layer that results when concrete is overly wet or overworked).

B. WIRE BRUSHING

Efflorescence is a fluffy deposit formed by the reaction of soluble alkaline products that migrate to the surface with carbon dioxide (Figure 4-33). It should be removed from cementitious surfaces by dry wire brushing before any washing occurs. Water washing will merely drive it into the concrete. Efflorescence does not normally occur on new concrete.

FIGURE 4-32. Top - Oil contaminated cores. Dollies have been attached for adhesion testing. Courtesy of Stonhard, Inc. Bottom - The water drop (contact angle) test used to determine the presence of residual surface contamination. This sample shows a high contact angle due to oil contamination. Courtesy of Stonhard, Inc.



C. WATER, DETERGENT, AND STEAM CLEANING

Grease and oil are best removed from concrete by alkaline cleaning solutions or by steam cleaning with added detergent. Heavy deposits of grease or oil should first be removed by scraping. Solvent cleaning tends to drive these contaminants into the concrete. These methods do not remove laitance effectively.

For plaster, stucco, dry wall, plaster board, and other cementitious surfaces with limited structural strength, washing with a mild detergent solution is normally sufficient to remove dirt and other loosely-held contaminants. Power washing with a detergent solution up to 2,000 psi (14 MPa) may be necessary on surfaces that are strong enough to withstand these pressures. (For further information on water cleaning methods, see Chapter 4.2.)

VIII. INSPECTION OF SURFACE PREPARATION OF CONCRETE - METHODS THAT ALTER SURFACE PROFILE

A. ABRADING

ASTM D 4259 describes surface preparation of concrete prior to coating. This practice is intended to roughen the surface profile of the concrete and remove foreign materials including existing coatings and weak surface concrete, such as laitance. These procedures include mechanical abrasion, water blast cleaning, and abrasive blast cleaning.

Power tools can be used to remove loose or otherwise defective concrete. A scarifying machine (Figure 4-34) can be used effectively on large areas of concrete floors. Care should be taken not to damage the floors with this machine.

Water blasting (with or without injected abrasive) may also be effective for surface cleaning of concrete, although it introduces water into the concrete and thus requires drying time before coating operations can begin.

Abrasive blasting of sound concrete is often the most effective method of cleaning. If abrasive blasting is specified, the inspector should verify that it is done according to the job specification and referenced standards. Blasting pressures and nozzle-to-concrete distances, must usually be controlled carefully to prevent excessive removal of concrete.

B. ACID ETCHING

ASTM D 4260 describes the use of acid to prepare concrete surfaces for coating. The practice is intended to

FIGURE 4-33. Efflorescence. Courtesy of KTA-Tator Inc.

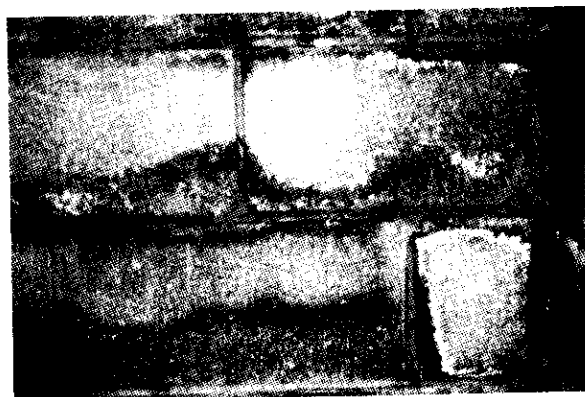


FIGURE 4-34. Scarifying machine. SSPC file photo.

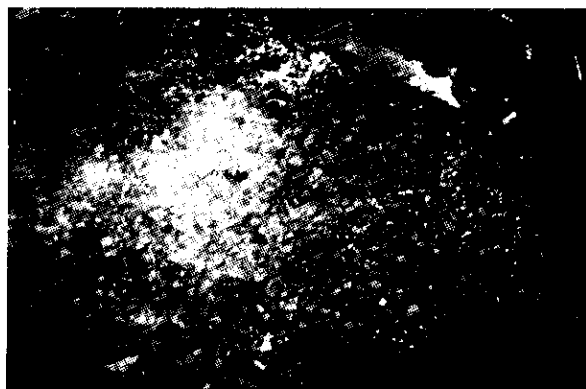


roughen the surface profile of the concrete and remove foreign materials and weak concrete laitance (Figure 4-35).

Caution: Acid etching should only be used where other methods are not possible. This is because:

- There are concerns regarding the disposal of the residue as hazardous waste.
- It wets the surface at a stage late in the application process.
- It may not be a reliable surface preparation method, depending on the type of contamination (e.g., organics or oily contaminants).

FIGURE 4-35. Surface after acid etching. SSPC file photo.



Acid etching (frequently with a 10% solution of muriatic acid) can be used to roughen smooth surfaces to produce better coating adhesion. It should be noted that standard safety and environmental procedures must be followed when using acids or other chemicals. Specially designated procedures must be followed when disposing of chemical wastes. Chemical spills should be cleaned up according to procedures specifically prepared for them.

Acids used in etching should be neutralized with bicarbonate solution and the clean surfaces then rinsed with water. Care should be exercised to scrub the concrete surface to ensure that the salts deposited from the acid etching process are removed. The process of acid etching followed by neutralization with bicarbonate may produce insoluble salt compounds that are not removed by water rinsing. It may therefore be necessary to further clean the rinsed surface by a method such as vacuuming (ASTM D 4285). The concrete should be allowed to dry sufficiently prior to applying the coating.

IX. TESTING FOR SURFACE CONTAMINATION - AFTER SURFACE PREPARATION

A. INCOMPLETELY NEUTRALIZED RESIDUAL CHEMICALS

Some residual chemicals, such as those left behind from chemical cleaning or etching, may adversely affect the

adhesion and performance of coatings applied over prepared concrete surfaces. The inspector may therefore be required to test the surface pH of the concrete before any coating is applied. To do this, the surface is rinsed with water, and the pH (alkalinity or acidity) of the rinse solution is measured. The procedures for testing the pH of a concrete surface are given in ASTM D 4262, and are described in Chapter 8. The inspector should also verify that the surface is vacuumed if specified.

B. GREASE OR OIL

After surface preparation, the inspector may again be required to verify that the surface is free of grease and oil contamination as described in Section III C of this subchapter.

C. DUST

After abrasion, the concrete surface should be blown down and tested for residual dust. This can be detected visually by applying and removing a piece of transparent adhesive tape or rubbing the surface with a dark cloth (see Chapter 8).

X. TESTING FOR CONCRETE SURFACE PROFILE (CSP) - AFTER SURFACE PREPARATION

After preparing concrete surfaces for coating, the concrete surface profile (CSP) can be determined by visual comparison to the molded replicates available from the International Concrete Repair Institute (ICRI). These standards range in roughness from a low of CSP 1 to a high of CSP 9, and include surfaces prepared to different levels by acid etching, grinding, shotblasting, scarification, and scabbling. They represent degrees of roughness suitable for application of sealers, coatings, and polymer overlays, up to a thickness of 1/4 inch. A chart (Method Selector) provided by ICRI indicates the normal recommended CSPs for these products and the recommended surface preparation methods to obtain them.

XI. TESTING FOR RETAINED MOISTURE (ASTM D 4263)

Retained moisture in concrete may be detrimental to the performance of certain coating systems. The inspector

may therefore be required to test the concrete for retained moisture. Testing for retained moisture may be required before surface preparation. It may also be required after surface preparation if a "wet" surface preparation method such as acid etching or water blasting is used.

A. PLASTIC SHEET METHOD (ASTM D 4263)

One commonly-used test for retained moisture is the plastic sheet method (ASTM D 4263). In this test, a plastic sheet is taped to the concrete surface and left in place for at least 16 hours (Figure 4-36). (Thus, when required, this test will delay work by about one day.) ASTM recommends testing every 500 ft² (47 m²) for floors, walls, and ceilings unless otherwise specified. This should include representative sections of each pour. This test is described in Chapter 8.

B. MOISTURE METER

A moisture meter may also be used to detect moisture on or under the surface of concrete (Figure 4-37). However, it is considered to be more appropriate for plaster or wood than for concrete and to be best used to detect surface rather than interior moisture. The meter uses two needles or probes protruding from a continuity gage. When the needles are placed on the surface, the gage indicates whether or not moisture is present there. To detect interior moisture, the substrate must be penetrated (e.g., by appropriately spaced concrete nails driven 0.25 or 0.5 in. (6.4 or 13 mm.) into the surface of the concrete). The use of a moisture meter is described in Chapter 8.

C. CALCIUM CHLORIDE DOME TEST

Another method of testing for retained moisture is the calcium chloride dome test method, currently being reviewed by ASTM (Figure 4-38). This method is used to obtain a quantitative value for the rate of moisture emission from a horizontal concrete surface such as a floor. In this method, a pre-weighed sample of anhydrous calcium chloride is placed on the concrete surface and is covered with a sealed plastic dome. After a designated amount of time (about 60 to 72 hours), the plastic dome is removed and the calcium chloride sample is weighed to determine the mass gain due to moisture. Moisture emission is then computed from the mass gain, the contact area of the calcium chloride on the

FIGURE 4-36. Plastic sheet test. Courtesy of S.G. Pinney & Associates Inc.

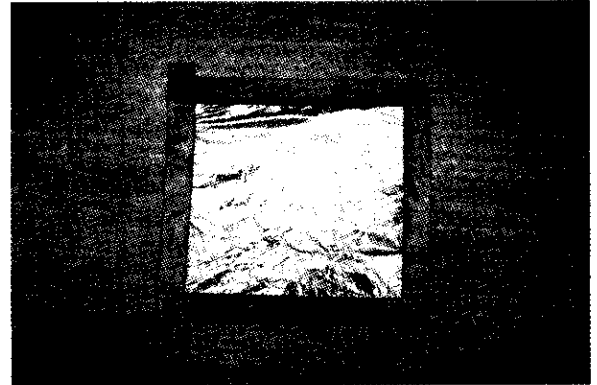
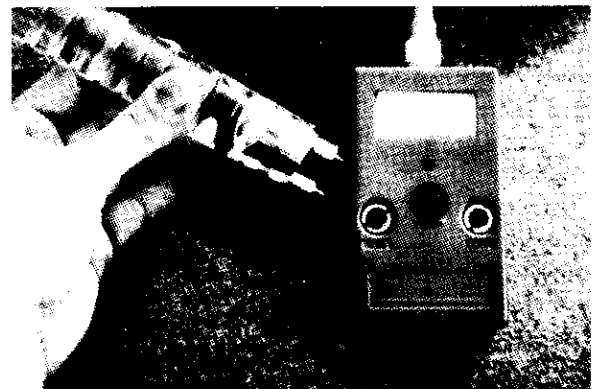


FIGURE 4-37. Use of a moisture meter on a concrete surface. Courtesy of KTA-Tator Inc.

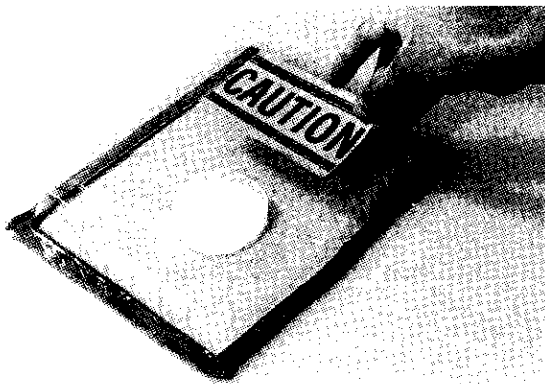
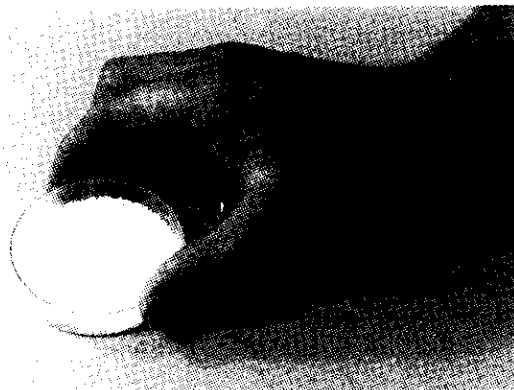
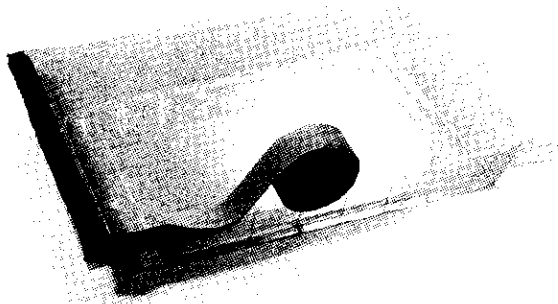


concrete, and the exposure time. This test is described in Chapter 8.

XII. SUMMARY

Surface preparation of concrete is necessary to remove contaminants that inhibit coating adhesion and to roughen surfaces to improve coating adhesion. Concrete surfaces should be prepared for coating only after they are adequately cured. Prior to surface preparation, concrete may

FIGURE 4-38. Calcium chloride dome test. Top - Affixing two-sided tape to plastic dome. Center - Placing dish of calcium chloride on surface to be tested. Bottom - Placing plastic dome over calcium chloride sample. (See Chapter 8 for further details.) Courtesy of Taylor Tools/Creative Marketing Resources.



require grinding or stoning to remove protrusions or fill surface holes and indentations.

There are several methods of concrete surface preparation that are not intended to roughen the surface profile. These include:

- Broom, vacuum, and air blast cleaning - used for removing surface dirt, dust, and other loose materials.
- Water, detergent, and steam cleaning - used for removing grease and oil.
- Wire brushing - used for removing efflorescence.

There are also several methods of concrete surface preparation methods that do roughen surface profile:

- Abrading - by procedures such as power tools, water blast cleaning, and abrasive blast cleaning.
- Acid etching, e.g. with a 10% solution of muriatic acid.

Whatever surface preparation methods are used, the inspector should monitor them and verify that the specified results are attained.

During surface preparation of concrete, the inspector should also verify that the level of surface contamination (e.g., acidic contaminants, grease or oil, and dust) is within the range allowed by the specification. The inspector may also be required to test the concrete surface for retained moisture.

Chapter 4.4

Inspection of Mixing, Thinning, and Coating Application

by Stephen G. Pinney

OUTLINE

- I. References
- II. Inspection of Mixing
 - A. Single Component Materials
 - B. Multiple Component Materials
- III. Measuring Viscosity
- IV. Monitoring Material Thinning
- V. Monitoring Straining
- VI. Ensuring that Coating Materials Do Not Become Contaminated
- VII. Inspection of Coating Application Equipment
- VIII. Inspection of Coating Application Methods
 - A. General Requirements
 - B. Application by Brush or Roller
 - C. Application by Conventional (Air) Spray
 - D. Application by Airless Spray
 - E. Trowel-applied Coatings
- IX. Inspection of Primer, Intermediate Coat, and Top-coat Application
 - A. Primer Coat Application
 - B. Intermediate Coat or Top Coat Application
- X. Requirements for Maintenance Painting
- XI. Wet Film Thickness Measurements
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- XII. Summary

I. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 4212 Test Method for Viscosity by Dip-Type Viscosity Cups

ASTM D 4285 Method for Indicating Oil or Water in Compressed Air

ASTM D 4414 Practice for Measurement of Wet Film Thickness of Organic Coatings by Notched Gages

ASTM E 337 Test Method for Measuring Humidity with a Psychrometer (The Measurement of Wet- and Dry-Bulb Temperatures)

SSPC: The Society for Protective Coatings (SSPC)

SSPC-PA 1 Shop, Field, and Maintenance Painting

SSPC-PA Guide 4 Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems

SSPC-PA Guide 5 Guide to Maintenance Painting Programs

II. INSPECTION OF MIXING

The inspector should verify that all coating materials are properly mixed. SSPC-PA 1 and the sections following provide some general guidelines for mixing of paints.

More specific mixing instructions for specific coatings should be obtained from the manufacturer's instructions.

A. SINGLE COMPONENT MATERIALS

All coatings should be completely mixed in clean containers before use. Where there is noticeable settling, and mixing is to be done either by power stirrers (Figure 4-39) or by hand, most of the paint should be poured off into a clean container. The settled material should first be lifted from the bottom of the container with a clean, flat paddle. Lumps should then be broken up and the settled material thoroughly mixed with the remaining material. The separated portion should then be returned slowly to the original container with simultaneous stirring. At this point, it may also be useful to mix or pour repeatedly from one container to another (boxing) until the composition is uniform. When power mixing water-borne coatings, care must be taken not to cause foaming by overmixing.

The bottom of the original container should be inspected for unmixed solids. If all such solids cannot be uniformly mixed in, it is an indication that there is something wrong with the material (e.g., it might have exceeded its shelf life), and it should be properly discarded. The inspector should ensure that a homogeneous blend is used. Color variation from that specified may be a problem with older coatings. The inspector should check to see that color variations do not occur.



FIGURE 4-39. Mixing a one-component material. Courtesy of KTA-Tator Inc.

FIGURE 4-40. Mixing a multi-component material. Courtesy of KTA-Tator Inc.



B. MULTIPLE COMPONENT MATERIALS

Many materials such as zinc-rich primers and chemically-curing epoxies, and polyurethanes are manufactured with more than one component. They require mixing of precise proportions prior to application to obtain optimum film properties (Figure 4-40). In all cases, the manufacturer's mixing instructions should be followed. It should be noted that with some products, hand mixing is unacceptable.

For mixing of multi-component materials, the inspector should:

- Verify that the proper components are mixed. Mixing of components from different coating products will result in an improper or incomplete cure.
- Verify that the proper proportions are mixed. It is good practice to mix complete kits (as packed by the manufacturer) rather than measuring out partial amounts. However, if only partial kits are necessary, they should be mixed carefully, using a measuring device or scale to ensure proper proportions. It is good practice to have a few small kits available when small quantities are required.
- Verify that each component is mixed individually prior to mixing the components together. All settled materials should be uniformly dispersed.
- Verify that all of the materials are uniformly blended. This may require the applicator to scrape material from

FIGURE 4-41. Measuring viscosity. Courtesy of KTA-Tator Inc.



the sides or bottom of the cans. Materials with heavy pigments (e.g., zinc) usually require constant agitation during application. Whenever in-pot agitators are required, the inspector should verify that they are in place and working.

- For chemically-curing materials, verify that the proper induction time (if necessary) is observed. Induction time is the period of time required after mixing and before application. This time allows the components of the material to partially react before application to ensure complete film curing after application. The inspector should also verify that the material is homogeneous (and re-mixed, if necessary) at the completion of induction time.

III. MEASURING VISCOSITY

The viscosity of a paint (its ability to flow) is affected by temperature. As temperature decreases, viscosity increases, and the paint's ability to flow diminishes. Thus, at low temperatures, thinning may be necessary to achieve a viscosity that will permit proper application.

The inspector should measure the viscosity of the paint before use, if required by the specification, or if viscosity is of concern due to weather conditions (e.g., during cold weather) or other circumstances. In the field, this can be done using a viscosity cup (ASTM D 4212; see Chapter 8, Figure 4-41). The manufacturer's instructions for thinning should be followed.

IV. MONITORING MATERIAL THINNING

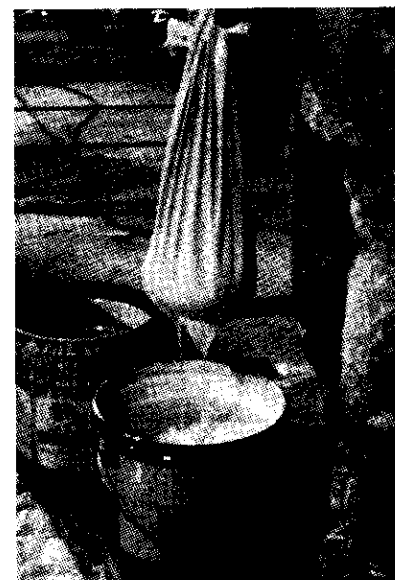
The inspector should verify that all coating materials are properly thinned. SSPC-PA 1 and this section provide some general guidelines for thinning of paints. More specific thinning instructions for specific coatings should be obtained from the manufacturer's instructions.

Some job specifications do not permit field thinning of coatings. Others permit thinning with the specified thinner in limited amounts, under specified conditions, e.g., when cold weather increases the viscosity, making application difficult. Likewise, if the substrate is hot, it may be permissible to add a high flash point thinner for slower evaporation and reduced mud cracking.

When a coating material is thinned, the inspector should verify that the specified or recommended thinner is used. The inspector should also verify that the amount of thinner added does not exceed specifications, and that the thinner is added in measurable quantities (e.g., quart cans). Also, the amounts of thinner used should never cause the coating to exceed VOC limitations.

Before thinning, both the coating and the thinner should be allowed to reach the ambient temperature at which the material is to be applied. The thinner should be added into

FIGURE 4-42. Straining. Courtesy of KTA-Tator Inc.



the mixed coating material, and the thinned coating should be mixed to a homogeneous state before it is applied.

V. MONITORING STRAINING

The inspector should observe that all materials are strained per the manufacturer's instructions or whenever lumps are observed (Figure 4-42). The strainers should be of a type to remove only lumps, etc., but not remove pigment. For example, a 30-60 mesh strainer is normally satisfactory for most coatings. (However, with high-performance flake-filled coatings, large flakes must remain to provide permeation resistance and other desired properties of the cured film.)

VI. ENSURING THAT COATING MATERIALS DO NOT BECOME CONTAMINATED

The inspector should verify that all necessary precautions are taken to avoid contamination of the coating materials. For example, for paints, the inspector should:

- Verify that lids are kept on mixed material to avoid dirt contamination prior to application.
- Verify that the open portions of buckets (e.g., in the case of airless spray application) are covered with cheesecloth.
- Observe that mixing equipment is cleaned with solvent or by mechanical methods at least after each day's use, and that waste solvent used in cleaning is properly disposed of.

VII. INSPECTION OF COATING APPLICATION EQUIPMENT

The job specification usually permits the contractor to choose his own method of coating application, as long as the specification requirements are met. In some instances, special equipment may be required. The inspector should check to see if the application equipment is clean and has the ability to apply the materials to be used. Further instructions for inspecting conventional coating application equipment are given in the sections that follow. Also, some instructions for inspection of specialty coating application equipment (e.g., shotcreting, thermal spray, and powder coating equipment) are given in Chapter 5.

VIII. INSPECTION OF COATING APPLICATION METHODS

A. GENERAL REQUIREMENTS

The inspector should verify that all coating materials are properly applied. The sections below provide some general guidelines for application of paints. SSPC-PA 1 is also a useful general reference for the coatings inspector. It includes a discussion of the factors affecting paint application, and a description of many recommended application methods. More specific application instructions for paints and other types of conventional coatings should be obtained from the manufacturer's technical data sheets.

- Monitor ambient conditions, as described in Chapter 4.1 Section IX. Verify that ambient temperature, surface temperature, relative humidity (ASTM E 337), and wind are in conformance with the job specification. For chemically-curing materials, also verify that the induction time is met and the pot life (useful life) of the material is not exceeded. The manufacturer's technical data sheets specify pot lives of mixed multiple-component materials at specific temperatures. Pot life decreases at higher temperatures and increases at lower temperatures. The temperature of the mixed multiple-component material should therefore be measured and the manufacturer's technical data sheet should be consulted to establish the pot life. Larger amounts of the mixed product will also reduce pot life because of the heat of reaction.

FIGURE 4-43. Monitoring spray application. SSPC file photo.



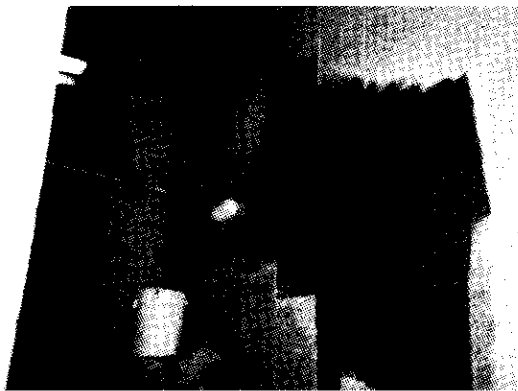
- Monitor the application process to assure material is being applied in a smooth, continuous film of uniform specified thickness, and free of dryspray, runs, sags, or other application related defects (Figure 4-43). For coating materials that require in-pot agitation, also verify that coating materials are agitated sufficiently (if specified) during application to ensure homogeneity without overmixing. Overmixing may entrap air.
- Measure (or assist/observe the applicator in measuring) wet film thickness to determine whether expected dry film thickness will meet specification requirements (discussed further in Section D, below).

Throughout the application process, the inspector observes the work and records what is observed. The inspector does not usually have the authority to interfere with the applicator's work, i.e., he cannot require the applicator to change his technique, unless required by the job specification. The inspector's main concern is that the end product meet all requirements. This is because specifications usually require a defined end product (e.g., dry film thickness) rather than a means of achieving it. Thus, he may advise the applicator that low wet film thicknesses may result in low dry film thicknesses.

B. APPLICATION BY BRUSH OR ROLLER

When the coating manufacturer recommends specific application equipment for brushing or rolling (Figure 4-

FIGURE 4-44. Roller application. Courtesy of KTA-Tator Inc.



44), its use should be verified by the inspector. The inspector should:

- Verify that brushes and rollers are the type and size recommended by the coating manufacturer, and are appropriate for use on the areas being painted. Special shaped brushes may be required for special applications, e.g., round/oval brushes may be required for rough surfaces, rivet heads, and constricted areas. Long nap rollers may be required for open work such as grills and cinder blocks. Also, the inspector should verify that the cores of rollers are compatible with the paint.
- Verify that brushes and rollers are clean and in good condition. Loose bristles and debris should be removed from brushes before they are used. The nap should be raised on rollers before they are used.
- Verify that the recommended amount of paint is applied to the brushes and rollers. Rollers should be loaded with paint then rolled out completely on newspapers (or the spreader screen, if used) to condition the fibers and to work out air bubbles.
- Verify use of proper overlapping and crosshatching techniques.
- Verify that the paint is brushed out as much as appropriate based on the generic type. If drips and sags occur, they should be brushed out immediately.
- Verify proper techniques for coating outside and inside corners.

C. APPLICATION BY CONVENTIONAL (AIR) SPRAY

When application is performed using conventional spray (Figure 4-45) the inspector should:

- Verify that the particular tip sizes recommended by the coating manufacturer are used
- Verify by the blotter test (ASTM D 4285) that the air used for conventional spray, is free of oil and moisture. (For more details on this test, see Chapter 8.)
- Verify that two operating pressure regulators are present so that the pot pressure and atomization pressure can be independently adjusted.
- Verify (by checking the spray pattern) that pot pressure is sufficient to obtain adequate material supply at the spray gun.

- Verify that application conditions result in a uniform, continuous film free of defects.
- Verify use of proper overlapping and crosshatching techniques.
- Verify proper techniques for coating outside and inside corners to obtain uniform coating thicknesses in these locations.
- Verify that a material agitator is used where required by the specification or coating manufacturer.
- Verify that proper triggering, 50% overlap of strokes, and uniform distance from substrate (no arcing) is used to obtain uniform coating thicknesses.

D. APPLICATION BY AIRLESS SPRAY

When application is performed using airless spray (Figure 4-46), the inspector should:

- Verify that proper pump, pressures, and hose and tip sizes (as required on the manufacturer's technical data sheet) are used.
- Verify that the pump pressure gages are in working order and the pressure relief valves are unrestricted. The pump should measure the air pressure in and the fluid pressure out.
- Verify that application conditions result in a uniform, continuous film free of defects.

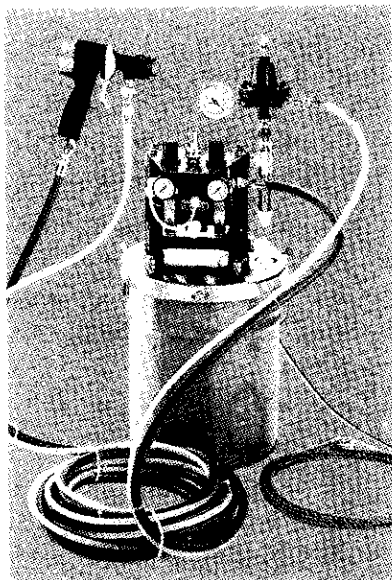
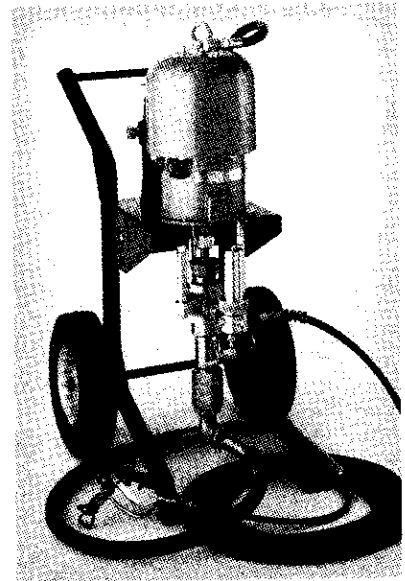


FIGURE 4-45.
Air spray
equipment.
Courtesy of
Graco Inc.

FIGURE 4-46.
Airless spray
equipment.
Courtesy of
Graco Inc.



- Verify that the applicator has not attempted to coat complicated areas such as bolt patterns. (Note: Conventional spray should be used to coat these areas.)
- Verify use of proper overlapping and crosshatching techniques.
- Verify proper techniques for coating outside and inside corners to obtain uniform coating thicknesses in these locations.
- Verify that a safety guard is used on the spray gun.
- Verify that proper triggering, 50% overlap of strokes, and uniform distance from substrate (no arcing) is used to obtain uniform coating thicknesses.

E. TROWEL-APPLIED COATINGS

For trowel-applied coatings (Figure 4-47), the inspector should:

- Verify that aggregates/fillers are completely wetted out.
- Ensure that adequate thickness is installed over welds and projections, and that uniform thickness is applied.

For fiberglass-reinforced, troweled linings, the inspector should:

- Ensure that fiberglass reinforcements are properly impressed in the basecoat to eliminate air pockets or wrinkles

- Verify that fiberglass reinforcement is properly saturated. When properly saturated, fiberglass takes on the color of the saturant resin with no "white" showing. It is easiest to detect imperfections when clear saturant resins are used.
- Verify proper lapping of fiberglass sheet. Lap is normally 1 inch to 2 inch minimum.

IX. INSPECTION OF PRIMER, INTERMEDIATE COAT, AND TOPCOAT APPLICATION

A. PRIMER COAT APPLICATION

The inspector should verify the following conditions prior to primer coat application:

- The surface has the specified surface preparation (roughness and cleanliness), and is free of contaminants. A test for soluble salt contaminants is often performed after the steel has been prepared by blast cleaning.
- The specified time range has been observed between application of any chemical treatment (e.g., pretreatment wash primer) and application of the prime coat. This is necessary for complete chemical reaction of the pretreatment and tight adhesion of the primer.

FIGURE 4-47. Application by trowel. Courtesy of Ceilcote/Master Builders, Inc.



B. INTERMEDIATE COAT OR TOP COAT APPLICATION

The inspector should verify the following conditions prior to intermediate coat or top coat application:

- The previous coat should be free of unacceptable defects such as dryspray, runs, sags (Figure 4-48), and other application-related defects. Also, the surface should be free of contaminants. A test for soluble salt contaminants is often performed after the steel has been prepared by blast cleaning. However, if a long interval occurs between coating layers, it may be advisable to check for contaminants on the existing coating to be overcoated.
- The previous coat should be dried or cured for the time required by the specification. (Information on testing for degree of cure is given in Chapter 4.5, Section V and in Chapter 8.)
- If the undercoat is a two-component, chemically-curing material, the overcoat should be applied within the recoat window time specified by the supplier of the undercoat.
- The dry film thickness of the previous coat should meet the requirements of the job specification. (See Chapter 4.5, Section II.)
- Each coat should completely obscure the previous coat. (Normally the colors are at least slightly different and contrasting.)

X. REQUIREMENTS FOR MAINTENANCE PAINTING

Specific guidelines for maintenance painting (Figure 4-49) are contained in and SSPC-PA Guide 4, "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems" and SSPC-PA Guide 5, "Guide to Maintenance Painting Programs."

According to Guide 4, the basic steps for maintenance repainting of oil-based, alkyd, and other conventional oleoresinous paint systems are:

- Determine the surface condition and recommended actions according to Table 1 of Guide 4.
- Choose the repainting system; spot test for compatibility with existing system, if necessary.

- Apply paint and touch up according to established procedures (SSPC-PA 1).
- Perform required inspection and testing of applied film and, if required, sampling of the paints used.

Guide 5 covers procedures for planning and carrying out a maintenance painting program. It applies to either one-time repaint or long-range repaint programs. Guide 4 covers the repainting of steel with the same generic paint system as the existing one. It applies to oil-based, alkyd, and other conventional oleoresinous paint systems.

According to Guide 5, the eight major tasks in maintenance painting are:

Task 1: Define Maintenance Painting Objective

Task 2: Plan and Conduct Condition Assessment

Task 3: Determine Corrective Action Required

Task 4: Establish Procedures for Corrective Action

Task 5: Prepare Contract

Task 6: Secure Contracts for Labor and Materials

Task 7: Monitor, Conduct, and Inspect Repainting

Task 8: Plan and Implement Follow-Up Activities

Task 7, "Monitor, Conduct, and Inspect Repainting," includes a useful summary of the inspector's general responsibilities during maintenance repainting. Other sec-

FIGURE 4-49. Severely pitted production piping on an offshore platform. Top - Before maintenance painting; Bottom - After maintenance painting. Both photos courtesy of Chevron USA.

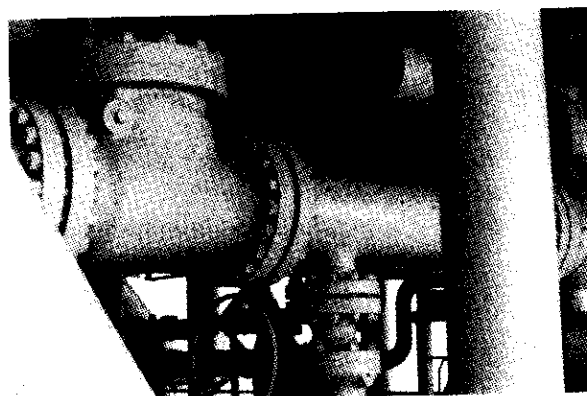


FIGURE 4-48. Example of a coating defect - sagging. SSPC file photo.



tions may also be of interest to the inspector. For example, Task 6, "Secure Contracts for Labor and Materials," includes some information on the pre-job conference; and Appendix A to SSPC-PA 5 describes a procedure that can be used to determine the compatibility of new paint over existing paint.

During maintenance painting, the coating inspector's basic responsibility is the same as for new construction painting: Verify compliance with the specification. However, some of the additional procedures that the inspector may be required to verify prior to maintenance painting are:

- Verify that all loose, cracked, brittle, and non-adherent paint is removed.
- Verify that all rust spots and damaged areas are cleaned, with cleaning extending out far enough on all sides so that tightly adherent paint will be overlapped.
- Verify that all exposed edges on remaining thick paint are feathered to the extent required by the specification.

XI. WET FILM THICKNESS MEASUREMENTS

Wet film thickness (WFT) measurements (Figure 4-50), in conjunction with the known percent volume solids of the coating material, can be used to determine if the proper dry film thickness of each coat of material is being applied.

The wet film thickness gages most commonly recommended for field use are the notch type. Most of them consist of a four-sided metal plate with "teeth" of varying heights cut into each edge. To make a measurement, the edge that includes the desired wet film thickness is pressed onto the surface, and wet film thickness is determined by identifying the shortest tooth wet by the paint film.

FIGURE 4-50. Wet film thickness (WFT) measurement. Copyright Brendan Fitzsimons, 1996. This illustration is taken from the Painting Inspectors Manual (now called the Protective Coatings Inspection Manual) published by Elcometer Instruments Ltd.



Important precautions when making wet film thickness measurements are:

- Use gage immediately after paint application.
- Test flat areas if possible. For curved surfaces, test along the length, not the width.
- Test smooth surfaces (free from irregularities).

Several areas should be checked for WFT. Also, it should be noted that using a wet film gage on "quick drying" coatings (inorganic zinc, vinyls, etc.) will yield measurements that are somewhat lower than the actual WFT. The detailed procedure for the notch type wet film gage is given in Chapter 8 and in ASTM D-4414.

The manufacturer will often list the desired WFT as well as the DFT on the application instructions. However, if this information is not readily available, or if the coating has been thinned, the WFT necessary to produce a certain DFT can be calculated from the formulas below.

A. WITHOUT THINNING

(EQ 1)

$$WFT = \frac{DFT}{\% \text{ Solids by Volume (in decimal form)}}$$

For example, if the desired dry film thickness of a coating containing 50% solids by volume is 3 mils (76 micrometers), the wet film thickness must be:

$$WFT = \frac{3 \text{ mils}}{0.5} = 6 \text{ mils (152 micrometers)}$$

B. WITH THINNING

(EQ 2)

$$WFT = \frac{DFT}{\% \text{ Solids by Volume (in decimal form)}}$$

$$\times (1 + \% \text{ by volume of thinner added (in decimal form)})$$

- Verify that all loose, cracked, brittle, and non-adherent paint is removed.
- Verify that all rust spots and damaged areas are cleaned, with cleaning extending out far enough on all sides so that tightly adherent paint will be overlapped.
- Verify that all exposed edges on remaining thick paint are feathered to the extent required by the specification.

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$$WFT = \frac{3 \text{ mils}}{0.5} = 6 \text{ mils (152 micrometers)}$$

B. WITH THINNING

(EQ 2)

$$WFT = \frac{DFT}{\% \text{ Solids by Volume (in decimal form)}}$$

$$\times (1 + \% \text{ by volume of thinner added (in decimal form)})$$

For example, if the above paint is thinned 10%, the wet film thickness must be:

$$WFT = \frac{3 \text{ mils}}{0.5} \times (1 + 0.1) = 6.6 \text{ mils}$$
$$= 168 \text{ micrometers}$$

XII. SUMMARY

The inspector should monitor the mixing and thinning of paint that is to be applied to concrete and steel surfaces. For single component materials, the inspector should verify that any settled solids are uniformly mixed into the liquid portion. For multicomponent materials, the inspector should verify that the components are mixed according to the specification and the manufacturer's instructions. This entails verifying that:

- The proper components and the proper proportions are mixed.
- Components are mixed individually before being combined.
- The combined material is mixed.
- The proper induction time is observed.

As required, the inspector should measure the viscosity of the paint and monitor any thinning that is necessary. He should make sure that the paint is strained per the manufacturer's instructions and that precautions are taken to avoid contamination of the coating materials.

Coatings may be applied to concrete and steel structures by several techniques, such as:

- Brush and roller
- Conventional spray
- Airless spray

For all application methods, the inspector should verify that the application equipment is as specified, clean, and suitable for the materials and surfaces to be coated.

Paint systems generally include primers, intermediate coats, and top coats. During application of all coats, the inspector has the following responsibilities:

- Monitor ambient conditions
- Monitor the application technique
- Measure or assist in measuring the wet film thickness to determine what the dry film thickness will be. The dry film thickness can be calculated from the wet film thickness, the % solids by volume of the paint, and the amount of thinning.

Depending on whether the paint is being applied as a primer, intermediate coat, top coat, or for maintenance, the inspector may be assigned additional responsibilities by the specification, e.g., for verifying that surfaces are properly cured and free of contaminants.

Chapter 4.5

Post-Application Inspection

by Stephen G. Pinney

OUTLINE

- I. References
- II. Measuring Dry Film Thickness
 - A. Steel
 - B. Nonferrous Metals
 - C. Concrete
- III. Holiday (Pinhole) Detection
 - A. Steel
 - B. Concrete
- IV. Adhesion Testing
- V. Determining Cure - Measuring Hardness and Solvent Resistance
- VI. Assessing the Appearance of the Finished Coating
- VII. Ensuring Proper Disposal of Unused Material
- VIII. Summary

ASTM D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base

ASTM D 2240 Test Method for Rubber Property - Durometer Hardness

ASTM D 2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor

ASTM D 3359 Test Methods for Measuring Adhesion by Tape Method

ASTM D 3363 Test Method for Film Hardness by Pencil Test

ASTM D 4138 Test Method for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means

ASTM D 4541 Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D 4752 Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub

ASTM D 4787 Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates

ASTM D 5162 Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coatings on Metallic Substrates

I. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 1005 Test Method for Dry Film Thickness of Organic Coatings Using Micrometers

ASTM D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Ferrous Metal Base

NACE International (NACE)

NACE RP0188-90 Discontinuity (Holiday) Testing of Protective Coatings

SSPC: The Society for Protective Coatings (SSPC)

SSPC-PA 2 Measurement of Dry Coating Thickness with Magnetic Gages

II. MEASURING DRY FILM THICKNESS

The inspector should measure and document the dry film thickness of the applied coating (Figure 4-51), as required by the job specification and referenced documents, such as the Quality Control Plan.

A. STEEL

The use of nondestructive dry film thickness gages for nonconductive coatings applied to a ferrous metal base is described in SSPC-PA 2 and ASTM D 1186. These gages fall into two distinct categories.

- Type I-Magnetic Pull-Off Gage
- Type II-Fixed Probe (Constant Pressure Probe) Gage

The procedures for calibrating and using various Type I and Type II gages are given in Chapter 8.

FIGURE 4-51. Measurement of dry film thickness (DFT).
Courtesy of Elcometer, Inc.

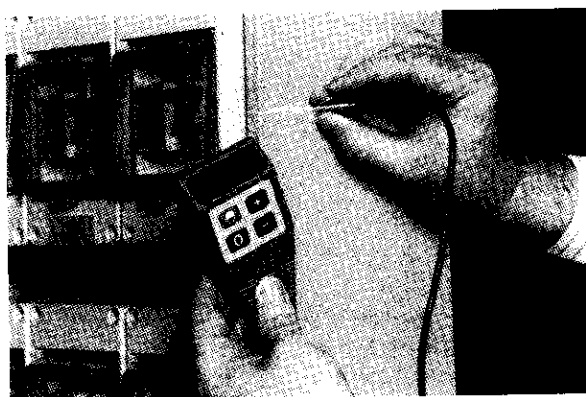
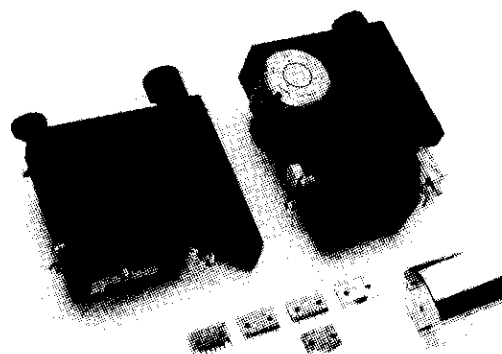


FIGURE 4-52. Destructive dry film thickness gage.
Courtesy of Elcometer, Inc.



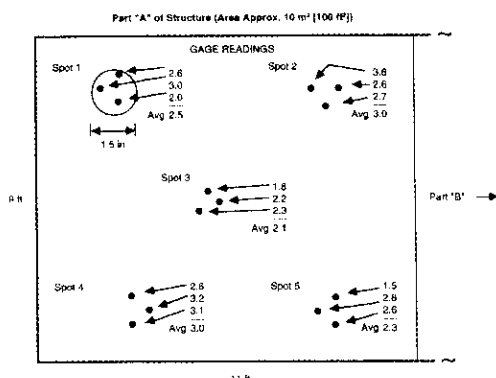
Dry film thickness can be measured destructively using a Tooke gage (Figure 4-52), as described in ASTM D 4138. This method, however, requires subsequent repair, so it is not normally used on coated steel surfaces, unless there is some question or problem about the use of a magnetic gage, or unless some information is desired regarding the thicknesses of individual coats comprising a total coating system. The procedures for calibrating and using a Tooke gage are given in Chapter 8.

When making dry film thickness measurements, the proper sampling technique should be used (Figure 4-53). To determine coating film thickness, three gage readings, one to three inches from one another, should be made for each spot measurement of the substrate or coated surface. Any unusually high or low readings that cannot be repeated should be discarded and the mean be taken as the spot measurement.

For large, flat, or otherwise uniform areas, five separate spot measurements should be taken every 100 ft² (9.3 m²). SSPC-PA 2 and ASTM D 1186 provides additional details. Readings must also be taken for gage calibration.

Note: For prefabricated lining materials, ASTM D 1005 can be used to determine the dry film thickness. It is more reliable on rigid rather than elastomeric materials.

FIGURE 4-53. Proper sampling technique for DFT measurement. From SSPC-PA 2.



The average coating dry film thickness on any substrate can also be calculated from the volume of coating used and the area coated, a practice commonly used when stripping pavements. The average dry film thickness is calculated as follows:

$$\text{DFT (in mils)} = \frac{\% \text{ Solids by Vol. (in dec. form)} \times 1600}{\text{Spreading Rate (in ft}^2/\text{gal)}} \quad (\text{EQ 1})$$

where the spreading rate is the square feet of area coated divided by the gallons of coating used, or

$$\text{DFT (in } \mu\text{m)} = \frac{\% \text{ Solids by Vol. (in dec. form)} \times 1000}{\text{Spreading Rate (in m}^2/\text{L)}} \quad (\text{EQ 2})$$

B. NONFERROUS METALS

The use of nondestructive dry film thickness gages for nonconductive coatings applied to a nonferrous metal base is described in ASTM D 1400. The instruments covered by this test method measure thicknesses by the use of eddy currents.

C. CONCRETE

Destructive dry film gages described above (ASTM D 4138) can also be used on cementitious surfaces such as concrete.

A relatively new, non-destructive method of measuring dry film thicknesses on concrete is using ultrasonic equipment (Figure 4-54). A coupling agent such as a glycol gel may be necessary, especially on rough surfaces, to transmit the ultrasonic pulse. Again, several measurements must be taken and averaged. It should be noted that ultrasonic testing works best on homogeneous coating films. If ultrasonic equipment is to be used on a non-homogeneous coating film (e.g., a coating broadcasted with aggregate), the coating manufacturer should be consulted to verify that the equipment is suitable. Standards for using ultrasonic instruments for determining dry film thickness of coatings have not been issued as of this writing; however, there is one under development by ASTM.

where the spreading rate is the square meters of area coated divided by the liters of coating used.

For example, the average dry film thickness of a coating containing 50% solids by volume applied at 80 ft²/gal (1.97 m²/liter) is:

FIGURE 4-54. Use of ultrasonic DFT gage. Courtesy of DeFelsko Corporation.



$$\text{DFT (in mils)} = \frac{0.50 \times 1600}{80 \text{ ft}^2/\text{gal}} = 10 \text{ mils}$$

or

$$\text{DFT (in } \mu\text{m)} = \frac{0.50 \times 1000}{1.97 \text{ m}^2/\text{L}} = 250 \mu\text{m}$$

It should be noted that these are theoretical values and allowance must be made for losses associated with transfer efficiency.

III. HOLIDAY (PINHOLE) DETECTION

The inspector should holiday test the applied coating as required by the job specification and referenced documents, such as the Quality Control Plan.

A. STEEL

Holiday (pinhole) detection is typically conducted on coating systems designed for immersion service, chemical storage, or burial. The systems are inspected for holidays after the intermediate or final coat has been applied. When holidays are detected, they should be marked for repair. If holidays are detected in an intermediate coat, they should be repaired prior to topcoat application. Failure to detect and repair pinholes or voids may result in moisture permeation through the coating film and premature failure. Holiday testing on steel surfaces can only be performed on non-conductive coatings. Holiday detection equipment generally falls into two categories: low voltage (wet sponge) (Figure 4-55) and high voltage (spark) testers. Low voltage testers are normally used on coatings with DFT of 20 mils (0.5 mm) or less and high voltage testers on coatings with DFT greater than 20 mils (0.5 mm). Holiday detection on metallic substrates is described ASTM D 5162 and in Chapter 8.

FIGURE 4-55. Wet sponge holiday detector. SSPC file photo.

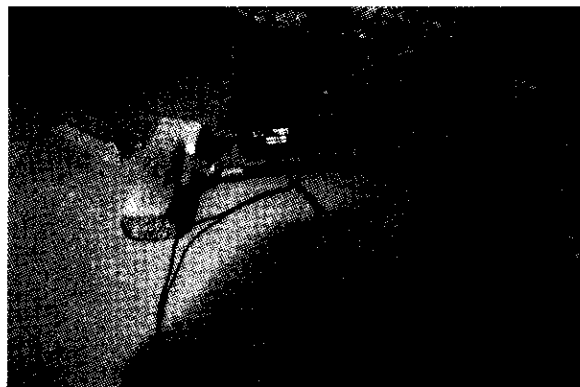


FIGURE 4-56. Holiday detection on concrete. Courtesy of Sauereisen.



B. CONCRETE

Concrete with a coating thickness of 20 mils (0.5 mm) or less can be inspected for discontinuities with a low-voltage, wet-sponge holiday detector, as described in ASTM D 4787 and Chapter 8. Moisture and salts in the concrete provide the necessary conductivity. This procedure has even been successfully used on older concrete structures.

FIGURE 4-57. Tape test for adhesion. Courtesy of KTA-Tator Inc.



The ground lead is connected to a steel reinforcing rod, to a nail driven into the concrete, or merely pressed tightly against the concrete. Alternatively, a conductive primer may be used to facilitate holiday testing.

When coating thicknesses exceed 20 mils (0.5 mm), a high-voltage holiday detector must be used (Figure 4-56) as described in ASTM D 4787. It is common to use 100 volts per mil (4 volts per micrometer) of coating. When holidays are detected, they should be marked for repair.

IV. ADHESION TESTING

The inspector should perform adhesion testing on the applied coating as required by the job specification and referenced documents, such as the Quality Control Plan.

The specification may require testing of the adhesion of individual coating layers to one another and to the substrate, both steel and concrete. Two different general methods of evaluating adhesion are discussed in Chapter 8:

- Tape Test - ASTM D 3359
- Tensile adhesion - ASTM D 4541 and ACI 503R, Appendix A

Field testing of coatings adhesion to substrates is usually accomplished using the cross-cut tape test described in

ASTM D 3359. Method A, which uses an "X" cut, is more suited to field use than Method B, which uses a cut lattice pattern (Figure 4-57). The ASTM D 4541 pull-off method is more quantitative, but it requires a flat, horizontal surface and an experienced operator for reproducibility. Both types of testing are destructive, so that coating repairs must be made after the adhesion tests are conducted.

Some inspectors use a sharp knife to cut into a coating to determine its adhesion and cohesion. However, this is a very subjective, unwritten test that is seldom used in a specification.

V. DETERMINING CURE - MEASURING HARDNESS AND SOLVENT RESISTANCE

The inspector should test the degree of cure of the applied coating as required by the job specification and referenced documents, such as the Quality Control Plan.

There are two types of test that may be performed in the field to determine the cure of a coating:

- Hardness
- Solvent Resistance (Figure 4-58)

FIGURE 4-58. MEK rub test. Photo by Russell Davison, SSPC.



There are several methods to determine hardness. One method uses a series of pencils of varying hardness lead (ASTM D 3363). Instrumental methods may also be used. A durometer (ASTM D 2240) can be used on rubber, cellular materials, elastomeric materials of at least 1/4 inch thickness. The Shore D durometer is used on harder materials and the Shore A durometer is used on softer materials. A Barcol impressor (ASTM D 2583) is appropriate for prefabricated lining materials made from reinforced and nonreinforced rigid plastics. Hardness testing is discussed further in Chapter 8.

Solvent resistance is assessed by rubbing a coating with a cloth containing methyl ethyl ketone (MEK) or other solvent. The procedure for this test is given in ASTM D 4752, and is described in Chapter 8.

VI. ASSESSING THE APPEARANCE OF THE FINISHED COATING

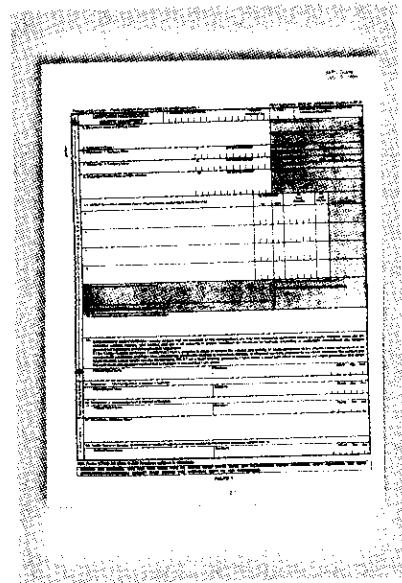
Appearance of the finished coating may be very important. The inspector should check for uniformity of color, gloss, and texture. Color comparisons should be made using the specified color chips. Glossy areas (hot spots) may occur where a coating has been applied too thickly and become resin-rich in localized surface areas. Conversely, dull spots may occur where a coating has been applied too thinly or has had moisture condense on the wet film.

VII. ENSURING PROPER DISPOSAL OF UNUSED MATERIAL

If assigned that duty by the job specification, the inspector should ensure that unused coatings and solvents are stored indoors in closed containers and disposed of in accordance with prevailing regulations. They should not be disposed of at the site, but can only be kept at the jobsite a short time (e.g., 90 days) after completion of the work.

Because of organic solvents or heavy metals, paint or thinner waste may be classified as hazardous, in which case, specific instructions are required for their disposal. The inspector may be required to keep a record of hazardous waste handling and disposal, and to verify proper sampling and documentation (Figure 4-59).

FIGURE 4-59.
Example of a hazardous waste manifest.
Illustration by
Russell Davison,
SSPC.



VIII. SUMMARY

There are many ways that a coating should be inspected after it is applied. For paint applied to steel and concrete, the specification usually has defined dry film thickness (DFT) requirements. On steel, DFT can be measured using non-destructive gages, categorized as Type I - Magnetic Pull-Off Gages and Type II - Fixed Probe (Constant Pressure Probe) Gages. DFT on steel can also be measured by a destructive gage, called a Tooke gage. On concrete, DFT can be measured using destructive gages or newer ultrasonic equipment. In all cases, the test method for DFT described in SSPC-PA 2 should be used. The average dry film thickness can also be calculated from the amount of coating used, its percent solids by volume, and the total area covered.

Depending on their intended service and the specification, coatings on steel and concrete may require additional inspection, such as:

- Holiday (pinhole) detection. For steel, two types of holiday testers are used: The low-voltage holiday tester, for coatings of DFT < 20 mils; and the high-voltage holiday tester, for thicker coatings. Coated concrete can also be tested with these devices.
- Adhesion testing. The specification may require either tensile adhesion testing, for which several instruments are available, or a "tape test."

- Cure. May be determined by hardness, or, for some paints, through a solvent rub test.
- Visual inspection for coating defects.

Besides performing various tests on the applied coating, the inspector may be assigned some final responsibilities for ensuring that unused materials are properly disposed of.

Appendix

Concrete Surfaces

by SSPC Staff and John L. Hausfeld

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 - B. Aggregate
 - C. Water
 - D. Admixtures
- IV. Pouring and Curing Concrete
 - A. Walls
 - B. Floors
 - C. Reinforced Concrete
- V. Common Features of All Cementitious Materials
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 - B. Porosity
 - C. Alkaline Environment
 - D. Soluble Products
 - E. Surface Texture and Irregularities
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- VI. Reasons for Coating Concrete and Other Cementitious Surfaces
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VIII. Coatings for Cementitious Surfaces

- A. Water Emulsion Coatings
- B. Textured Coatings
- C. Elastomeric Coatings
- D. Lacquers
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- IX. Coatings to Control Rebar Corrosion
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I. SCOPE

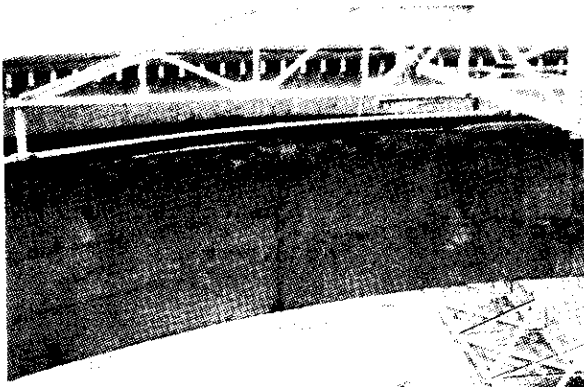
This appendix provides basic information about concrete, appropriate for personnel concerned with coatings operations. It describes the components of concrete and methods of concrete construction. It also discusses the unique features of concrete and other cementitious surfaces that affect coating work, and reasons for coating these substrates. Finally, it contains an overview of the various types of coatings and other materials applied to concrete, such as sealers and penetrants, fillers, caulks, and surfacing.

II. REFERENCES

Federal Specifications

TT-C-555 Coating, Textured (for interior and exterior masonry surfaces)

FIGURE 4-60. A concrete tank. Courtesy of KTA-Tator Inc.



III. COMPONENTS OF CONCRETE

Concrete is a mass of sand, gravel, or crushed rock bonded together by a hardened paste of hydraulic cement and water. When these ingredients are properly proportioned and mixed, they form a workable blend that can be poured into a form of desired size and shape. Workable blends are easily mixed, handled, transported, and placed with vibration without the loss of homogeneity. The water reacts with the cement to convert the concrete into a hard and durable product (Figure 4-60). In addition to structures of poured concrete, there are several other building materials that use cement as the binder that holds them together. These include concrete and cinder block, plaster, stucco, and brick.

A. CEMENT

Portland cement, hereafter simply referred to as "cement", is a kiln-dried and finely pulverized mixture of lime, alumina, silica, iron oxide, and small amounts of other materials. ASTM defines five types of cement, each of which provides special properties to concrete.

B. AGGREGATE

Aggregate (i.e., sand, gravel, or crushed rock) serves as an inert, low-cost material that imparts good physical properties to the concrete (Figure 4-61). It usually constitutes about 75% of the volume of the concrete.

C. WATER

Water both converts the mixed concrete to a pourable consistency and reacts with the cement (a process called hydration) to harden the concrete. The water to cement ratio (W/C) is largely responsible for determining the strength of the concrete, as well as its shrinkage and time to recoat. Ratios in the range of 0.4 to 0.5 are common with 0.4 used for marine concrete. These ratios result in compressive strengths between 2,500 and 5,000 psi (17 and 34 MPa), the higher values for high-strength components.

D. ADMIXTURES

Admixtures are materials other than cement, aggregate or water that are added to the batch of concrete immediately before or during mixing to impart desirable properties to it. Water-reducing admixtures, such as superplasticizers, permit the use of less water in the mix so that greater strength results. Superplasticizers also maintain good workability or "slump." Air-entraining admixtures increase the resistance of the hardened concrete to alternate cycles of freezing and thawing. Accelerator admixtures increase the early strength of concrete. Retarder admixtures can be used to delay the set of concrete in hot weather.

IV. POURING AND CURING CONCRETE

A. WALLS

Concrete for walls is poured into vertical forms and vibrated to reduce the number of air pockets in it (Figure 4-62). These forms are usually pre-coated with release agent for their easy removal from the concrete after it has cured. Residual release agent on the concrete must be removed before it is coated.

The forms are held in place with steel tie-rods. After removal of the forms, the ends of the tie-rods projecting from the concrete must be removed by burning or cutting. If the forms are not tightly butted against each other, concrete will enter the joint between them to form thin projections sometimes called fins.

FIGURE 4-61. Aggregate used in concrete. SSPC file photo.

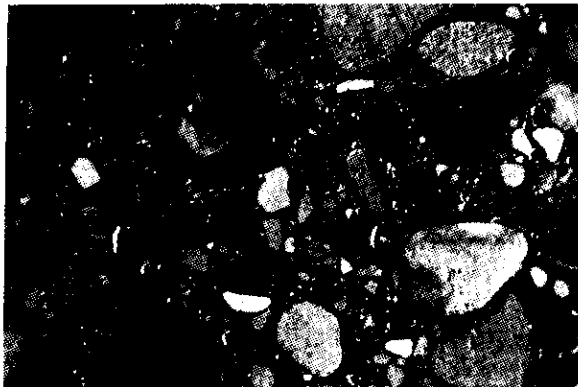
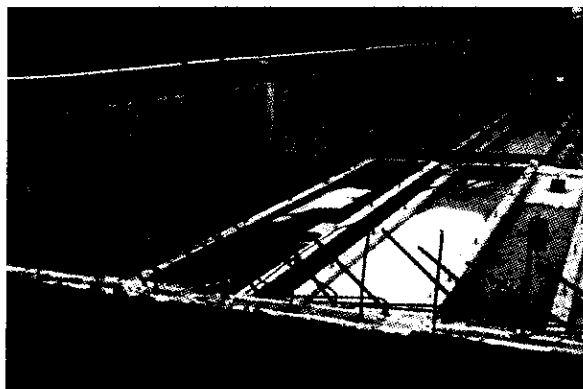


FIGURE 4-62. Vertical forms for poured concrete walls. SSPC file photo.



B. FLOORS

After pouring, concrete floor surfaces are smoothed with a board, trowel, or broom to give a "board (or float) finish," a "trowel finish," or a "broom finish" (Figure 4-63). Each of these finishes is relatively void-free, and each has a distinctively different surface roughness. The roughness of a surface may affect its coatability. For example, a broom finish should not be used if the coating film thickness is to be less than 100 mils (2.5 millimeters). The smoothness of a concrete surface may also affect its coatability. For

example, a trowel finish is frequently so smooth that it does not allow for adequate coating adhesion. Thus, a trowel finish may be followed by a broom finish, acid etch, or abrasive blasting to obtain better coating adhesion and/or reduce slipperiness.

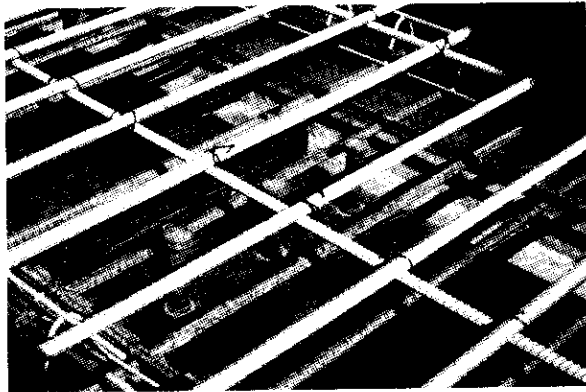
C. REINFORCED CONCRETE

Steel reinforcing bars (rebar) are often used in concrete beams to impart resistance to tension or compression, depending upon their configuration (Figure 4-64). Prestressed concrete is formed using steel bars, wires, or ropes running the length of concrete beams. These are tightened against a metal plate on each end of the form before the concrete is poured. This tensioning is then

FIGURE 4-63. Finishing concrete floors. Both SSPC file photos.



FIGURE 4-64. Rebar. Courtesy of S.G. Pinney & Associates, Inc.



imparted to the concrete beams to strengthen them and minimize cracking.

V. COMMON FEATURES OF ALL CEMENTITIOUS MATERIALS

Concrete, concrete block, plaster, stucco, and brick are all cementitious materials that have the following features that affect their paintability:

- They require moisture for curing.
- They are porous.
- They are alkaline.
- They contain soluble products that can migrate with moisture.
- They contain surface texture and often irregularities, unless smoothed.
- They are prone to cracking.

A. MOISTURE FOR CURING

Concrete requires moisture for curing. On vertical pours, the water added to the original mix is retained by the forms. On horizontal pours, water is intentionally added during the initial curing process. After removal of forms, sufficient time must be allowed for the excess water to be lost by evaporation before coatings can be applied. (This will depend on curing conditions and the W/C ratio.) If the concrete is overly wet or overworked, a weak brittle layer

(laitance) may result. It must be removed from the cured concrete before coating.

B. POROSITY

All cementitious construction materials are porous to a certain extent. Depending on environmental and service conditions, it is often necessary to reduce their permeabilities.

C. ALKALINE ENVIRONMENT

Concrete and other cementitious surfaces are alkaline. Because of this, coatings applied directly to them must be alkali-resistant. Thus, oil-base coatings such as alkyds should never be applied directly to them. Alkalinity causes drying oils to become saponified (hydrolyzed and converted into fatty acid soaps) and disbonded.

D. SOLUBLE PRODUCTS

Because concrete and other cementitious surfaces are porous, moisture migration occurs as a result of temperature and humidity differentials. The migrating moisture often carries with it soluble alkaline products from the cement. When these products migrate to the surface, they

FIGURE 4-65. Rebar corrosion on a pile. Courtesy of S.G. Pinney & Associates, Inc.

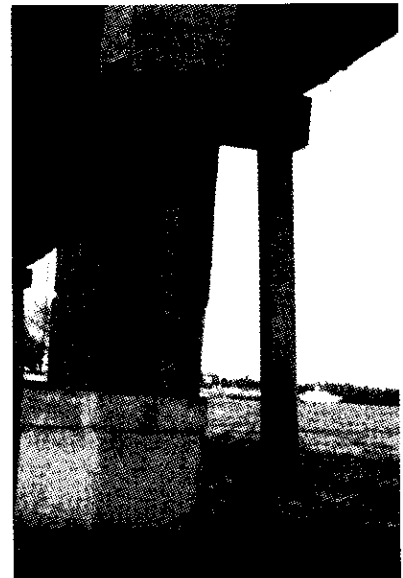


FIGURE 4-66. Cracking at the base of a pillar. SSPC file photo.



react with carbon dioxide in the air to form fluffy deposits called efflorescence. Efflorescence frequently occurs around doors and windows on masonry block walls where water has entered the wall in these incompletely sealed areas and migrated to the surface. Efflorescence must be removed by dry brushing before painting the concrete to obtain good coating adhesion.

Soluble salts on concrete surfaces can also migrate inward and cause problems. Particularly at marine locations, chloride ions can permeate concrete, subjecting steel reinforcing bars to corrosion (Figure 4-65). The corrosion products that are formed are much greater in volume (about 6:1) than the original steel and expand with great force to cause concrete to crack and spall.

E. SURFACE TEXTURE AND IRREGULARITIES

Poured concrete surfaces can contain bug holes, fins, and other surface irregularities. Because of the inherent surface texture and surface irregularities, it is relatively difficult to obtain holiday-free films on concrete. It is also difficult to accurately measure wet and dry-film thicknesses.

F. CRACKING

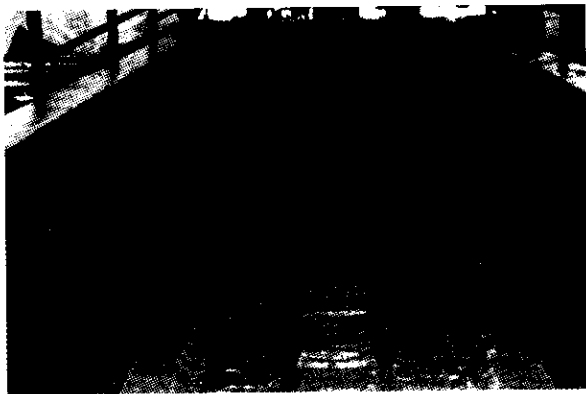
Properly prepared concrete may appear to be a hard, tough construction material, but microscopic examination of its surface reveals that it actually contains thousands of

microcracks, usually initiated during the curing process. These microcracks are not considered to be defects, as they serve as a means to relieve the stresses caused by the water evaporation and shrinkage that occur during curing. However, under some conditions, microcracks can propagate to form significant cracks that affect the structural integrity of the concrete (Figure 4-66). Some of these conditions are:

- **Excessive loss of water.** The greater the loss of water and shrinkage, the greater the tendency for microcracks to become larger, more serious cracks. To control cracking due to excessive water loss, water-reducing admixtures and other techniques are used to keep the W/C ratio as low as practical.
- **Temperature changes.** Expansion and contraction caused by temperature changes will also cause volume changes in the concrete. Freezing and thawing of water in the concrete will also cause volume changes that can lead to crack propagation.
- **Loading.** Heavy loadings cause dimensional changes that stress the concrete. Thus, steel reinforcement is often placed in concrete to increase rigidity and resistance to dimensional change. To control cracking due to loading, concrete structures should be designed for minimum deflection.
- **Corrosion of steel reinforcing.** The steel reinforcing (rebar) in concrete is subject to corrosion, especially in the presence of chloride ion. The steel corrosion products occupy several times the volume of the steel and thus stress the concrete. Once cracking from corrosion of rebar occurs, it may be followed by spalling of localized areas of the surface concrete.
- **Alkali-aggregate reactions.** Complex chemical reactions occur to reactive silicates and other components in the concrete. Potassium, sodium, and calcium hydroxides in the cement form a gel at the surface of the aggregate. Moisture reacts with this gel causing expansion and tension cracking. These reactions are very slow and require about 80% relative humidity, so that alkali-aggregate deterioration may not become significant for 15 or 20 years. ASTM has standards for aggregates that eliminate the faster reacting products. The use of slower reacting aggregates will greatly reduce cracking by alkali-aggregate reactions.

It should be noted that in some cases, microcrack propagation can be controlled by pre-stressing or post-tensioning the concrete. Pre-stressing involves controlling expansion

FIGURE 4-67. Concrete walls sealed to reduce water permeability. SSPC file photo.



so that any microcracks formed during curing are compressed in place.

VI. REASONS FOR COATING CONCRETE AND OTHER CEMENTITIOUS SURFACES

There are several reasons for coating concrete and other cementitious surfaces. These include:

- **To enhance appearance.** Some cementitious surfaces require a finish for cosmetic reasons only. However, many cementitious surfaces are attractive when unpainted. When such surfaces are coated, it may create a maintenance problem.
- **To reduce water-permeability.** Sealing exterior or interior walls to prevent moisture entry may be necessary where severe environmental or service conditions exist (Figure 4-67). This is especially true in geographical areas where wind-driven rains are common. It is not uncommon to seal only the exterior walls in such areas to permit any moisture that enters from the exterior to pass to the interiors of buildings through "breathing coatings."
- **To control cracking and spalling.** When concrete is sealed to reduced water-permeability, a secondary effect is control of cracking and spalling due to rebar corrosion. This type of cracking and spalling can also be controlled by applying coatings to rebar to be embedded in the concrete or by cathodic protection.

- **To line tanks.** Concrete tanks are frequently lined to contain such products as water and fuels. The linings must be very resistant to the products contained. Concrete secondary containment systems for storage tanks are also lined to contain spills until treated.
- **To control dust.** Coating cementitious surfaces may help to keep walls and floor clean in areas where sensitive equipment must be kept dust-free. FDA-approved coatings must be used in food processing areas. Even in common warehouses, coating floors provides dust control and ease of cleaning.
- **To protect the substrate.** Coating exterior concrete surfaces can reduce their deterioration by natural weathering and freeze/thaw cycling. It may also help control efflorescence.
- **To permit easy clean-up of contamination** (for example in food production plants or nuclear facilities.)
- **To improve lighting by reflectivity.** Reflective epoxy and polyurethane floor coatings have been effectively used to enhance the lighting or reduce lighting costs. A good example is hangar floors where the reflective lighting increases the visibility under aircraft wings. Grit is often placed in these coatings to increase slip-resistance.
- **To impart identification or other information**

VII. SEALERS, FILLERS, CAULKS, AND SURFACERS USED ON CEMENTITIOUS SURFACES

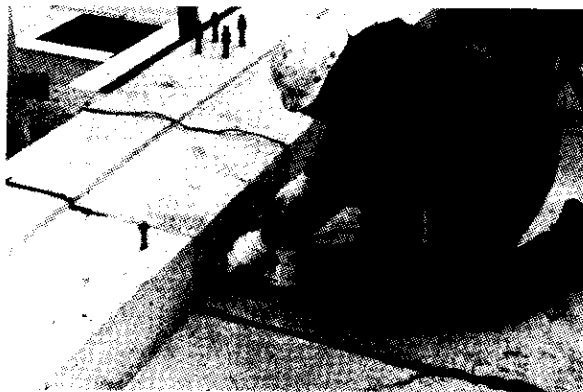
Before coating, the following types of product are frequently applied to cementitious surfaces:

- Sealers and Penetrants
- Fillers
- Caulks
- Surfacing

A. SEALERS AND PENETRANTS

Sealers and penetrants are products (frequently colorless silicones) that soak into concrete surfaces to fill very small holes to provide dust control and reduce water penetration. They may be applied by brush, roller, or spray.

FIGURE 4-68. Caulking a concrete surface. Courtesy of Sauereisen.



B. BLOCK FILLERS

Fillers are normally high-solids water-borne products usually applied by roller to rough, relatively porous surfaces such as concrete block. They are used to reduce the permeability of the block and provide a surface more suitable for coating.

C. CAULKS

Caulks are used to: (1) seal joints or other openings to keep out moisture, dust, heat, or other elements and/or (2) provide a surface for painting an attractive finish. Viscous liquid (pourable or self-leveling) caulks are applied to horizontal joints or openings and flow to form the contour of the desired surface (Figure 4-68). Mastic or high-viscosity, non-sag caulks retain their form whether applied to horizontal or vertical surfaces. Caulks must be elastomeric in moving joints, but may be rigid elsewhere.

Although many generic types of caulk exist, those that cure to a hardened finish do so by one of the following mechanisms:

- Air-oxidation of drying oils
- Solvent or water evaporation
- Chemical reaction of components
- Moisture curing
- Cooling or hot melt products

Selecting the best caulk for a particular job depends upon:

- Special needs (odor, flammability, paintability, etc.)
- Joint design (horizontal/vertical, moving/fixed, damp/dry, etc.)
- Desired performance (impact resistant, non-shrink, etc.)

D. SURFACERS

Surfacers are used to fill bug holes, tie-rod holes, and other voids. They are normally high-solids, low-shrinkage thermosetting epoxies applied by trowel or squeegee.

VIII. COATINGS FOR CEMENTITIOUS SURFACES

The following different types of coating have historically been used to coat various cementitious surfaces:

- Water emulsion coatings
- Textured coatings
- Elastomeric coatings
- Lacquers
- Heavy-duty, high performance coatings

A. WATER EMULSION COATINGS

Water-emulsion (latex) coatings, normally acrylic, are used extensively on interior and exterior concrete/masonry surfaces for cosmetic purposes. They are somewhat porous to water vapor ("breathing") and so permit the passage of limited amounts of entrapped water. These coatings are used extensively on stucco, plaster, dry-wall, and plaster-board surfaces. If an oil-base coating is desired on a cementitious surface for better scrubability or special gloss or color, it can be applied over an emulsion or other alkali-resistant primer.

B. TEXTURED COATINGS

Textured coatings are thick, e.g., 30 mils (76 micrometers) or more, rigid coatings that are used to seal walls from wind-driven rain, cover minor surface defects, or to provide a weather-resistant attractive finish. They can be used on interior or exterior walls and are available in fine, medium, and coarse finishes, depending upon the type of inert filler material. They are described in Federal Specifi-

FIGURE 4-69. Coated concrete in immersion service.
Courtesy of KTA-Tator, Inc.



cation TT-C-555. The binder can be an emulsion, alkyd, or rubber-base product. A related type of thick textured coating uses hydration of cement as the film curing mechanism. These coatings are usually applied by spray or roller.

Textured coatings can provide fifteen or more years of service without cracking or peeling. When they become faded or discolored, or when a change of color is desired, they can easily be topcoated with conventional water-emulsion coatings.

C. ELASTOMERIC COATINGS

Elastomeric coatings of acrylic emulsion or polyurethane compositions are available to seal walls from wind-driven rain, cover surface defects (relatively large cracks or other voids must first be caulked with a flexible product), or provide a weather-resistant, attractive finish. They may have elongations as much as 500%. These thick coatings, like textured coatings, may require a special primer to bond them tightly to concrete/masonry surfaces. Because of their good overall properties, they have performed successfully on concrete roofs and catchment basins in Bermuda used to collect rain water. They are usually applied by spray or roller.

D. LACQUERS

Lacquers (solutions of acrylic, vinyl, or chlorinated rubber binder) were once used extensively on concrete/masonry

surfaces. They were normally applied in two or more coats to give 2 to 8 mils (50 to 200 micrometers) of protection. In houses, they were often used in kitchen and bathroom areas to provide moisture resistance and scrubability. They are seldom used today because of their high VOC contents. One common exception is a variance frequently given to coat exterior swimming pools with a chlorinated rubber coating. Epoxies perform well on interior concrete pools but chalk too much for exterior service.

E. HEAVY-DUTY, HIGH-PERFORMANCE COATINGS

Heavy-duty, high-performance coatings are used where the severity and/or service conditions require it. Epoxy and polyurethane floor coatings have previously been mentioned. Thermosetting epoxies are normally used on food processing or nuclear plants. Aliphatic polyurethane coatings are frequently used as a finish over an epoxy system for exterior service to provide good resistance to the sun's ultraviolet light. Such systems are also used on secondary containment walls, inside which storage tanks are located, to contain spills in the event of an accident.

Linings and other coating systems in immersion service have special requirements such as high-film thicknesses and resistance to the products contained (Figure 4-69). Bituminous coatings have been used extensively in the past but are used less today because of health and environmental concerns. Epoxy mastic and coal tar epoxy systems are used extensively as waste water treatment tank linings. Composite products containing fiberglass (chopped, mat, or roving) combined with polyester, vinyl ester, or epoxy resins are frequently used to provide a tough, rigid surface. There are also some high-performance elastomeric materials that offer excellent chemical resistance that have been recently introduced into the market.

IX. COATINGS TO CONTROL REBAR CORROSION

Control of rebar corrosion can be achieved by: (1) hot-dip galvanizing or powder coating with fusion-bonded epoxy. (2) cathodic protection, (3) incorporating polymers such as epoxies into the concrete mix to reduce permeability, and/or (4) pouring a thick (e.g., 3 in; 8 mm) cover of dense concrete over them. Coating the concrete may in some cases help control rebar corrosion. Cathodic protection of rebar is most frequently used on concrete bridge decks and

waterfront structures. Coating of rebar with fusion-bonded epoxy is probably the most frequently used technique for controlling its corrosion.

X. SUMMARY

Concrete is a building material made up of sand, gravel, or crushed rock bonded together by a hardened paste of hydraulic cement and water. It may also contain admixtures that give it special properties, such as improved workability. Concrete and other cementitious materials have several features that must be considered when they are to be coated. They require moisture for curing, are porous, and contain soluble products that can migrate with moisture. Also, they are alkaline and can have irregular surfaces. Concrete surfaces may be coated for one or more reasons, depending on their intended purpose and use. Coatings for concrete include water emulsion coatings, textured coatings, elastomeric coatings, lacquers, and heavy-duty, high performance coatings. Besides these coatings, materials such as sealers, fillers, caulks, and surfacers are often applied to concrete surfaces.

Chapter 5.0

Inspection of Specific Coating Materials: Introduction

by SSPC Staff

OUTLINE

- I. Scope
- II. Format
- III. Summary

I. SCOPE

This chapter is divided into several sub-chapters. Chapter 5.1 presents information about several generic types of "conventional" coatings. This includes general properties and environmental and safety concerns associated with the coatings. It is intended to supplement the information given in Chapters 3 and 4 on basic coating inspection and documentation procedures.

The conventional coatings described in Chapter 5.1 are:

- Lacquers, Solutions of Synthetic Resins (Vinyl, Chlorinated Rubber, and Acrylic)
- Water Emulsion (Latex) Coatings (Acrylics and Vinyls)
- Oil-Based Coatings
- Epoxy Coatings
- Coal Tar Epoxy Coatings
- Polyurethanes
- Polyester and Vinyl Ester Coatings
- Pretreatment Wash Primers
- Organic Zinc-Rich Coatings

FIGURE 5-1. Inorganic zinc-rich coating on a nuclear torus, an example of a specialty coating in use in an industrial environment. Courtesy of S.G. Pinney & Associates, Inc.



Chapters 5.2 - 5.14 present information on some of today's "specialty" coatings (Figure 5-1). In these sub-chapters, the unique protective properties of the coatings are discussed, as well as any distinct or additional inspection requirements, and special safety concerns. Like 5.1, these sub-chapters are intended to supplement the information given in Chapters 3 and 4.

The specialty coatings/linings described in Chapters 5.2 through 5.14 are:

- Chemical-Resistant Brick and Tile Linings, 5.2
- Coal Tar Coatings, 5.3

- Elastomeric Polyurethanes, Thick-film, 5.4
- Fiberglass-Reinforced Plastic (FRP) Linings, 5.5
- Fluoroelastomeric Coatings, 5.6
- High Bake Phenolic and Epoxy Phenolic Coatings 5.7
- Powder Coatings, 5.8
- Natural and Synthetic Rubber Linings, 5.9
- Shotcrete, 5.10
- Tapes, 5.11
- Thermal Spray Metallic Coatings for Steel, 5.12
- Thermoplastic Sheet Linings, 5.13
- Inorganic Zinc-Rich Coatings, 5.14

Many of these coatings have been produced for unique industrial applications. For example:

- Tank lining that must be resistant to different harsh chemicals
- Coatings that protect both steel and concrete and can bridge fine cracks in the concrete
- Coatings that are resistant to a wide range of environmental zones (For a description of the different types of environmental zones and suggested painting systems for these zones, see Table 1, extracted from the Steel Structures Painting Manual, Volume 2, Systems and Specifications.)
- Very high-temperature coatings

Although this chapter does cover many of the generic coating types used for such industrial applications, it is by no means exhaustive. For example, three types of coatings mentioned later in this book, silicones, mortars/cementitious coatings, and galvanizing, are not included. For more information on these and other types of coatings, consult the Bibliography, Appendix H.

II. FORMAT

As far as possible, a standard format was used in each of the sub-chapters to discuss each of the coating/lining systems:

- Scope
- References
- Properties and Typical Uses of the Coating
- Inspection of Materials
- Surface Preparation

- Coating/Lining Application
- Health and Safety
- Post-Application Inspection
- Summary

(Many times, however, there are additional or slightly different headings.)

Scope outlines and defines what items will be covered in the sub-chapter.

References lists standards and guides for application and inspection of the specific type of coating. The latest issue, revision, or amendment of the reference standards should be used unless otherwise specified.

Properties and Typical Uses of the Coating are described. In addition to chemical and physical properties, esthetic, economic, or other unique aspects are discussed, when considered appropriate by the author. For example:

- General corrosion protection
- Resistance to heat, water, chemicals, solvent, abrasion, etc.
- Flexibility/hardness

Inspection of Materials briefly describes the components of each system to provide a total understanding of the system. The proper storage, shelf-life, and other special requirements for proper materials inspection are also discussed in this section. For example, upon receipt, prefabricated linings must be inspected for tears, punctures, deformity, proper thickness, and other deficiencies.

Surface Preparation includes a discussion of surface treatment, cleaning, and profile requirements (Figure 5-2). For example:

- Before abrasive blasting for shotcreting, an anchor system (wire mesh, T-type, anchors, etc.) must be installed.
- Irregular surfaces on new concrete should be filled before coating.
- Before application of high-bake phenolics to steel, surface contaminants can be removed by preheating to a temperature that exceeds the final bake or the operating temperature by 50°F (10°C), whichever is higher.

TABLE 1. Typical SSPC Painting Systems for Environmental Zones, extracted from Steel Structures Painting Manual, Volume 2, "Systems and Specifications," Seventh Edition, SSPC: The Society for Protective Coatings, Pittsburgh, PA, 1995, p. 5.

Environmental Zone	Zone Conditions*
0	Dry interiors where structural steel is embedded in concrete, encased in masonry or protected by membrane or non-corrosive contact type fireproofing.
1A	Interior, normally dry (or temporary protection). Very mild (oil base paints now last six years or more).
1B	Exteriors, normally dry (includes most areas where oil base paints now last six years or more).
2A	Frequently wet by fresh water. Involves condensation, splash, spray or frequent immersion. (Oil base paints now last five years or less.)
2B	Frequently wet by salt water. Involves condensation, splash, spray or frequent immersion. (Oil base paints now last three years or less.)
2C	Fresh water immersion
2D	Salt water immersion
3A	Chemical exposure, acidic (pH 2.0 to 5.0)
3B	Chemical exposure, neutral (pH 5.0 to 10.0)
3C	Chemical exposure, alkaline (pH 10.0 to 12.0)
3D	Chemical exposure, presence of mild solvents. Intermittent contact with aliphatic hydrocarbons (mineral spirits, lower alcohols, glycols, etc.)
3E	Chemical exposure, severe. Includes oxidizing chemicals, strong solvents, extreme pHs or combinations of these with high temperatures.

* Consult the individual specifications and commentaries for additional details.

FIGURE 5-2. Preparation of welds, an example of a surface preparation requirement. Courtesy of Amoco Chemicals.

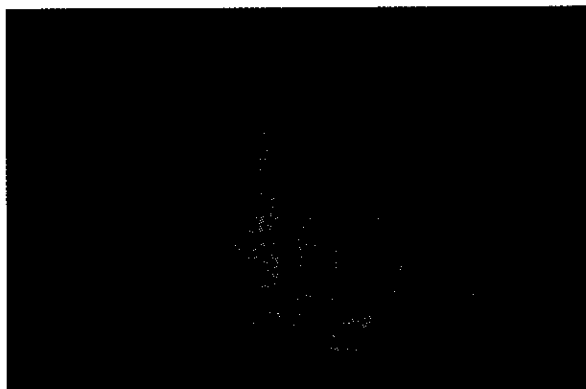


FIGURE 5-3. Shotcrete, an example of a coating type with special application requirements. Courtesy of Sauereisen.



Coating/Lining Application includes the following types of information:

- Requirements for special application equipment (Figure 5-3)
- Special priming requirements
- Proportioning, mixing, thinning, induction time, pot life, ambient conditions necessary for satisfactory application, etc.--if procedures differ from those for conventional coatings.

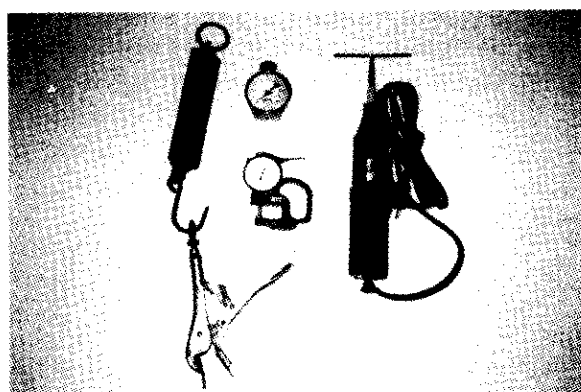
- Preparation of test panels during coating application of materials that cannot tolerate destructive testing.
- Wet film thickness measurement
- Curing Requirements
- Repair of Coating Defects

Health and Safety discusses hazards associated with specialized coating/lining systems. These include fire, respiratory, and toxicity concerns.

Post-Application Inspection describes both visual and instrumental techniques for inspections after the application/curing of specialized coatings/linings and their limitations (Figure 5-4). For example:

- Visual inspection of tapes for proper overlap and the absence of nicks, cuts, wrinkling, and other defects
- Visual inspection of fiberglass-reinforced plastic coatings for resin-rich and resin-lean areas
- Tapping gunite coatings lightly with a hammer and listening for a dull sound indicating a lack of adhesion to the substrate
- Use of special equipment for measuring the thickness of very thick coatings/linings (e.g., wet film thickness in excess of 50 mils (1.3 mm)).
- Testing coal tar coatings for dry film thickness early in the morning, because they may soften during the heat of the day

FIGURE 5-4. Equipment needed for post-application inspection of rubber linings. Courtesy of RJF International Corporation.



III. SUMMARY

The coatings inspector must understand the properties of conventional coatings as well as many specialty coatings. The properties of conventional coatings are described in Chapter 5.1. The properties and special inspection requirements for many specialty coatings are described in the remaining sub-chapters of Chapter 5.

The coatings inspector must also be familiar with environmental concerns, such as VOC content, and safety concerns for working around various coating materials. Chapter 5 also provides this type of information. With this knowledge, the inspector can provide the level of service necessary to ensure that conventional and specialty materials are properly utilized.

Chapter 5.1

Conventional Coatings

by William R. Slama, Albert L. Hendricks,
and Richard W. Drisko

OUTLINE

- I. Scope
- II. References
- III. Non-Convertible Coatings
 - A. Lacquers
 - B. Water Emulsion (Latex) Coatings
- IV. Convertible Coatings
 - A. Oil-Based Coatings
 - B. Epoxy Coatings
 - C. Coal Tar Epoxy Coatings
 - D. Polyurethane Coatings
 - E. Polyester and Vinyl Ester Coatings
 - F. Pretreatment Wash Primers
 - G. Organic Zinc-Rich Coatings
- V. Summary

I. SCOPE

This sub-chapter describes the properties of several "conventional" types of coatings. These are conventional in the sense that they are generally applied by brush, roller, air- and airless spray techniques, or trowel, and usually require surface preparation by abrasive blasting to levels of SSPC-SP 10 or less. In addition, they can generally be inspected using just the basic procedures outlined in Chapter 4.

The descriptions of different generic coating types in this sub-chapter will focus on their general properties, includ-

ing mechanism of film formation, curing mechanism, and resistance to various substances and exposures. Environmental concerns (such as VOC content) and special safety concerns are also discussed because of their importance to the inspector.

The types of coatings described in this sub-chapter are:

- Lacquers, Solutions of Synthetic Resins (Vinyl, Chlorinated Rubber, and Acrylic)
- Water Emulsion (Latex) Coatings (Acrylics and Vinyls)
- Oil-Based Coatings
- Epoxy Coatings
- Coal-Tar Epoxy Coatings
- Polyurethanes
- Polyester and Vinyl Ester Coatings
- Pretreatment Wash Primers
- Organic Zinc-Rich Coatings

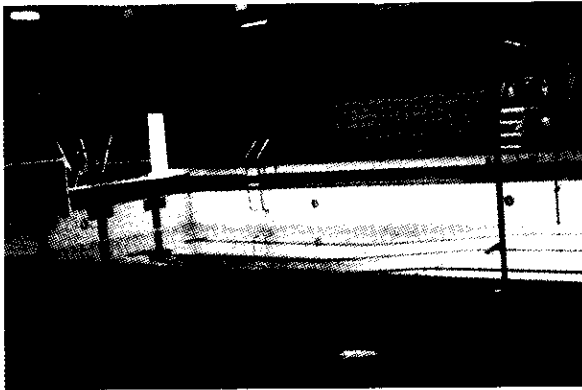
II. REFERENCES

SSPC: The Society for Protective Coatings (SSPC)

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

SSPC-Paint 27 Basic Zinc Chromate - Vinyl Butyral Wash Primer (DOD-P-15328)

FIGURE 5-5. Vinyl coating inside a swimming pool.
SSPC file photo.



U.S. Military Specifications

DOD-P-15328 Primer (Wash), Pretreatment (Formula No. 117 for Metals) (SSPC Paint 27)

III. NON-CONVERTIBLE COATINGS

Non-convertible coatings are not changed chemically during film formation. Their binders are merely deposited from solution or dispersion after evaporation of organic solvent or water.

A. LACQUERS

Lacquers are solutions of natural resins (e.g., shellac and bituminous materials) or synthetic resins (e.g., vinyls, chlorinated rubbers, and acrylics) in organic solvents (Figure 5-5). Upon coating application and solvent evaporation, the resins are deposited unchanged chemically to form protective films. These durable films have good water and general chemical resistance (especially to acids and alkalis), but, being thermoplastic, poor solvent and heat resistance. They usually have a low film build, but dry so rapidly that they can be quickly topcoated to build up the film thickness. They require an abrasive blasted surface, and, in a few cases, pretreatment wash priming for good adhesion. They are applied in multiple coats and are easy to topcoat and repair. They can be formulated for good gloss retention. The good weathering of acrylic lacquers is duplicated in acrylic water-emulsion coatings.

The chief limitation of the above lacquers is their high VOC content, which may completely eliminate them from industrial maintenance and architectural use.

Lacquers from Synthetic Resins

(Vinyls, Chlorinated Rubbers, and Acrylics)

Advantages

- Rapid drying and recoating
- Good general chemical resistance
- Good in water immersion
- Good gloss retention possible
- Good durability
- Easy to topcoat and repair

Limitations

- High in VOCs
- Poor solvent resistance
- Low film build
- Blasted surface necessary for coating
- Occasional poor adhesion

B. WATER EMULSION (LATEX) COATINGS

Latex coatings have been and continue to be used successfully to coat wood and masonry structures (Figure 5-6). The relatively porous nature of their films allows water vapor to pass through them, i.e., they are "breathing" coatings. This makes them less susceptible to blistering. Binder materials must be specially selected for latex coatings to be used on steel.

Water-emulsion coatings have excellent flexibility, relatively low cost, and ease of topcoating and repair. Drawbacks include poor solvent and heat resistance (as with all thermoplastics), poor performance in immersion and other severe environments, and difficulties in bonding to smooth coated surfaces. Poor bonding is related to the limited content of organic solvents, which can soften the smooth undercoats to promote adhesion. Because of this limited adhesion, it is necessary to sand enamels and/or use a surface conditioner or other drying oil product before topcoating with a latex coatings. Also, latex paints do not cure

FIGURE 5-6. Latex coating on a chemical tank. Courtesy of Rohm and Haas.



well at temperatures below 50°F (10°C), as the dispersed particles do not coalesce to form a durable film.

Several types of water-borne emulsions (e.g., acrylics, styrene, butadiene-modified acrylics, etc.) are also available for use on atmospheric steel surfaces. These products retain the advantages of previously described emulsion coatings, while providing protection to steel structures.

Water Emulsion (Latex) Coatings

Advantages

- Reduced level of VOCs
- Easy to apply (and clean up), topcoat, and repair
- Fast to dry for recoating
- Reduced solvent odor
- Excellent flexibility
- Low cost
- Safer (reduced flammability/solvent exposure)

Limitations

- Limited durability
- Poor chemical and solvent resistance
- Poor wetting of surfaces
- Poor immersion service
- Best cure above 50°F (10°C)

- Poor heat resistance

IV. CONVERTIBLE COATINGS

Convertible coatings are changed by chemical reaction during curing to a higher molecular weight, solid film. The reactions may be between separately-packaged coating components or between the coating and oxygen, water, or carbon dioxide from the atmosphere.

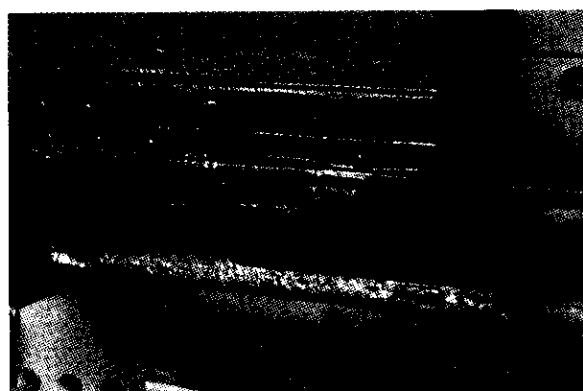
A. OIL-BASED COATINGS

Coatings based on drying oils (e.g., linseed, tung, soya bean, or fish oils) cure by reaction with oxygen from the atmosphere. Although these films may be completely dry in less than a day, curing of the total film takes much longer. Reaction with oxygen slowly continues throughout the life of the coating. Because the oxygen can enter the film only at its surface, the film thickness must be no more than that recommended by the supplier. If applied more thickly, the film can dry preferentially at the surface, leaving the underlying coating soft and uncured. This usually results in wrinkling of the film.

All air-oxidizing coatings have limited solvent resistance. However, as they continue to oxidize and cross-link, they become harder, more brittle, and less soluble in solvent.

Unmodified drying oil coatings can be formulated to have low VOC content by using low viscosity oils. However, as

FIGURE 5-7. Alkyd coating on a bridge. SSPC file photo.



the oil content is reduced by chemical modification, formulation of low VOC coatings with a low viscosity becomes much more difficult. Thus, the current wide use of alkyd and other modified drying oil products may be curtailed by future VOC limitations.

Oleoresinous (unmodified drying oil) coatings as initially developed were very easily applied. They did, however, have several drawbacks. They were slow to dry, had residual tack, and provided a limited period of protection. They could not be used in sea water immersion service or on alkaline substrates (e.g., concrete), because they are easily hydrolyzed by alkalinity. Drying was accelerated by incorporation of metal driers, but chemical modifications were required to significantly improve film properties.

Alkyd coatings use resins formed by the reaction of polyhydric alcohols (e.g., glycerin) and polybasic acids (e.g., phthalic acid) followed by modification with drying oils (Figure 5-7). They cure much faster than unmodified drying oil formulations to form a harder film and improved resistance properties. They retain the good application properties of the unmodified coatings but with some loss in flexibility.

Silicone alkyd coatings were developed by modifying alkyd resin with silicone (typically 30% of total resin) to provide greater gloss retention and weather and heat resistance. They are frequently used as finishes for alkyd systems to increase gloss retention and general performance.

Epoxy ester coatings are another modification of drying oils to improve performance, particularly chemical resistance. However, the expense of this improvement was a loss of gloss retention in exterior (ultraviolet) exposure. These products should not be confused with the two-component epoxies that normally provide a higher level of performance.

Uralkyd (drying oils modified with polyurethane) coatings have properties similar to those of alkyds, but form a harder film, so that they can be used on wood floors or furniture. They usually also have decreased drying time and enhanced resistance to chemicals, moisture, and weathering.

Oleoresinous phenolic (oil-modified phenolic) coatings are made by cooking phenolic resins with drying oils. They have good water resistance and can be used in water

immersion. However, they tend to discolor with age and become hard and brittle.

Alkyd and Most Other Air-Oxidizing Coatings

Advantages

- Easy to apply, topcoat, and repair
- Good flexibility possible
- Good surface wetting and adhesion
- Good gloss retention possible
- Relatively inexpensive

Limitations

- Future VOC requirements expected to be a problem
- Poor chemical and solvent resistance
- Poor water immersion resistance
- Poor alkali resistance

B. EPOXY COATINGS

Epoxy coatings are the most common two-component thermosetting products. An epoxy resin is based on a reaction product of phenols, commonly bisphenol A, bisphenol F or cresol, with epichlorohydrin. Epoxy coatings are available in solvent-free, solvent-containing, or water-containing formulations.. (Epoxy phenolic and phenolic high bake coatings are discussed further in Chapter 5.7.)

The two components of an epoxy coating are commonly called the base and the curing agent, although they are both best described as co-reactants. The curing agent is used to polymerize the epoxy resin and has a major influence on the mechanical and chemical resistance properties. Curing agents most commonly used are aliphatic amines, amine adducts, ketimines and polyamides.

Epoxy coatings bond well to abrasive blasted steel and clean concrete, and are very durable in most environments. Their films are hard and relatively inflexible. Thus, they can't expand or contract much without cracking. They chalk freely in sunlight, some losing over a mil of thickness a year. Thus, an aliphatic polyurethane finish coat is frequently applied over an epoxy coating to impart resistance to the sun's ultraviolet light (both for appearance and prevention of loss of epoxy coating).

Epoxy resin coatings are formulated with a variety of pigments to develop greater flexibility, increased adhesion, abrasion resistance and stability. These systems develop excellent resistance to a variety of substances including inorganic acids, alkalies, solvents, salt solutions and water.

Epoxy-polyamide coatings are probably the most widely-used epoxy type because of their good water and corrosion resistance and their relative tolerance to moisture and incompletely cleaned surfaces. The polyamide curing agent is actually a resinous product with attached amino groups. This makes the cured films somewhat softer and more resilient and flexible than amine-cured epoxies, but they have less chemical, particularly acid, resistance. They are used mostly where their good water resistance can be utilized, such as on ship hulls and linings for water tanks.

Amine-curing epoxy coatings are hard, tightly-bonded, chemical resistant products that are used a great deal for lining chemical storage tanks and in other severe environments. An oily, amber film of primary amine may arise to the surface of the coating, especially when applied in cold, damp weather. It then reacts with carbon dioxide and water in the air to form a glossy product. This "amine blush" must be removed before topcoating. Amine curing agents are usually toxic and may cause skin irritation. Thus, safety precautions must be taken during their use.

Amine adduct epoxy coatings are products in which the amine curing agent has been partially reacted with a relatively low molecular weight epoxy resin. This reduces the health hazards, lessens the tendency to blush, and makes mixing ratios less critical, since a greater volume of curing agent is used. Cured products have properties similar to those of amine-cured epoxies.

Ketimine epoxy coatings utilize a "blocked" ketimine curing agent formed chemically by loss of water between a primary amine and a ketone. After mixing of components and application, moisture from the atmosphere reacts with the ketimine to regenerate the amine and the ketone. The ketone is merely lost by evaporation, but the amine reacts with the epoxy resin as normally occurs with amine-curing epoxies. The low viscosity of the amine curing agent permits formulation of high-solids products, as well as slower curing products with a longer pot lives and curing times.

Phenolic epoxy coatings are specially formulated to produce hard, dense, chemically-resistant films. Indeed, they

have the best combination of chemical, solvent, and heat-resistance of all epoxies. It should be noted that "phenolic epoxies" comprise a whole family of hybrid coatings made by reacting phenolic resins with epoxy resins. Depending of the relative proportions of the two resins and consequently their method of curing, these may be called "phenolic epoxies" or "epoxy phenolics." The term "novolac epoxy" is also used to describe a special type of phenolic epoxy derived from bisphenol F. High-bake epoxy phenolic coatings are discussed further in Chapter 5.7.

Epoxy mastic coatings are high-solids, high-build epoxy coatings, usually at least 5 mils (127 micrometers) dry film thickness, and often aluminum filled. Because of their good wetting properties, they are "surface tolerant" and can be applied over incompletely cleaned steel. Because of their relatively weak solvents, they are compatible with most other coatings.

Typical Epoxy Coatings

Advantages

- Low VOC formulations
- Good solvent and water resistance
- Many have good chemical resistance
- Tough, durable, slick film
- Good adhesion
- Good abrasion resistance possible

Limitations

- Limited pot life
- Chalk freely in sunlight
- Limited flexibility
- Cure best above 50°F (10°C)
- Topcoating a problem (short time window)
- Blasted surface preferred
- Amine curing agents toxic
- Amine-cured coatings subject to amine blush

Epoxies, generally, will have a shelf life that may range from 12 to 24 months, but with high solids epoxies, the shelf life may be as short as 6 months.

The components of epoxy coatings must be thoroughly mixed prior to application. Equipment utilized for mixing

should be spark free, clean and of adequate size to ensure a homogeneous mix. Most chemically curing epoxies require a sweat-in (induction) time which varies depending on the composition of the coating system prior to application. The amount and type of thinner to be added must be as recommended by the lining manufacturer and will depend on the equipment utilized and the ambient temperature conditions during spraying. It is important that the thinner added is compatible with the coating if it is not recommended by the manufacturer of the coating.

Epoxy systems are available that can be applied by trowel application. These systems may be used on concrete or steel; the criteria for inspection would be similar as outlined for the spray applications. The inspection of concrete surfaces will require the determination as to moisture content, the presence of a membrane curing material and the amount of bug holes which require filling. Surface preparation prior to the application of an epoxy may require dry abrasive blasting, water blasting or scarification. An epoxy filler is then generally applied by trowel or squeegee forcing the material into the voids. Inspection to determine the degree of filling is an important requirement.

C. COAL TAR EPOXY COATINGS

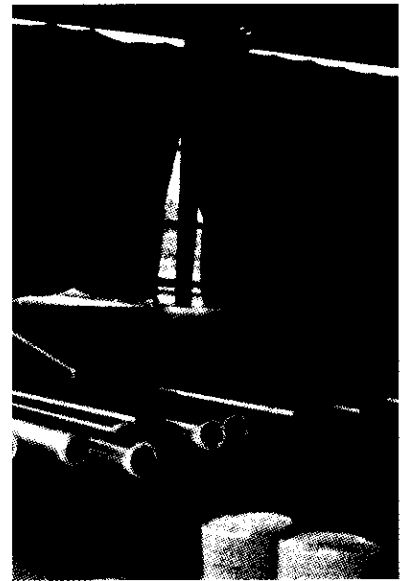
Coal tar epoxy coatings are blends of epoxy and coal tar components (Figure 5-8). (Coal tar coatings are discussed further in Chapter 5.3.) The coal tar reduces cost, improves water resistance, and provides for greater film build. However, because of the coal tar, these products tend to become brittle in sunlight, causing loss of adhesion. There is also concern about toxic effects of the coal tar. They are used today mostly on steel piling, tank linings, and buried piping.

Coal-Tar Epoxy Coatings

Advantages

- Low in VOCs
- Good water resistance
- Good film build
- Good abrasion resistance
- Relatively low cost

FIGURE 5-8. Coal tar epoxy on exterior of steel pipe. Courtesy of US Army Construction Engineering Research Laboratories.



Limitations

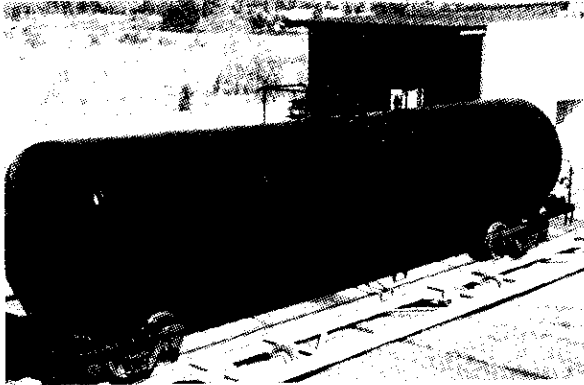
- Toxic; need personal protective equipment during application
- Limited pot life
- Blasted surface needed
- Topcoating a problem (short time window)
- Available only in black or dark red

D. POLYURETHANE COATINGS

Polyurethane coatings are usually two-package systems, one an isocyanate component and the other a polyol component (Figure 5-9). These coatings are available in a variety of formulations, giving rise to a variety of properties (e.g., they may be hard/brittle or elastomeric). Low-temperature curing is achievable for polyurethane coatings, and they perform well in most environments. The toxicity of the isocyanate component is, however, of concern, and personal protective equipment, including respirators, must be used when applying polyurethane coatings.

Two basic chemical types of polyurethanes are aliphatic and aromatic. Aliphatic polyurethanes have excellent weathering in sunlight. Aromatic polyurethanes chalk and discolor in sunlight, but they have better chemical resistance in immersion. Both types can readily be formulated

FIGURE 5-9. Polyurethane coating on exterior of a railcar. Courtesy of S.G. Pinney & Associates, Inc.



to be low in VOCs. Because the isocyanate component may react with water, polyurethanes are moisture sensitive during storage and application. Also, the gloss of polyurethane coatings may drop when the wet film is exposed to high humidity. It should be noted, however, that there are moisture-curing polyurethanes, which are one-component products that cure by reaction of the binder with moisture from the atmosphere. As with oil-modified polyurethanes, they are frequently used as clear or pigmented coatings for wood floors.

Two-Component Polyurethane Coatings

Advantages

- Can be low in VOCs
- Good water resistance
- Good hardness or flexibility
- Aliphatics have good gloss and color retention
- Aromatics have good chemical resistance
- Good durability
- Good abrasion resistance
- Low-temperature curing achievable

Limitations

- Toxic; need personal protection
- Moisture sensitive; gloss may drop

- Skilled applicator needed

E. POLYESTER AND VINYL ESTER COATINGS

Unsaturated polyester and vinyl ester thermosetting resins are used as a base for a useful group of high-performance, corrosion-resistant linings for steel, concrete, and other surfaces (Figure 5-10). Though their actual derivation and composition are somewhat different, polyesters and vinyl esters are so similar in composition and curing mechanisms that they can be classed together for purposes of inspection. The inspector should be aware of the characteristics of these lining systems.

Polyester and vinyl ester resins contain unsaturated groups which are reacted with unsaturated monomers, such as styrene. The combination of resin and monomer forms a relatively low viscosity material to which an initiator (catalyst) is added at time of use to initiate curing. These initiators are usually an organic peroxide, such as methyl ethyl ketone peroxide. Because the small amount of the peroxide catalyst used greatly accelerates curing, a skilled applicator must be used to ensure proper proportioning and mixing.

- Limited pot life
- Blasted surface required when used as primer
- More expensive than epoxies

FIGURE 5-10. Polyester coating on exterior of a tank. SSPC file photo.



The final lining product may utilize various reinforcements and fillers to counteract or minimize the effects of shrinkage and enhance or provide valued properties to the lining such as lowering the coefficient of expansion, providing greater tensile strength, and a high degree of permeation resistance. The resin, monomer and filler form the basic film. Other ingredients are needed to produce a practical, useful, corrosion protection system. These include necessary elements such as promoters, inhibitors, thixotropic agents, polar agents, leveling agents, pigments, coupling agents, plasticizers, air inhibition preventers, and wetting agents.

Polyester and vinyl ester films can have relatively high thicknesses. System types range from inert flake reinforced, spray applied linings as thin as 15-20 mils (380 - 500 micrometers) to trowel applied systems as thick as 200 mils (0.5 cm), heavily filled with graded aggregate composed of silica, carbon or other material. In many cases, layers of fiberglass or other types of reinforcement are incorporated to further tailor the lining's physical characteristics for optimum performance. (Chapter 5.5 discusses fiberglass-reinforced plastic.)

The resulting cured linings are relatively hard, solid materials. They have excellent chemical resistance, especially acid resistance. They also have good solvent and water resistance and are frequently used as special linings such as on tank bottoms. Modification to enhance flexibility is somewhat limited since many plasticizers will decrease chemical resistance.

Polyester and Vinyl Ester Coatings

Advantages

- Can be low in VOCs
- High film build
- Good water resistance
- Good solvent and chemical resistance
- Good abrasion resistance
- Can have good temperature resistance

Limitations

- Limited pot life
- Skilled operator needed
- Blasted surface required

- Peroxide component is hazardous
- Special application equipment required

Polyester and vinyl ester linings contain volatile monomers such as styrene. Although the monomers are formulated to react completely, some of the monomer evaporates into the work space during the applications and initial curing. Proper ventilation should be provided to maintain the levels of volatile monomer or solvent within safe working ranges. (The OSHA TLV-TWA for styrene is 100 ppm). Additionally, these monomers and the solvents utilized for cleanup during installation may be flammable or combustible and should be treated accordingly.

F. PRETREATMENT WASH PRIMERS

Pretreatment wash primers for steel and aluminum (e.g., DOD-P-15328 and SSPC Paint 27) are used to promote adhesion or provide temporary corrosion protection before applying a full coat of primer. They are two component products: polyvinyl butyral in alcohol solution with corrosion inhibitor (basic zinc chromate) and a solution of phosphoric acid. Upon mixing, the components react with each other and with the metal to form a tightly adhering film. They are applied at 0.3 to 0.5 mils (8 to 13 micrometers) and dry fast (less than a half hour) to provide good temporary protection from corrosion. Pretreatment wash primers are very high in VOCs, but they usually have a temporary exemption from VOC regulations.

Pretreatment Wash Primers

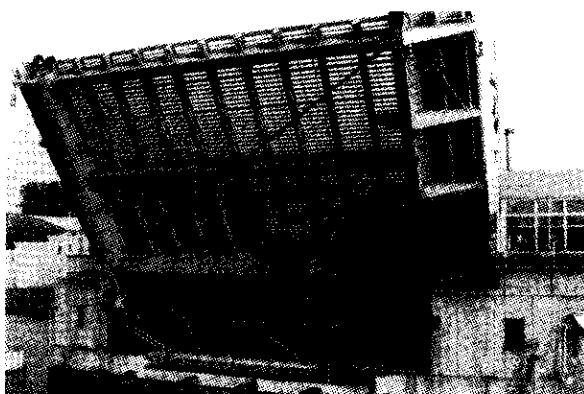
Advantages

- Promote adhesion of primers
- Provide temporary corrosion protection
- Fast drying

Limitations

- Film may fail cohesively when applied too thickly
- High in VOCs
- Uses are limited
- Contains toxic chromate

FIGURE 5-11. Organic zinc-rich coating on a bridge. Courtesy of Michigan Department of Transportation.



G. ORGANIC ZINC-RICH COATINGS

Organic zinc-rich coatings (Figure 5-11) utilize an organic resin rather than an inorganic silicate binder for film formation. (Inorganic zinc-rich coatings are discussed in Chapter 5.14.) They protect steel galvanically as well as by barrier protection, but do not provide as high a level of galvanic protection as do inorganic zinc-rich coatings.

Organic zinc-rich coating films may form by simple solvent evaporation (e.g., those that utilize phenoxy, vinyl, or chlorinated rubber resins) or by chemical reaction of components (e.g., those that utilize epoxy or polyurethane resins).

Film properties of organic zinc-rich coatings are similar in most respects to those of zinc-free organic coatings using the same resin. Organic zinc-rich coatings don't require as high a level of cleanliness of blasted steel surface as do inorganic zinc-rich coatings, and they are easier to topcoat. The zinc in both inorganic and organic zinc-rich coatings is attacked by acid and alkali.

Organic Zinc-Rich Coatings

Advantages

- Can be low in VOCs
- Very good atmospheric durability
- Relatively easily topcoated

- Moderate surface prep. needed

Limitations

- Requires skilled operator
- Requires constant pot agitation
- Unsuitable for acid or alkali
- High initial cost
- Normally requires topcoat
- Lower abrasion and temperature resistance than inorganic zinc-rich products.

V. SUMMARY

The inspector must be familiar with many different generic coating types, which vary widely in their physical and chemical properties. Non-convertible coatings (those that are not changed chemically during film formation) include lacquers and water emulsion (latex coatings). Convertible coatings (those that are changed chemically during film formation) include oil-based coatings, epoxies, coal tar epoxies, polyurethanes, polyester and vinyl ester coatings, epoxy phenolics, and organic zinc-rich coatings. Pretreatment wash primers, used to promote adhesion or provide temporary corrosion protection, are also convertible coatings.

There are many factors that contribute to the satisfactory performance of a protective coating. These may be surface preparation or application characteristics, resistance to exposure conditions, esthetic considerations, safety and environmental considerations, cost, and maintainability. While some generic coating types are clearly best for certain uses, each coating type has its advantages and limitations. The bibliography (Appendix H) lists various sources that the coatings inspector may consult for more detailed information on individual generic coating types. Additional information is available in other SSPC documents and from coating specialists.

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Generation Facilities. He has authored or revised many ASTM standards. He is also a member of SSPC and ASME.

Mr. Slama has published papers on elevated temperature polymer testing, fire test methods for plastics, chemical resistant polymer linings, epoxy machinery grouts, and design of crack-bridging linings for concrete. He holds two patents on fluoroclastomeric composite linings.

BIOGRAPHICAL SKETCH

Albert L. Hendricks is President of Wisconsin Protective Coatings Corporation, where he has been employed since 1958. His activities there have been directly related to coating work at various levels, including manufacturing, testing, research, quality control, application, and specifying.

Mr. Hendricks has been an active member of NACE International since 1961. He has served as Chairman of the National Membership Committee, Chairman of T-14, and Vice Chairman of T-6. He was also on the NACE Board of Directors from 1974 to 1977. Mr. Hendricks is also actively involved on various technical committees within SSPC, ASTM, ACI, and AWWA.

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BIOGRAPHICAL SKETCH

William R. Slama is the Manager of Technical Support for Master Builders, Construction Products division. Prior to this, he was Manager of R&D for ten years, and Technical Director for ten years at Ceilcote Co. In these positions, he has been responsible for research and development and technical support for thermosetting polymer products. His expertise is in chemical-resistant linings, coatings, and floorings; polymer concrete; and epoxy machinery grouts.

Mr. Slama has been active in ASTM committees since the 1960s, especially Committee C3 on Chemical-Resistant Non-Metallic Materials and D33 on Linings for Power

Chapter 5.2

Chemical-Resistant Brick and Tile Linings

by Walter Lee Sheppard, Jr.

OUTLINE

- I. Scope
- II. References
- III. Properties and Typical Uses of Chemical-Resistant Brick and Tile Linings
 - A. Bricks and Tiles
 - B. Mortars
 - C. Membranes
- IV. Preliminary Inspections
 - A. Inspection of Site
 - B. Inspection of Materials
 - C. Inspection of Equipment
 - D. Workforce Qualifications
- V. Application of Membrane
- VI. Application of Brick/Tile Lining Over a Membrane
 - A. Mixing of Mortar
 - B. Brick Cutting
 - C. Application of Mortar and Placement of Brick/Tile
 - D. Joint Work
 - E. Detection and Repair of Air Voids
 - F. Installation of Lining Near Expansion Joints
 - G. Installation of Lining at Nozzles, Inlets, Outlets, and Weirs
- VII. Installing Brick/Tile Without Membrane
- VIII. Safety
- IX. Post Application Inspection
- X. Summary

I. SCOPE

The types of materials covered in this sub-chapter are chemical-resistant ("acid- and alkali- resistant") brick, ceramic block, and tile linings, applied using chemical-resistant mortars. Chemical-resistant brick/tile systems can be applied directly over uncoated steel and concrete substrates (including flooring or decks). They can also be applied over substrates that have been coated with a liquid-tight membrane system. (Note: Further information relevant to inspection of chemical-resistant brick and tile linings can be found in Chapters 3, 4, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM C 267 Test Method for Chemical-Resistance of Mortars, Grouts, and Monolithic Surfacing

ASTM C 279 Specification for Chemical-Resistant Masonry Units

ASTM C 287 Specification for Chemical-Resistant Sulfur Mortars

ASTM C 386 Practice for the Use of Chemical-Resistant Sulfur Mortars

ASTM C 395 Specification for Chemical-Resistant Resin Mortars

ASTM C 397 Practice for the Use of Chemically Setting Chemical-Resistant Silicate and Silica Mortars.

ASTM C 398 Practice for the Use of Hydraulic Cement Mortar in Chemical-Resistant Masonry

ASTM C 399 Practice for the Use of Chemical-Resistant Resin Mortars

ASTM C 466 Specification for Chemically Setting Silicate and Silica Chemical-Resistant Mortars

ASTM C 658 Specification for Chemical-Resistant Resin Grouts for Brick or Tile

ASTM C 723 Practice for Chemical Resistant Resin Grouts for Brick or Tile

ASTM C 811 Practice for Surface Preparation of Concrete for the Application of Chemical Resistant Resin Monolithics Surfacing

ASTM C 868 Test Method for Chemical-Resistance of Protective Linings

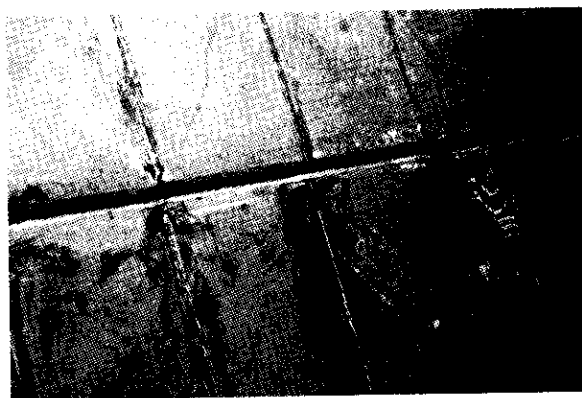
ASTM C 1106 Test Method for Chemical-Resistance and Physical Properties of Carbon Brick

III. PROPERTIES AND TYPICAL USES OF CHEMICAL-RESISTANT BRICK AND TILE LININGS

Chemical-resistant brick, block, and tile linings are designed for use where thermal, corrosive chemical, and/or abrasive conditions of exposure exceed the limits of the substrate, and of other types of linings/coatings, to provide the needed protection to the underlying substrate. These brick, block, or tile lining are installed with fully mortared side and bed joints, free of air bubbles or voids (Figure 5-12).

When a chemical-resistant brick, block, or tile lining is wet with a corrosive liquid, the lining first becomes saturated, then a limited amount of the corrosive liquid reaches the surface of the substrate below the lining. If the attack

FIGURE 5-12. Top - Example of properly laid chemical-resistant brick lining. Courtesy of the author. Bottom - Example of a very bad, totally unacceptable brick laying job. Courtesy of the author.



of the corrosive liquid is sufficiently slow, the substrate may survive long enough to provide satisfactory life.

However, where the attack is too rapid, it may be necessary to place a liquid-tight membrane between the substrate and the chemical resistant brick lining to increase the life expectancy of the structure. Such a membrane is selected for its resistance to the specific corrosive material to be contained.

Further information on standard practice for installation of chemical-resistant brick and tile linings can be found in ASTM C 386, ASTM C 397, ASTM C 398, ASTM C 399, ASTM C 723, and ASTM C 811.

A. BRICKS AND TILES

Chemical-resistant brick and tile materials may be fired clays such as red shale, fire clay, and porcelain. The chemical resistance of a fired clay material depends on two things: 1) the composition of the clay, which varies with its source, and 2) the temperature at which it is fired. Typically the manufacturer identifies a material's resistance in general for the planned service. Red shale and fire clay are generally resistant to acids above pH 3 and alkalis below pH 10. If the owner is concerned whether a material is suitable for the anticipated exposures or needs specific assurance, he can have it tested according to the appropriate procedures cited above (see References). (Note: Porcelain has the highest chemical resistance of the clay materials; however, it is generally only practical for thin linings.)

Chemical-resistant brick and tiles may also be carbon brick. Carbon bricks are made mostly from petroleum heavy oils or asphalts, and are used for exposures to concentrated alkalis and acids, especially for acid fluoride exposures.

B. MORTARS

The chemical-resistant mortars and grouts used with chemical resistant bricks and tiles are of the following types:

1. Plastics - Furan, phenolic, epoxy, vinyl ester, polyester, polyurethane, and acrylic, which may be trowel-applied or sprayed. Plastic mortars are two-component materials. They contain a liquid component and a granular/sand-type component. The granular/sand-type component contains a hardening agent that reacts with the liquid material to make the mortar set. It is the type of granular/sand component and the type of hardening agent that determine the thermal and chemical-resistance of the mortar. The various types available supply chemical and thermal resistances ranging from strong oxidizing acids to strong alkalis, and temperatures ranging from about 212°F to 400°F (100°C to 204°C), depending on formulation.

2. Silicates (either potassium or sodium) - Trowel-applied. Like the plastic mortars, silicate mortars contain a liquid component and a granular/sand-type component with a hardening agent. It is the selection of sodium or potassium and the type of hardening agent that determines the ther-

mal and chemical-resistance of the mortar. Silicate mortars are used primarily for strong acids, especially when strong solvents are present as well. However, silicate mortars should never be selected for use where they will be subjected to even low concentrations of alkalis or even mild acid fluorides.

3. Sulfur mortars - These are single component materials, consisting of sulfur with either a silicate sand filler or a powdered carbon filler. Available as blocks or crushed, they are melted and poured into the joints or cavities to be filled. In general, sulfur mortars are resistant to strong non-oxidizing acids, to weak alkalis (below pH 10), and resistant to temperatures up to about 220°F (104°C). However, they cannot be used at higher temperatures, nor can they be exposed to the direct contact of steam.

Note: Carbon fillers--not sand--must be used in chemical-resistant mortars and grouts in all areas where hydrofluoric acid (even at concentrations as low as 50 parts per million) is to be encountered.

Coatings called chemical-resistant monolithics are sometimes used by themselves (without brick/tile) to provide corrosion protection to bare steel or concrete, or membrane-coated steel or concrete surfaces. Chemical-resistant monolithics are quite similar in formulation to chemical-resistant mortars except that they contain mixtures of sand and gravel of much larger particle size in addition to the type of fine particles present in mortar formulations. Inspection requirements for chemical-resistant monolithics may therefore be quite similar to requirements for chemical-resistant mortars. Monolithics, however, are generally applied in a much thicker layer and are subject to more shrinkage than mortar-laid acid brick. Expansion joints in monolithics must therefore be installed more closely together.

C. MEMBRANES

There are many types of chemical-resistant membranes that can be placed between the masonry lining and the substrate to seal the area and prevent the passage of liquids that have saturated the masonry. The most common type is hot applied coal tar or asphalt. This is applied by melting the membrane material, pouring or spraying it on the surface, and spreading it carefully with a squeegee. Membranes may also be troweled or spray-applied epoxies,

vinyls, vinyl esters, or other plastic materials, often with glass fiber reinforcing.

Membranes may also be sheet linings of rubber (synthetic or natural) or flexible plastics, including fluoroelastomers. Plastic membranes are sometimes applied as semi-rigid blocks, with anchor pins under them. These are set into the forms in which the concrete substrate is cast, then after the concrete has cured, the joints between the blocks are welded closed with the same plastic material.

Instead of a membrane, a layer of hydraulic cement may be placed between the steel substrate and the brick. This may be done in cases where the exposure is to medium temperatures and pH ranges from 6 - 10. The hydraulic cement survives long enough to satisfy the operations. (Note: Portland cement, with latex added, is occasionally used in exposures down to pH 4, e.g., in paper mills.)

IV. PRELIMINARY INSPECTIONS

A. INSPECTION OF SITE

The inspector should make certain that the site is protected from the weather. For the duration of the installation, the area must be kept completely dry, free of rain, spillage, high winds, etc., and be kept at temperatures above 60°F (16°C) and under 100°F (38°C).

The inspector should check the area where brick cutting is to be done. It should be sufficiently removed from application area so that dust and chips cannot reach the application area. If it is too close to application area, it should be moved away before work is allowed to proceed. At the conclusion of each shift, before the workmen leave, they should clean up and remove all waste, including chips. *The next shift should not be permitted to start work until all waste from the last shift is removed.*

B. INSPECTION OF MATERIALS

The inspector should verify the identity of all brick/tile, mortars, coatings, and membrane materials to be certain they are exactly as specified. The inspector should also verify that all materials are stored in accordance with the manufacturers' recommendations. Temperatures of materials should be monitored daily to be certain that they are kept within the range specified by the manufacturer. Materials should also be kept dry.

The inspector should verify the quantities of materials at the site and compare them to the supplier's records to ensure that no materials will run out before completion of the job.

The inspector should check all brick, tile, and all other blocks to be used to be certain that they are clean and dry. Too often, brick, etc. and equipment are shipped to the jobsite on open bed trucks and exposed to the elements. If this is the case, road dirt, mud, and other materials may be on the surface of the brick and equipment, and they may be wet from rain or splash.

C. INSPECTION OF EQUIPMENT

The inspector should inspect the equipment as follows:

- Verify that all trowels, mortar boxes, etc. are clean, free from rust, oil, etc., and are kept protected from moisture, under cover, and at temperatures in the 60°F to 90°F (16°C to 32°C) range for the entire period of the job.
- Verify that all unauthorized tools (asphalt mops, serrated trowels, etc.) are removed from the jobsite, and kept away from it at all times.
- Check the speed of all paddle or rod mixers. The maximum permitted speed is 350 rpm. If the unit is designed to run only at a speed greater than this, it must be replaced, since experience has indicated that higher speed mixers can beat air into the mix, creating bubbles and air voids in the masonry (or monolithic) joints.

Note: In general, no special equipment is used for mixing mortars. Basically, mortars of all kinds are mixed in the same equipment used for portland cement. However, they should be cleaned with water at once after use to prevent semi-cured cement from building up in them and damaging subsequent batches.

D. WORKFORCE QUALIFICATIONS

The inspector should verify that the installer's workforce meets all of the specification requirements, including experience and training, qualification, etc. (see sidebar).

V. APPLICATION OF MEMBRANE

When the job specification calls for chemical resistant brick and tile linings installed over a liquid-tight membrane, the inspector should consult other sub-chapters of Chapter 5 as appropriate and follow these guides for monitoring membrane application and inspecting the membrane prior to application of the brick or tile. The inspector should verify that all substrates to be lined with brick or tile have been properly prepared as stated in the manufacturer's literature and the job specification.

VI. APPLICATION OF BRICK/TILE LINING OVER A MEMBRANE

A. MIXING OF MORTAR

During mixing of the mortar, the inspector should:

- Verify that ambient conditions are within the manufacturer's stated acceptable temperatures for application and cure.
- Verify that the quantity of each component put in the box is in accordance with the manufacturers' specified proportions, and that they are put in the mortar box in the correct sequence. If the mortar is a single component silicate, verify that the proper proportion of water to powder is mixed, exactly as recommended by the manufacturer. Under no circumstance should more water or liquid component be added than recommended. Also verify that the proper mixing time is allowed and that the mortar is totally uniform in texture before the mortar is delivered to the masons. Many dry silicates are slow in dissolving and reacting. If the masons do not realize this, they may hastily add too much water and end up with too fluid a mix.
- Verify that the mixing is complete, and the batch is uniform and smooth. (Check the corners of the box and the bottom for dry areas and lumps.) All batches should be mixed to complete uniformity--no lumps or dry areas--prior to issuance to the masons.
- Verify that the time from the beginning of mix to when the last bit of mortar of the batch is consumed is no greater than the manufacturer's recommended work life. Also, toward the end of each batch, check the consistency of the mortar to be sure that it has not become too stiff to use.
- Verify that any mortars (or monolithics) that are too stiff to use are discarded. Any attempt to re-work or mix into the next batch should be noted. If a new batch becomes contaminated with old material, all work should be stopped at once until all the batch so contaminated has been removed and discarded.

B. BRICK CUTTING

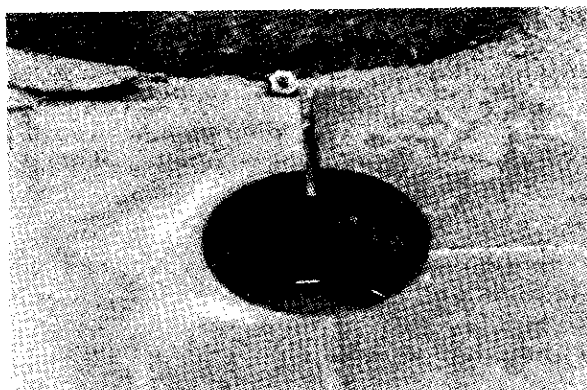
In normal bricklaying, brickmasons frequently "hammer cut" (break) brick when a shorter piece is needed. This practice, however, should not be used when laying chemical resistant brick (unless specifically approved by the design engineer). The contact surfaces formed between hammer cut brick and adjacent brick are very irregular and too difficult to fill and to seal completely, resulting in irregular shaped and often large mortar joints. This may result in cracking due to shrinkage on cure over long periods of time. In chemical resistant construction, joint sizes are strictly controlled, and voids can be created when larger thicknesses of mortars shrink as they cure. Saw cut brick are required to give smooth, flat surfaces and to assure completely uniform and void-free joints. (See procedures under Finish Coat application, discussion of nominal joint size.)

C. APPLICATION OF MORTAR AND PLACEMENT OF BRICK/TILE

In chemical resistant construction, the technique for buttering (spreading mortar on) and applying brick/tile is basically the same as when working with portland cement. The only difference is in taking great care to prevent air voids, i.e., there should be sufficient thickness of mortar so that as the tile/brick is pressed into position, all air behind it is pushed out (Figure 5-13). To accomplish this, the trowel should always be moved parallel to the face of the tile/brick (and all grooves in back completely filled with mortar prior to laying them). The trowel movement should not be curved as it passes around the corners of brick. This motion reduces the amount of mortar in the corner joint and results in an air pocket.

Mortar is usually applied directly to the substrate, as well as buttered on the back and edges of the brick/tile. The buttered surface of the brick/tile is then laid onto the buttered substrate surface. The inspector should observe each mason as he butters and lays the brick/tile. The proper technique is as follows:

FIGURE 5-13. View through hole from test boring, through brick, mortar bed, and into concrete substrate. Courtesy of the author.



- The mason should use a generous, indeed excessive, amount of mortar, and lay it on all contact surfaces in a heavy flat uniform coating, without voids. The corners between the bottom and side joints should be square (at right angles) and not rounded.
- The brick should then be pressed down against the membrane (or steel or concrete) surface and slid sideways, smoothly against the adjacent brick, squarely and evenly, extruding mortar continuously from all joints.

Note: Cut brick surfaces should always be placed as interior joints—never as outside joints, or as part of an expansion joint. This is because the cut surface (with the outside brick fired surface removed) will always have a higher fluid absorption than the uncut brick surface. Also, for strength reasons, it is preferred to place these bricks inside the rest of the structure, surrounded if possible by whole brick.

- With the edge of his trowel, the mason should then cut off the extruded excess, return the excess to his pallet and scoop up the mortar for his next brick.

D. JOINT WORK

For chemical resistant brickwork, the nominal joint size for resin and silicate mortars is 1/8 inch (3.2 mm), but in no case should it be less than 1/16 inch (1.6 mm). For sulfur mortars, the nominal joint size is 1/4 inch (6.4 mm), but not less than 3/32 inch (2.4 mm) to allow plenty of room for flow. If tilesetter's techniques are used (i.e., if the

grout is applied after the tile is set), a 1/4 inch (6.4 mm) nominal joint size is also required for resin or silicate mortars. If the wider joint is not used when grouting, air trapping and voids will certainly result.

E. DETECTION AND REPAIR OF AIR VOIDS

Air voids at the surface can be detected by careful visual examination. If air voids are present, tiny holes or blisters will be visible. Probing with a fine gauge wire can tell the inspector if this is a surface phenomenon or a path into an inner cavity. Air voids may be the result any of the following:

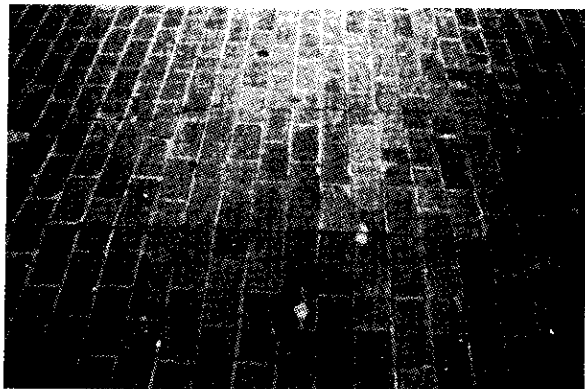
- Too high speed a mixer
- Moisture in the mix or on the substrate surface
- Air in the substrate. If the temperature is rising, air in the substrate expands and comes out as a bubble. (This phenomenon is often found in the spring and fall, particularly at construction sites where there are large thermal changes between day and night, as in Arizona and New Mexico.)
- Air in the mix, trapped there by the mason as he applies it to the brick. Observe his hand movements.

If there are only a few bubbles or blisters, and they are indeed a surface phenomenon, they can be allowed to remain; however, if there are more than a few such bubbles or blisters, the source should be located, and the affected portion of the lining should be repaired.

It is not possible to repair an air void by troweling fresh material over it, or pressing fresh material into it with the trowel. This merely encapsulates the air and creates inferior brickwork. It should be scraped and searched for cavities. Holes of this kind can only be repaired by cutting out the area to make the void bigger, then carefully packing it, using a pointed trowel - pushing the air out in front of the trowel as the trowel advances. Repair should not be attempted with the standard mason's trowel.

It is very close to impossible to repair small air voids with a trowel. The best procedure is to remove the brick around them, thoroughly mortar the surfaces of the interior of the hole so created, and then replace with clean new brick heavily mortared.

FIGURE 5-14. Cracking of a floor due to inadequate expansion joints. Courtesy of the author.



F. INSTALLATION OF LINING NEAR EXPANSION JOINTS

The placement and construction of expansion joints are especially important in chemical resistant masonry work (Figure 5-14).

Proper placement of expansion joints in vessel linings must be determined by computation, using the coefficient of thermal expansion for the brick and the mortar for the anticipated thermal range of the vessel when in use. For floors in normal use, expansion joints are usually placed every 10 feet to 15 feet (3.1 to 4.6 meters) -- and around all fixed objects and over penetrations into or through the slab. The inspector should verify that all expansion joints are:

- Installed at the exact spots specified
- The specified widths
- Continuous, all ending in either another expansion joint or a sliding joint, so that they are not immobilized by terminating in a fixed object

He should also note the edges and lines of the expansion joints to be sure that they are straight, uniform in width, smooth and true, and that the edges are right angles, not rounded, sloped, or chipped.

The inspector should examine the brick along the edge of the expansion joints to be sure that nowhere along the edge

of joint is there a cut brick of less than one-half the brick length. If it is necessary to adjust the line of brick with a cut brick of less than one-half the brick length, this lesser dimension brick should be laid in the line of brick one course back from the course along the edge of the joint.

The inspector should observe the placement of the expansion material to be sure that it is located in accordance with the drawings, is of the specified material, and is installed tightly without voids and in the specified manner.

G. INSTALLATION OF LINING OF NOZZLES, INLETS, OUTLETS, AND WEIRS

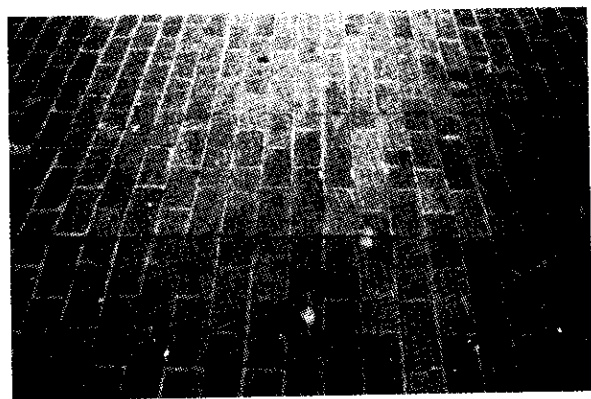
The inspector should observe the installation of the linings of all nozzles, inlets and outlets. If done by less experienced men, these are the areas of greatest concern and most likely to contain trapped air and voids.

Treatment of nozzles, inlets, outlets, and sleeves, varies to some degree with the vessel and its use. Inlets are usually best either flush with the inside surface of the vessel or extended slightly into it. Outlets are best slightly recessed into the wall or floor so that the vessel will drain completely and leave no puddles.

Sleeves are used in inlets and outlets that are not large enough to brick line. The inlet or outlet pipe is lined with the membrane before it is built into the wall. When the brick lining is completed, the sleeve (cut to exact dimensions required) is coated externally with the mortar. The pipe is also coated with mortar. The sleeve is then slowly pushed into the pipe until it reaches the required position. The excess of mortar is then removed from the port of entry, and the exit port is checked and pointed as necessary.

For nozzles, all sleeves should be heavily buttered with an excess of material and the interior of the nozzle also buttered before the sleeve is slid into place, pushing excess mortar in front of it. The excess should be cut off carefully and the inspector should at once examine both inside and outside joint surfaces for indications of air voids. If any are noted, the inspector should make certain that they are corrected at once while the mortar is soft. The inspector should also observe closely the laying of the brick up to and around the nozzle lining to be sure that it is correct.

FIGURE 5-14. Cracking of a floor due to inadequate expansion joints. Courtesy of the author.



F. INSTALLATION OF LINING NEAR EXPANSION JOINTS

The placement and construction of expansion joints are especially important in chemical resistant masonry work (Figure 5-14).

Proper placement of expansion joints in vessel linings must be determined by computation, using the coefficient of thermal expansion for the brick and the mortar for the anticipated thermal range of the vessel when in use. For floors in normal use, expansion joints are usually placed every 10 feet to 15 feet (3.1 to 4.6 meters) -- and around all fixed objects and over penetrations into or through the slab. The inspector should verify that all expansion joints are:

- Installed at the exact spots specified
- The specified widths
- Continuous, all ending in either another expansion joint or a sliding joint, so that they are not immobilized by terminating in a fixed object

He should also note the edges and lines of the expansion joints to be sure that they are straight, uniform in width, smooth and true, and that the edges are right angles, not rounded, sloped, or chipped.

The inspector should examine the brick along the edge of the expansion joints to be sure that nowhere along the edge

of joint is there a cut brick of less than one-half the brick length. If it is necessary to adjust the line of brick with a cut brick of less than one-half the brick length, this lesser dimension brick should be laid in the line of brick one course back from the course along the edge of the joint.

The inspector should observe the placement of the expansion material to be sure that it is located in accordance with the drawings, is of the specified material, and is installed tightly without voids and in the specified manner.

G. INSTALLATION OF LINING OF NOZZLES, INLETS, OUTLETS, AND WEIRS

The inspector should observe the installation of the linings of all nozzles, inlets and outlets. If done by less experienced men, these are the areas of greatest concern and most likely to contain trapped air and voids.

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tight, with no voids, and without evidence of badly cut brick or excessively large joints.

In the placement of weirs, divider walls, and other masonry barriers in a tank lining, the inspector should check to be certain that there are header bricks locked into the bottom and side walls to keep the brick in an unsupported wall from moving out of position and creating a void.

VII. INSTALLING BRICK/TILE WITHOUT MEMBRANE

Where bricks (hollow tile or ceramic tile) are laid without membranes and with a layer of hydraulic cement (or latex hydraulic cement or epoxy or other bonding bed) between shell and brick (or tile) lining, as, for instance, in certain installations in paper mills and mining operations, the inspector should:

- Examine the steel shell prior to lining to verify that surface preparation is as specified.
- Verify the condition of the tile or brick (cleanliness) and of the mix of the mortars (as described previously) used to lay them before the brick (or tile) are laid.
- Verify that all joints are full and free of voids (as described previously) as the mortar is grouted between the brick and the shell, and that the mortar is mixed properly and free of air bubbles and voids.

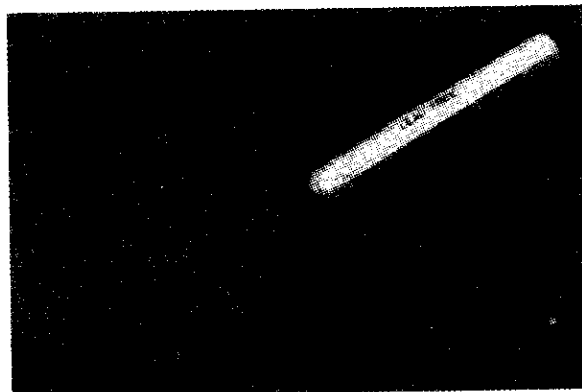
Where tile is used as a smooth surfacing for the exposed surface of a wall or an abrasion resistant lining of a steel chute, or as a vessel lining, the inspector should:

- Verify steel surface preparation as specified.
- Verify that all tile are clean and dry
- Verify that all bonding mortars are mixed and applied exactly as specified and without any air voids in either bed or joint.

VIII. SAFETY

If the manufacturer has indicated possible dermatitis effects from the mortar being used (e.g., phenolic mortar), the inspector and other workers should be warned, and should take any necessary precautions. These may include:

FIGURE 5-15. A recessed joint that will require repair.
Courtesy of the author.



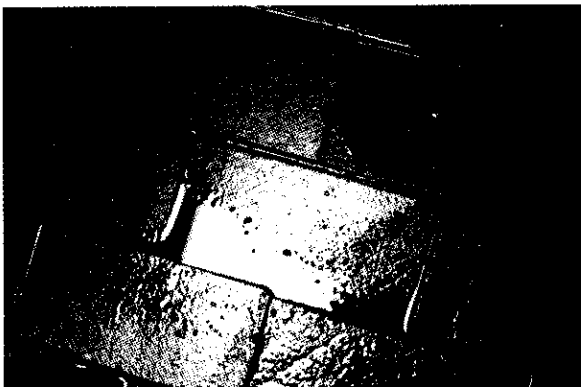
- Using protective clothing and devices, including gloves
- Washing frequently, and changing clothes daily (Clothes that are still damp with soft, partly cured mortar should not be used.)
- Making certain that all ventilation fans are placed behind workmen to blow fumes away from them (not in front of them).
- Seeing that all smoking, eating, and drinking is done away from the site, and that hands are washed before these actions or going to the latrine.

Respirators are not normally required for such work, but if they have been required by the safety professionals, the inspector should verify that they are properly used. The inspector should also wear all necessary personal protective equipment.

IX. POST-APPLICATION INSPECTION

The inspector should continue daily checks on temperature, cover, weather protection, etc., until the mortars are totally cured, when tested in accordance with the manufacturer's instructions, or when released by the owner's management. If a storm should damage the weather protection so that the work is exposed to water extremes before cure is complete, the work will probably never cure and all brick should be removed and discarded, and replaced with new brick and mortar. Thermal extremes may also

FIGURE 5-16. Top - Flooding of a floor in a food plant to check for complete drainage. As indicated by the puddles that remain, this is a poorly laid floor. Courtesy of the author. Bottom - Close-up of the floor showing low spots on individual bricks. Courtesy of the author.



cause irreparable damage, but before removal, the materials manufacturer should be consulted.

Finished surface cleanliness and appearance, and the quality of workmanship should be in accordance with a sample provided prior to the start of the job (see sidebar). Anything falling below the quality of the sample should be rejected by the inspector--if he has that authority--and the applicator instructed to remove it and replace it. Recessed joints and pinholes in joints that appear after job completion are indications of void beneath the surface and should be cause for removal and replacement of affected units (Figure 5-15). Repair by pointing should not be attempted.

For rough surfaces, surface grinding of tile and brick to obtain a smooth surface is not an acceptable correction unless specifically approved by the owner and his engineer, since it produces a product of far lesser quality and shorter life.

A good way to further inspect a chemical resistant brick or tile floor is to flood it with water to the highest point and check for puddling as the water drains (Figure 5-16). If the floor fails to drain completely, the installation is faulty and early damage may result if there is no membrane, or if the membrane has been poorly applied. Puddling at the edge of a drain is a serious installation fault that should be corrected by the installer. If the levels of any of the puddles are noticeably lower the next day, it is an indication of voids in the brick (or tile) joints. To check this, sample cores should be taken from the lowest points in the puddles. Cores should also be taken next to any pillars or other vertical structures.

After work is completed, the inspector should verify that all rubbish, and waste, such as damaged brick, tile, and waste mortar, are removed from the site and discarded in accordance with the applicable environmental regulations. Reclaiming is not acceptable without specific authority in writing from the owner.

X. SUMMARY

Chemical resistant brick and tile linings are used for thermal insulation and to protect against abrasion and corrosive chemical attack. They may be applied over uncoated steel or concrete substrates, or substrates coated with a liquid-tight membrane system. When monitoring the installation of chemical resistant brick and tile linings, one of the major responsibilities of the inspector is to ensure quality workmanship. It is critical that the bricks or tiles are cut, laid, and positioned properly and according to the specification. Two important concerns are the avoidance of air voids in the lining, and the proper size and location of expansion joints. The inspector also has the usual inspection responsibilities for monitoring ambient conditions, materials, equipment surface preparation, etc.

One of the hazards that the inspector may face when inspecting the installation of chemical resistant brick and tile linings is exposure to mortars, which may contain irritating vapors. The inspector should therefore ensure that

proper ventilation is in place and have the protective clothing and devices necessary to protect himself.

ACKNOWLEDGEMENTS

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Richard F. Rimbach - Consultant

Ronald R. Skabo - Ch2M Hill

BIOGRAPHICAL SKETCH

Walter Lee Sheppard, Jr., PE is the president and consulting engineer of CCRM, Inc. He has been involved in the design, selection, specification, and use of "acid-resistant" brick and mortar construction, and of rubber, synthetic rubber, plastic, and asphaltic-based membrane systems, both with and without brick surfacing protection, since 1938; and, as they were created, monolithic surfacings, including sulfur concrete and polymer concretes. He has written thirty or more technical papers on the design, application, and uses of these materials. His papers have also addressed the inspection and supervision of work in progress, troubleshooting, and failure analysis. Mr. Sheppard has also written the first book in English on "Chemically Resistant Masonry" (2nd edition 1982, Marcel Dekker), and edited and contributed a large portion to a volume entitled "Chemical and Corrosion Resistant Masonry Components Handbook." (Noyes Publications).

Mr. Sheppard is a member of NSPE, NACE International, AAEE, and ASTM. He is a 1932 graduate of Cornell University and a 1933 graduate of the University of Pennsylvania.

VERIFICATION OF ACCEPTABLE WORKMANSHIP FOR CHEMICAL RESISTANT BRICK/TILE LININGS

Chemical resistant brick/tile linings include materials of different coefficients of expansion, and tensile, compressive and thermal properties, thus they are subject to delamination or fracture if not installed properly. They must be installed by masons experienced in this specialty and they must be free of air voids and all defects that could cause spalling, fracture or leaking. Three critical factors in ensuring the desired performance of these linings are:

- Materials selection and installation of all components of the lining
- Proper selection, location, and installation of expansion joints
- Proper installation of materials at all nozzle linings and all areas where walls change direction

When improper or unacceptable workmanship is found in surface coatings on a steel or concrete substrate, the unacceptable work can be removed reasonably quickly, and the coating reapplied properly without too much expense or lost time. However, if errors or low quality workmanship are found in brick and tile linings, then much time must be consumed in removing defective area and restoring the required surface finish before the lining can be replaced, delaying and vastly increasing the cost of the project. Therefore, if the inspector is given the authority, he should stop the construction at any time that he finds unsatisfactory workmanship, and not let it resume until the unsatisfactory work has been removed and corrected.

If given the authority to do so, some inspectors of chemical resistant brick and tile linings may take the following preliminary steps to ensure acceptable workmanship:

- Verify that the successful (low) bidder is not suspiciously low, has not missed or forgotten anything. If suspiciously low, go over his bid with him to be certain he agrees that it is correct. If this is part of another and much larger bid package, ask on whose bid this part of the bid is based, and verify with the material supplier that this installer is approved, with experience in the work.
- Request that the installer show evidence (names, places and dates) of the satisfactory completion of at least three similar installations within the last two years, and certify that either the foreman or lead craftsman of these jobs will be on hand working at this job for the full time of the construction.
- After award of contract, conduct continual consultation with the installer and material supplier to be certain that all are in

agreement, that materials the installer will use are acceptable, and the specifications and design suitable for the exposures the owner anticipates. In addition, the manufacturer's tables of resistance should be checked to verify that the coating material selected is appropriate for the chemical and thermal exposure that the owner anticipates. All questions and disagreements should be resolved and agreed upon before any work starts. Full minutes should be kept at all meetings, and these should be signed by all participants.

Once the work begins, the inspector may take the following additional steps to ensure acceptable workmanship:

- Make a point of meeting the foreman of the installer's crew when he arrives, verifying that he and/or the lead man of his team is the same one responsible for the prior jobs used by the installer to establish his experience. Once work begins, check to be sure that the experienced lead man is on site. If given the authority to shut the job down at any time, make certain that the installer understands that if the trained and experienced man leaves the job for any longer time than a call of nature, the job will be shut down until his return.
- Observe the instructions given to all brick masons and tilesetters on the job. Ensure that each one understands the differences between laying/setting this type brick or tile and laying/setting face or refractory brick or common tile. A sample section or area, say 6 feet x 10 feet (1.8 meters x 3.1 meters) may be completed and approved by the inspector first, and all work later may be compared to the approved sample for quality and acceptability. Check the work of all personnel on site at regular intervals to ensure that an acceptable level of work is being maintained and that no experienced worker has been replaced by a new and inexperienced worker.

If such requirements are not stated in the specification, the inspector should bring them to the attention of the owner. If the inspector and the owner are not aware of these considerations, the result may be most unfortunate.

Chapter 5.3

Coal Tar Coatings

by Henry R. Stoner

OUTLINE

- I. Scope
- II. References
- III. Description of Coal Tar Coatings
- IV. Classification and Properties of Coal Tar Coatings
- V. Coating Systems
- VI. Limitations of Coal Tar Coatings
- VII. Inspection of Materials
 - A. Storage Conditions
- VIII. Surface Preparation
- IX. Coating Application
 - A. Mixing and Thinning
 - B. Special Application Equipment
 - C. Application of Prime Coat
 - D. Application of Subsequent Coats
- X. Safety
 - A. Toxicity
 - B. Personal Protective Equipment
 - C. VOCs
- XI. Post Application Inspection
 - A. Film Thicknesses
 - B. Holiday Testing
 - C. Cure
 - D. Adhesion
- XII. Summary

I. SCOPE

This sub-chapter describes the various classes of coal tar coatings and their properties, including compatibility with one another. It also describes the special inspection points for application of these coatings and some of the problems that can occur when these coatings are applied in the field. (Note: Further information relevant to inspection of coal tar coatings can be found in Chapters 3, 4, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 36 Test Method for Softening Point of Bitumen (Ring and Ball Apparatus)

ASTM D 962 Specification for Aluminum Powder and Paste Pigments for Paints.

ASTM D 3359, Test Methods for Measuring Adhesion by Tape Test; Test Method A.

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ASTM D 4541, Method for Pull-Off Strength of Coatings Using Portable Adhesion Tester.

American Water Works Association (AWWA)

AWWA/ANSI C-203, Coal Tar Protective Coatings and Linings for Steel Water Pipelines Enamel and Tape - Hot Applied.

SSPC: The Society for Protective Coatings (SSPC)

SSPC Paint 27, Basic Zinc Chromate - Vinyl Butyral Wash Primer (DOD-P-15328)

SSPC-Vis 1, Visual Standard for Abrasive Blast Cleaned Steel

SSPC-PA 1, Shop, Field, and Maintenance Painting

SSPC-PA 2, Measurement of Dry Coating Thickness with Magnetic Gages

III. DESCRIPTION OF COAL TAR COATINGS

Coal tar coatings contain specially processed coal tar or coal tar pitch as their binder. These binder products are obtained from the distillation of high-temperature crude coke oven tars, and consist primarily of a complex combination of three or more membered condensed ring aromatic hydrocarbons.

The difference between the terms "coal tar" and "coal tar pitch" lies in the softening points of these two binder products. The term "coal tar" is used when the product has a softening point of approximately 120°F (49°C) or less; the term "coal tar pitch" is used when the product has a softening point greater than 120°F (49°C). Throughout this sub-chapter, the term "coal tar coatings" will be used to refer to coatings that have either coal tar or coal tar pitch as their binder.

IV. CLASSIFICATION AND PROPERTIES OF COAL TAR COATINGS

The coal tar coatings, most of which are cut back (dissolved) in suitable solvents, are divided into six classes for the purpose of this discussion. The first three classes of coal tar coatings are:

Class 1 - Low viscosity, solvent cutback, without inert fillers.

Class 2 - High viscosity, solvent cutback, with inert fillers (Figure 5-17).

Class 3 - Very high viscosity, solvent cutback, containing inert fillers. These may have a thixotropic gel structure that can be broken down with adequate mixing.

These three classes are all lacquer type coatings. They are solutions, and their films all have about the same chemical and water resistance performance. They vary mainly in the thickness of the film that can be applied in a single coat. Thicker films of these higher viscosity classes can be applied in one coat. (Note: Although a thicker film may be applied, two applications are often needed to provide the overall protection required of the coating.)

Class 4 coal tar coatings are hot-applied thermoplastics, containing no solvents but containing inert fillers. Class 4 coatings are referred to as "enamels" (Figure 5-18). These enamels are solid at ambient temperatures and require special handling and application techniques. It is highly recommended that AWWA C-203 be followed when applying using these enamels.

Class 5 coal tar coatings are high-viscosity emulsions composed of coal tar, mineral fillers, colloidal clay and water. Their viscosity is like that of latex paints. Sometimes sand (having mesh size similar to that used in concrete), is added to the topcoat to provide a finished surface that is less slippery when wet.

FIGURE 5-17. Coal tar cutback on galvanized pipeline for burial. Courtesy of US Army Construction Engineering Research Laboratories.



Class 6 coal tar coatings are polymer and/or resin modified, with or without solvents. Although this classification is often used, the products are really coal tar modifications of other generic types and their film properties are more similar to the other generic types. The most common type, coal tar epoxy, is described in Chapter 5.1. Other coal tar modified generic types include polyurethanes and vinyls.

Practically all coal tar coatings are black in color because the basic color of coal tar/coal tar pitch is black (Figure 5-20). Aluminum pigment powder may be added to these coatings immediately prior to the coating's application at the jobsite. This gives a slight surface color change sufficient to distinguish between coats at the time of application (see Section X D).

V. COATING SYSTEMS

Classes 1, 2, and 3 coatings are normally self priming and can also be applied in multiple coats (i.e., Class 1 on Class 1, Class 2 on Class 2, Class 3 on Class 3) that adhere well to one another. This is because the solvent in the subsequent coat redissolves the surface of the last applied coat. However, when Classes 1, 2, and 3 are to be exposed to the atmosphere during their life, alligatoring and mudcracking of their immediate surfaces may occur, which may or may

not penetrate to the substrate. To avoid this phenomenon, a Class 5 coating, which does not have as great a tendency to alligator or mudcrack, is applied after the solvent has evaporated from the applied Class 1, 2, or 3 coatings.

Class 4 coatings cannot be used as a prime coat. A primer for Class 4 coatings is found in AWWA C-203. Class 4 coatings, which contain no solvents, are not normally applied in multiple coats (unless special conditions are met during machine applications). See AWWA C-203 for protecting the surface of Class 4 coatings. Class 4 coatings can, however, be used to make touch-up repairs. They have to be at a molten temperature between 450 to 500°F (232 to 260°C) before they are applied to AWWA C-203 enamels.

Class 5 coatings need to be applied over a primed steel surface otherwise flash rusting of the steel will occur and its color will exude through the coating. Primers for Class 5 coatings are often derived from thinned Class 1 coatings. Class 5 coatings can be applied in multiple coats. Subsequent coats adhere to previously applied coats because the aromatic oils in the tar effect a monolithic type bond (after drying and curing) to the surface of the last applied coat.

Class 6 coatings can be applied with or without priming, depending on the polymer generic type. For coal tar polyurethanes, the steel substrate must be primed with a compatible primer (usually an epoxy) for satisfactory bonding and performance. The manufacturer's literature should be checked for where and when to use compatible type primers for Class 6 coatings.

Class 6 coatings can be applied in multiple coats; however, there are a few problems that can occur in the field. For example:

- The rays of the sun will cause the surface of Class 6 coatings to cure rapidly making them insoluble and inert so that the topcoats will not adhere; hence, delamination between coats will occur.
- Where multiple coats of a Class 6 coating are to be applied, any condensation, dew or rain that collects on the surface of the previous coats will not allow the subsequent coat to develop adequate adhesion, even though the surface of the previous coat appears dry.

Class 6 coatings that are thermosetting therefore have special requirements for topcoating, and specific procedures

FIGURE 5-18. Mechanical application, in the field, of a Class 4 coal tar enamel coating to a 28 inch diameter steel pipe. Courtesy of the author.



must be obtained from the manufacturer and followed explicitly, otherwise delamination and other failures may occur.

VI. LIMITATIONS OF COAL TAR COATINGS

In comparison with coatings that may be used in similar service areas (e.g., wastewater treatment plants, steel marine pilings, pipelines, underground service), coal tar coatings may give greater and longer lasting service. However, they do have some limitations:

- They cannot be applied over most other coatings because they will affect the adhesion of the base coating to the substrate.
- They can not be painted over with pastel colored paints since the aromatic oils in the coal tar/coal tar pitch coatings will bleed through the pastel colored paints and turn the topcoat(s) beige in color.
- They cannot be mixed with asphalt-based coatings, since the degree of compatibility between coal tars/coal tar pitches and asphalts is about one-half percent by weight. Additions of greater percentage proportions will result in sludging of each vehicle. They cannot be thinned with aliphatic solvents, such as mineral spirits. They cannot be applied over or be a base coat for asphalt type coatings because the aromatic oils in the coal tar/coal tar pitch will have an effect on the eventual drying of the asphalt coatings. These oils will solubilize the asphalt and remain in its film causing the asphalt to remain too soft for its intended use.

VII. INSPECTION OF MATERIALS

Inspection of the coal tar coatings at the jobsite for their routine characteristics, such as viscosity, mixing abilities, weight per gallon, and the like, should follow the procedures described in Chapter 4.

A. STORAGE CONDITIONS

For the most part, coal tar coatings can withstand storage at temperature extremes:

- Classes 1, 2, 3, and 4 can be stored from 0°F (-18°C) to 110°F (43°C) with no undue problems.
- Class 5 coatings cannot be stored below 32°F (0°C). Once a Class 5 coating freezes, the constituents of the

emulsion completely separate and they cannot be reincorporated back into a homogenous coating. When in this condition, the coating cannot be used and has to be discarded. Class 5 coatings can, however, withstand storage at temperatures up to 100°F (38°C) and possibly withstand storage at higher temperatures, such as up to 120°F (49°C), for short periods of time.

- Class 6 coatings can withstand low temperature storage as noted for Classes 1, 2, 3, and 4.
- For the multiple component thermosetting types, storage at temperatures above 100°F (38°C) may be a problem if the curing agent decomposes, reacts, or loses its effectiveness.

The manufacturer's instructions should be followed for storage temperature limitations for the class of coal tar coating being used at the jobsite.

VIII. SURFACE PREPARATION

Inspection of surface preparation is needed to provide the life and performance expected of coal tar coatings. With new steel, the abrasive blasting, if specified, should meet the requirements of the job specification. The level of cleanliness required varies with the type of product used. The use of SSPC-Vis 1 is highly recommended as a means to determine conformance with blast cleaning requirements.

Any factory lacquer on new steel at the jobsite should be removed as the coal tar coatings are incompatible with factory lacquers.

If a previously painted surface is to be topcoated with a coal tar coating, it must be inspected to ensure that the previously applied coating has good adhesion and that the topcoat will not affect the adhesion and performance of the total system. A test patch, with sufficient drying and curing time between coats should be made and evaluated.

IX. COATING APPLICATION

A. MIXING AND THINNING

Most coal tar coatings will have some degree of settling and must be thoroughly mixed before using. Any settling should be incorporated back into the coating with adequate agitation.

Class 3 coatings may have a gel structure that needs substantial mixing with power mixing equipment to reduce its viscosity prior to applying.

Only the specified thinners and allowable limits thereof should be used (e.g., Class 5 coal tar coatings should be thinned with clean or potable water only). Often thinning is unnecessary and prevents the attainment of the required film build. Thinners that are too weak in solvency will cause the coal tar/coal tar pitch to sludge and destroy the coating. Thinners too strong will also have a deleterious effect on the coal tar coatings.

B. SPECIAL APPLICATION EQUIPMENT

With the exception of Class 4, all classes of coal tar coatings can be applied at ambient temperatures using standard or heavy duty application equipment. This equipment includes brushes, rollers, conventional air and airless spray equipment. Some trowel grades found in Classes 3 and 6 may not lend themselves to be applied with roller or any spray equipment used at ambient temperatures. These trowel grades may require the use of heavy duty spray pumps, spray equipment inline heaters, special diameter hoses and special sized tips for ease of spray applications.

Brushes to be used should be of the natural bristle type. The use of brushes with plastic bristles should be avoided. Tampico bristle brushes can be used for brushing trowel grade coal tar coatings. This type of brush can also be used for applying molten Class 4 coal tar coatings.

Rollers should be constructed using cores made from phenolic resin saturated materials or from a core that will not be dissolved or attacked by the solvents and/or the aromatic oils found in the coal tar and coal tar pitch used in this group of coatings.

If heavy duty, plural component airless spray equipment is used for Class 6 coatings, it should be inspected, making sure that the rates and volumes of each component to be delivered to the mixing chamber of the spray equipment meet the requirements of the coating manufacturer. Care should be taken to ensure that the mixed material does not sit for too long in the hoses, especially when the hoses are lying in the sun. Black colored hoses absorb a lot of the sun's heat, which speeds up the reaction of the mixed material in the hose. This can cause plugging of the hose should the spraying operation be stopped for any extended

FIGURE 5-19. Applying a Class 6 epoxy modified coal tar pitch coating to the interior of a 20 foot diameter steel pipe. Courtesy of the author.



time, for example, while moving a scaffold or taking a lunch break.

C. APPLICATION OF PRIME COAT

The prime coat or first coat should be applied as soon as practical to the prepared surface of the substrate, but in no case after flash rusting of the substrate begins.

If the substrate is a non-ferrous metal (e.g., aluminum, brass), SSPC-Paint 27 (Basic Zinc Chromate - Vinyl Butyral Wash Primer) should be used prior to applying any primer or first coat of the coal tar coating--except for Class 4 systems.

Where concrete or masonry surfaces are to be coated, a thinned coat of a Class 1 coating is used as a prime coat. To make a thinned coat, two volumes of Class 1 coating and one volume of the manufacturer's recommended thinner are mixed. This mixture is applied over a properly prepared, usually abrasive blasted concrete or masonry surface. This should be allowed to dry at least overnight for the evaporation of the solvent from these surfaces. In cooler weather, below 60°F (16°C) allow longer dry times.

Where a Class 6 coal tar epoxy system is specified, the prime coat is prepared by thinning two volumes of the mixed component coating with one volume of the manufacturer's recommended thinner. This is applied to a prop-

erly prepared, usually abrasive blasted, concrete or masonry surface. It is allowed to dry and cure overnight prior to topcoating with full coats of the coal tar epoxy.

During application, since the coal tar coatings are black in color, no part of the substrate should be visible. Where the substrate is visible, touch up will be required. Chapter 4.4, Section IXA should be used as a guide for primer application. All sags, runs and other coating imperfections should be corrected to meet the requirements of the specification.

Wet and dry film thicknesses should be measured using the procedures outlined in SSPC-PA 2. Primer application should fall within the dry film thickness limits outlined in the specification, or if not available, within the dry film thickness limits recommended by the manufacturer.

D. APPLICATION OF SUBSEQUENT COATS

SSPC-PA 1 should be used as a guide for the application of intermediate and finish coats. Improper application techniques with coating Classes 2, 3, 5, and many Class 6 coatings (considered high build coatings) may result in surface defects, such as fish eyes, severe orange peel, runs and sags, etc. These defects can cause deficient film thicknesses, requiring additional coating to be applied. It is essential that the coating is properly atomized as it leaves the spray tip, and that the coating is laid properly on the

previously applied film; otherwise, the resulting large particles will impinge the surface of the applied coating and cause the aforementioned deficiencies to appear on the surface of the finish coat.

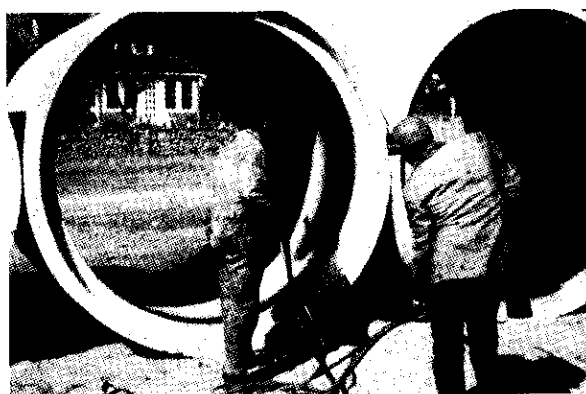
To differentiate between coats, especially in low light areas, two ounces of leafing type aluminum pigment powder, meeting ASTM D 962, Class B. Medium, can be added and mixed into each gallon of coal tar coating Classes 1, 2, 3, 5, and 6 immediately prior to their application. No pigment powder is to be added to Class 4 or to Class 6, Coal Tar Epoxy, SSPC-Paint 16, Red. After the pigment powder is added, the coating container should not be sealed since explosive gas pressure may develop.

Time between the application of coats of Class 1, 2, 3, and 5 coatings is not critical; however, since Classes 1, 2, and 3 are lacquer type coatings, sufficient solvent must be evaporated prior to applying the next coat. It takes at least fourteen days at ambient temperatures for the solvents to evaporate. The manufacturer should be consulted to determine how soon the next coat can be applied.

Many Class 6 coatings have time limitations for application of subsequent coats. The manufacturer's instructions should always be consulted regarding time between coats.

Some Class 6 coatings, however, can be applied in a wet-on-wet condition, meaning that when the applied coat has become dry-to-touch and not fully cured, another coat can be immediately applied. This method is recommended for application in the field, where the black coating surfaces can reach well over 100°F (38°C), leading to rapid curing of surfaces and the risk of limited adhesion resulting in intercoat delamination.

FIGURE 5-20. Applying a class 2 coal tar pitch coating to a 72 inch concrete pipe. Courtesy of the author.



X. SAFETY

A. TOXICITY

Coal tar coatings may contain low concentrations (less than 1 percent by weight) of materials that are suspected carcinogens. Coal tars can also cause sensitization of bare skin in some individuals. Other hazardous ingredients that may be present in coal tar coatings include epoxy resins, polyamine and/or polyamide co-reactants, isocyanates, and hydrocarbon solvents. Chapter 7 contains further information on the hazards of these materials.

B. PERSONAL PROTECTIVE EQUIPMENT

The inspector and workers should be aware that special safety precautions are needed when handling and applying this group of coatings. These include using gloves, long sleeve shirts, protective skin creams on unprotected areas of the skin, and respirators. These coatings require greater use of safety equipment than do most coatings such as alkyds and epoxy esters that use mild solvents. In all cases, the requirements listed in the manufacturer's MSDS should be followed.

C. VOCs

The volatile organic compound (VOC) content of coal tar coatings depends on the class. Information on the VOC content of a particular product should be obtained from the manufacturer's data sheet. For general reference, however, Table 1 shows some typical VOC contents of the various classes of coal tar coatings.

XI. POST APPLICATION INSPECTION

Visual appearance, film thicknesses, film cure, holiday detection, sags and runs, etc., are some, but not all, of the film characteristics that must be addressed in the inspection of the new film.

A. FILM THICKNESSES

Other than Class 1, coal tar coatings are applied in excess of fifteen (15) dry mils (381 micrometers) and up to fifty

(50) mils wet (1270 micrometer) films. As a result, the inspector must have wet and dry film gages that can be used in these film thickness ranges. Class 1 coatings, because of their thin, varnish-like consistency, can be measured with thin film measuring gages. SSPC-PA 2 should be followed.

Should the dry film thickness of the intermediate coat be lower than what is specified, an additional amount of the intermediate coat should be applied so that the dry film thickness meets the specification or the manufacturer's requirements. Where the thickness of the intermediate coat is greater than the limits specified, the manufacturer should be consulted as to whether or not the additional intermediate coat thickness is acceptable.

Any film thickness variance in the finish coat should be corrected. Where the total film thickness is low and does not meet the specification or the manufacturer's recommendations, additional coating should be applied. If the thickness exceeds the requirements of the specification, the manufacturer should be consulted for corrective steps, if any, that need to be taken to reduce the excessive film build.

B. HOLIDAY TESTING

If the coating is to be immersed, it should be holiday tested for discontinuities, pinholes and voids. The manufacturer should be consulted for proper holiday detection techniques and voltages to be applied during testing, or the holiday detection methods described in Chapter 8 should be used.

C. CURE

Film cure, depending on the class of coal tar coating, should be evaluated prior to putting the coated structure into service. Generally, instructions from the manufacturer regarding the time requirement for cure and the effect of temperature during cure, if followed precisely, should be satisfactory.

D. ADHESION

The pull-off strength test (ASTM D 4541) can be used on various Class 6 coatings. For other classes, the tape test method found in ASTM D 3359, Test Method A, should be used. The adhesion of SSPC-Paint 16, Coal Tar Epoxy to

TABLE 1. VOC content of coal tar coatings.

Class	VOC content
Class 1	4.0 - 5.5 lbs/gal (480 - 660 g/L)
Class 2	2.5 lbs/gal (300 g/L)
Class 3	2.0 lbs/gal (240 g/L)
Class 4	0
Class 5	0
Class 6	0 - 2.1 lbs/gal (250 g/L)

abrasive blasted new steel laboratory test panels has been evaluated using test method ASTM D 4541, and the pull-off strength has been found to be at least 1000 psi (7 MPa).

XII. SUMMARY

Coal tar coatings can be divided into six classes, based on their viscosity, solvent cut-back, inert filler content, physical state (e.g., emulsion vs. solution) and modification. The different members of these classes vary in their properties such as water resistance, allowable film thicknesses, thinning, priming requirements, application characteristics, and compatibility with one another. Although the inspector of coal tar coatings has the usual responsibilities for inspection of coating materials, monitoring ambient conditions, surface preparation, and coating application, there are also some special requirements for coal tar coatings. When applying some coal tar coatings, leafing aluminum pigment powder is added to differentiate between coats. Sunlight interferes with the curing of some of these coatings. Moisture can interfere with the intercoat adhesion of some of these coatings.

Coal tar coatings have several disadvantages, for example, they cannot be applied over most other coatings. They also may cause skin irritation and sensitization. The inspector should take all necessary precautions to protect himself from these harmful effects.

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Charles G. Munger - deceased

William A. Wood, Jr. - International Paint

BIOGRAPHICAL SKETCH

Henry R. Stoner is the president of Henry R. Stoner Associates, Inc., a consulting firm assisting the industrial paints and coatings industry. Before this, he was with Koppers Company for 32 years. He joined Koppers in 1956, and held various positions until his retirement in 1988. Most recently, he was Manager of Governmental Compliances (1986-1988). Prior to that he was Coatings Operations Manager, East (1984-1986); Technical Director, Koppers Coatings (1972-1984); Coatings Development Chemist (1969-1972); and Chief Chemist (1964-69). Mr. Stoner has also assisted paint companies in third world countries under the auspices of the International Executive Service Corps.

Mr. Stoner is an active member of SSPC. He also holds membership in many other organizations including American Chemical Society; Steel Water Pipe Manufacturers Technical Advisory Committee and Steel Water Tank Committee of the American Water Works Association; American Society of Testing Materials, D-01 and D-33 Groups; New York Paint and Coatings Association; New York Federation of Coatings Technology; and NACE International.

Mr. Stoner is a native of Ambridge, PA. He received a B.S. Degree in chemistry in 1952 from Geneva College.

Chapter 5.4

Thick Film Elastomeric Polyurethanes

by Dean M. Berger

OUTLINE

- I. Scope
- II. References
- III. Properties and Typical Uses of Thick Film Elastomeric Polyurethanes
 - A. Flexibility (Elongation)
 - B. Impact and Abrasion Resistance
 - C. Erosion (Wear) Resistance
 - D. Water (Moisture) Resistance
 - E. General Corrosion Resistance
 - F. Resistance to Ultraviolet Light (Weathering)
 - G. Reflectance of Light
 - H. Laboratory Testing
- IV. Materials
- V. Surface Preparation
- VI. Coating Application
 - A. Slower-Cure Aliphatic and Aromatic Products
 - B. Rapid-Dry Aliphatic and Aromatic Products
- VII. Post Application Inspection
 - A. Visual Inspection
 - B. Drying and Curing
 - C. Adhesion
- VIII. Safety
- IX. Summary

I. SCOPE

The objective of this sub-chapter is to describe the unique features of elastomeric polyurethane coatings with a dry film thickness greater than 30 mils (760 micrometers), and to explain how these features affect the inspection of these coatings applied to steel, concrete, or other surfaces. (Note: Further information relevant to inspection of thick-film elastomeric polyurethanes can be found in Chapters 3, 4, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers - Tension

ASTM D 470 Test Methods for Crosslinked Insulations and Jackets for Wire and Cable

ASTM D 573 Test Method for Rubber - Deterioration in an Air Oven

ASTM D 624 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers

ASTM D 2240 Test Method for Rubber Property - Durometer Hardness

ASTM D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

ASTM E 96 Test Methods for Water Vapor Transmission of Materials

NACE International (NACE)

NACE TM0186-94 Holiday Detection of Internal Tubular Coatings of 250 to 760 Micrometers (10 to 30 Mils) Dry Film Thickness

III. PROPERTIES AND TYPICAL USES OF THICK FILM ELASTOMERIC POLYURETHANES

Thick-film polyurethane coatings vary widely in their formulations and mechanisms and rates of curing. They consist of separately packaged isocyanate and polyol components. When these components are combined, they undergo a chemical reaction to form a film of polyurethane coating.

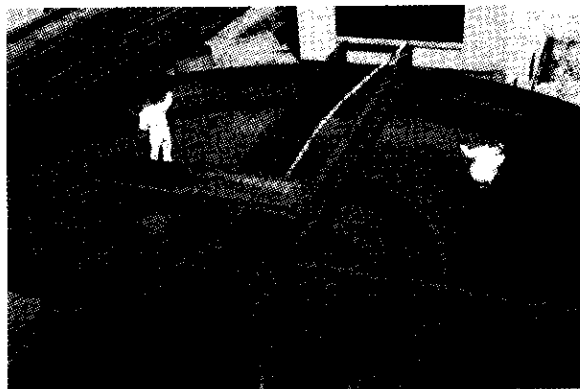
The reaction rates of two-component polyurethanes may vary greatly with changes in the chemistry of the co-reactants. They can therefore be classified as either "relatively slow curing" or "rapid curing" products. They can also be classified as aromatic polyurethanes and aliphatic polyurethanes, depending on the chemical composition of the isocyanate component.

Following is a list of some of the properties of elastomeric polyurethanes, discussed in relation to end use. It should be noted that the selection of elastomeric polyurethanes is generally based on end use, although a combination of properties is usually desirable.

A. FLEXIBILITY (ELONGATION)

Having typical elongation values of 100 - 200%, elastomeric polyurethanes can provide the flexibility desired on surfaces where movement occurs, such as on concrete walls and floors. Fine cracks in these surfaces may be bridged by these elastomeric products.

FIGURE 5-21. Thick film urethane used to protect settling tank against abrasion and corrosion. Thickness range, 50 - 60 mils (1.3 - 1.5 mm). Courtesy of ITW Devcon Engineered Coatings.



B. IMPACT AND ABRASION RESISTANCE

Because elastomeric polyurethanes are easily deformed and then return to their original condition, they find good use in service where other products are damaged by impact or abrasion (Figure 5-21).

C. EROSION (WEAR) RESISTANCE

Elastomeric polyurethanes are not easily eroded by sand or other matter. They are used as pipeline coatings where they protect from rock damage and mine tailing. They perform well where wind- or water-borne sand would rapidly erode other coatings and on parking lots where other coatings are worn away by vehicle tires.

D. WATER (MOISTURE) RESISTANCE

Because of their good water resistance, elastomeric polyurethanes are frequently used to seal atmospheric concrete surfaces and line concrete or steel water tanks. They are frequently used to waterproof concrete or wood, even against wind-driven rain.

E. GENERAL CORROSION RESISTANCE

Thick-film elastomeric polyurethane coatings have good corrosion resistance. They also have good chemical resistance. For this reason, these products are used to line tanks, secondary containments, and other structures that may come into contact with harsh chemicals.

F. RESISTANCE TO ULTRAVIOLET LIGHT (WEATHERING)

Aliphatic polyurethanes have good resistance to degradation by ultraviolet light, and are therefore used in exterior atmospheric service. Aromatic polyurethanes are rapidly degraded by ultraviolet light, but usually have better chemical resistance.

G. REFLECTANCE OF LIGHT

Aliphatic products are also used on polyurethane foam roofs where they reflect much of the sun's heat, reducing air-conditioning requirements.

H. LABORATORY TESTING

Table 1 lists some of the tests that are used to determine the film properties of elastomeric polyurethanes. These tests are normally performed in the laboratory. They are done mainly for quality control and to make sure the product performs as specified.

TABLE 1.

Property Tested	Test Method
Permeance to moisture	ASTM E 96, Procedure B
Shore hardness	ASTM D 2240 (done in field)
Cut/tear resistance	ASTM D 624 and ASTM D 470
Elongation and tensile strength	ASTM D 412
Abrasion resistance	ASTM D 4060, CS17 wheel, 1,000 revolutions with 1 kg (2.2 lb.) weight
High temperature resistance	ASTM D 573
Holiday detection of tubular coatings	NACE TM0186-94

FIGURE 5-22. Thick film urethane used to protect slurry silo against abrasion. Thickness range, 100 - 150 mils (2.5 - 3.8 mm). Courtesy of ITW Devcon Engineered Coatings.



IV. MATERIALS

As described in Chapter 4, the inspector should verify the identity, condition, and storage of all materials. Any rejected materials should be segregated or removed from the storage facility.

V. SURFACE PREPARATION

For application of thick-film elastomeric polyurethanes, surface preparation to SSPC-SP 10 is normally required; however, surface preparation requirements vary with both the surface (steel, concrete, or other) and the product used. Some products may require surface conditioning of concrete. The manufacturer's instructions should always be followed.

VI. COATING APPLICATION

Recommended procedures for application of thick-film elastomeric polyurethane coatings vary with both end use and the product used (Figure 5-22). The manufacturer's instructions should always be followed.

A. SLOWER-CURE ALIPHATIC AND AROMATIC PRODUCTS

The most common method of application of two-component slower-cure products is by airless spray pump equipment. The two components are mixed and sprayed with a single gun. The inspector should check to be sure that proper mixing ratios of components are used to ensure that the chemical reaction involved in film formation is complete. The inspector should also ensure that the pot life of the product is not exceeded. Pot lives of the slower-curing products typically vary between 15 minutes and 4 hours.

B. RAPID-DRY ALIPHATIC AND AROMATIC PRODUCTS

Special plural-component equipment is required for application of two-component rapid-curing products, since the pot life may be only a few second (typically less than 30 seconds). Components are precisely metered by pump and mixed in the line or at the nozzle before spraying. A third line with solvent is used to purge the residual mixed product and to flush the system after use. Heaters may be used with this equipment to reduce coating viscosity or further accelerate curing. Some coating suppliers sell their own application systems for use with their proprietary products, while others recommend the use of standard systems from the usual application equipment suppliers.

The inspector should verify that the type of spray equipment and the mixing ratios of the pumps conform to the manufacturer's application instructions. The inspector should also verify that the application equipment is operating correctly.

VII. POST-APPLICATION INSPECTION

Thick-film elastomeric polyurethanes vary widely in their composition, properties, uses, methods of surface preparation and application, and hazards. All of these factors have an effect on the inspection of their films (Figure 5-23). In addition, inspection requirements are also normally related to end use.

A. VISUAL INSPECTION

The inspector should visually inspect the coating film for runs, sags, voids, and other surface film defects.

FIGURE 5-23. Thick film urethane used in circulating water lines at a power plant. Thickness range, 60 - 80 mils (1.5 - 2 mm). Courtesy of ITW Devcon Engineered Coatings.

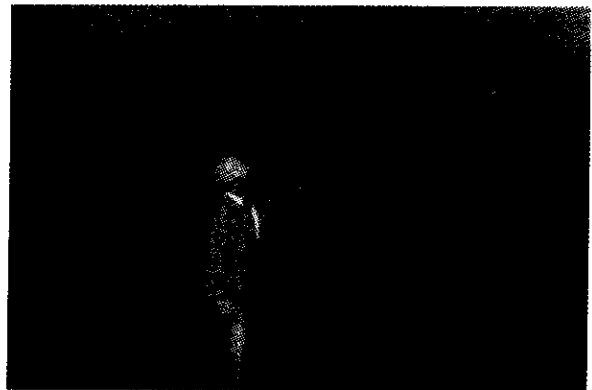


TABLE 2. Typical drying/curing times of thick-film polyurethanes at different temperatures.

Condition	Time to Achieve Condition at Different Temperatures		
	50-60°F (10-15°C)	70-80°F (20-26°C)	90-100°F (32-40°C)
Slower-curing two-component products			
Dry surface	3 hours	1.5 hours	1 hour
Hard film	24-36 hrs.	18 hours	2 hours
Recoat (min.)	1-2 hours	1 hour	<1 hour
Recoat (max.)	72 hours	48 hours	24 hours
Full cure	7 days	5 days	3 days
Rapidly-curing two-component products			
Dry surface	4-6 min.	4-5 min.	2-3 min.
Hard film	20 min.	15 min.	10 min.
Recoat (min.)	7 min.	5 min.	4 min.
Recoat (max.)	8-10 hours	6-8 hours	4 hours
Full cure	2-3 days	36-48 hrs.	30-40 hrs.

B. DRYING AND CURING

Recommended drying and curing times of elastomeric polyurethanes can vary significantly with the type of product used. The inspector should verify that the proper drying and curing times are maintained. Manufacturer's instructions should always be followed; however, as a gen-

eral guide, Table 2 shows how drying and curing times may vary for slower curing vs. rapidly curing products at different ambient temperatures. A Shore A hardness test in accordance with ASTM D 2240 can be used to determine if very thick (e.g., 60 mils (1.5 mm) or more) coatings have completely cured.

C. ADHESION

Destructive adhesion tests can be run on the applied film or on test panels coated at the same time. In this procedure, parallel lines one inch apart are cut through the coating to the substrate. The leading edge of the total coating system is cut back from the substrate with a razor blade at least one inch and secured to a metal clamp, so that the one-inch-wide strip can be tested. A spring scale is attached to the clamp and pulled at a perpendicular angle at a steady rate of disbondment. The adhesion value in pounds per lineal inch (pli) is read directly from the scale. Values in the 30 - 40 pli (5.4 - 7.1 kg/cm) are common, but those in the range of 10 - 20 may be acceptable for some materials and applications. It should be noted that the adhesion values obtained using this procedure are only approximate. Much more precise adhesion values, if required, should be determined by a laboratory.

VIII. SAFETY

There are many hazards that may be present during the application of polyurethane coatings. One in particular is exposure to isocyanates. Most unreacted isocyanates are toxic or harmful to some degree to skin, eyes, and respiratory tracts, so that worker exposure to them during application must be limited as much as possible. Protective clothing, including gloves, eye protection, and face creams should be used to avoid skin contact. Respirators should be worn, as specified by the supplier, safety regulations, or other specification requirements. Good ventilation is required in enclosed areas.

The polyols used in most polyurethane coatings are relatively safe but may contain some toxic ethylene oxide as a contaminant.

The job specification and associated documents such as MSDSs should be consulted for further information about the hazards of these materials and other hazards that may be present. In addition, Chapter 7 provides further information on safety for the coatings inspector.

IX. SUMMARY

There are many different types of thick-film elastomeric polyurethanes. They may be aliphatic or aromatic, and rapid- or slower-curing. Although aromatic polyurethanes are rapidly degraded by ultraviolet light, aliphatic polyurethanes have good resistance to ultraviolet light. In general elastomeric polyurethanes have many desirable properties, including resistance to impact, abrasion, chemicals, and moisture.

In addition to monitoring ambient conditions, surface preparation, mixing, and coating application, the inspector should verify the proper operation of any special equipment that is used. The inspector should also ensure that proper drying and curing times are maintained.

A particular hazard of working around polyurethanes is exposure to isocyanates. The inspector should take all necessary precautions to protect himself from the harmful effects of these compounds.

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Donald G. Reinert - Atlas Minerals & Chemicals Inc. (retired)
Oliver W. Siebert - Siebert Materials Engineering, Inc.

BIOGRAPHICAL SKETCH

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Mr. Berger is a member of the Federation of Societies for Coatings Technology (FSCT), Washington Paint Technical Group (WPTG), NACE International, and SSPC. He has been a member of NACE and SSPC since 1960. Within SSPC, he has served on the Surface Preparation, Epoxy, Zinc-Rich, and Inspection Committees. He also served six years on the Board of Governors. In 1993 he was named the first honorary life member of SSPC. Mr. Berger is also a member of ASTM D-1, D-33, and G5 and is currently Executive Director of the National Board of Registration of Nuclear Safety Related Coating Engineers and Specialists.

Mr. Berger has published numerous articles, chapters in books, and served as Technical Editor of SSPC Volume 1 in 1993. He is a graduate of North Central College and served three years in the Navy.

Chapter 5.5

Fiberglass-Reinforced Plastic (FRP) Linings

by Otto H. Fenner

OUTLINE

- I. Scope
- II. References
- III. Properties and Typical Uses of FRPs
- IV. Inspection of Job Site Conditions
- V. Inspection of Materials
- VI. Surface Preparation
 - A. Surfaces to Be Lined
 - B. Abrasive Blasting
- VII. Lining Application
 - A. Ambient Conditions
 - B. Inspection of Equipment
 - C. Mixing and Thinning
 - D. Prime Coat Application
 - E. Embedment of Fiberglass Mat and Topcoating
 - F. Special Considerations for Linings
- VIII. Health and Safety
 - A. Ventilation
 - B. Personal Protective Equipment
 - C. Fire Protection
- IX. Post-Application Inspection
 - A. Visual Inspection
 - B. Hardness
 - C. Holiday Testing
- X. Summary

I. SCOPE

The purpose of this sub-chapter is to provide a set of directions to inspectors of "mat and resin" fiberglass-reinforced plastic (FRP) linings applied to steel vessels. The term "mat" includes:

- Mat - randomly oriented chopped glass fibers loosely held together with binder.
- Veil - very thin mat composed of glass fibers.
- Woven roving - heavy glass fiber fabric of strands woven together.

Although it covers inspection of the entire FRP installation process, e.g., observing the workshop area for cleanliness, verifying the storage and handling of raw materials and supplies, and ensuring adherence to the specification and design requirements, it is not intended to provide a detailed description of the application techniques and installation steps necessary for FRP linings. (Note: Further information relevant to inspection of FRP linings can be found in Chapters 5.1, 3, 4, 7, and 8. Chapter 5.1 describes the properties of polyester and vinyl ester linings; Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM C 582 Specification for Contact-Molded Glass-Fiber Reinforced Thermosetting Plastics (RTP) Laminates for Corrosion Resistant Equipment.

ASTM D 638 Test Method for Tensile Properties of Plastics

ASTM D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

ASTM D 2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor.

ASTM D 4097 Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks.

ASTM D 4285 Method for Indicating Oil or Water in Compressed Air

ASTM D 4357 Specification for Plastic Laminates Made from Woven Roving and Woven Yarn Glass Fabrics

ASTM D 4414 Practice for Measurement of Wet Film Thickness of Organic Coatings by Notched Gauges

ASTM D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

ASTM D 4541 Method for Pull Off Strength of Coatings Using Portable Adhesion Testers

ASTM D 4618 Specification for the Design and Fabrication of Flue Gas Desulfurization System Components for Protective Linings

ASTM D 4787 Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates

ASTM E 337 Test Method for Measuring Humidity with a Psychrometer (The Measurement of Wet- and Dry-Bulb Temperature)

NACE International (NACE)

Reinforced Polyester and Epoxy Linings-NACE Publication 6A187; Prepared by NACE Task Group T-6A-31, 1987.

Reinforced Polyester and Epoxy Linings - NACE T-6A-31 Report-1/1986.

NACE RP0178-95 Fabrication Details, Surface Finish Requirements and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service

SSPC: The Society for Protective Coatings (SSPC)

SSPC-PA 2 Measurement of Dry Coating Thickness with Magnetic Gages

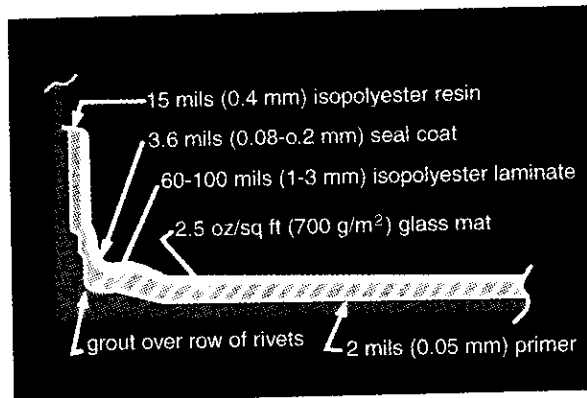
SSPC-Vis 1 Visual Standard for Abrasive Blast Cleaned Steel

SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

III. PROPERTIES AND TYPICAL USES OF FRPs

Fiberglass-reinforced plastic (FRP) linings are unsaturated polyester and vinyl ester thermosetting resin linings into which layers of fiberglass are incorporated to optimize the lining's performance (Figure 5-24). They are commonly used to control internal corrosion of above-ground petroleum storage tank bottoms. The main reinforcements used with polyester and vinyl ester resin linings on steel vessels are 1.5 oz./ft² (460 g/m²) "E" glass mat and 10 mil (250 micrometer) thick "C" glass veil. E glass mat has electrical properties, strength, and durability appropriate for most applications. C glass mat is chemical-resistant, i.e., it is resistant to corrosion by most acids. A 10 oz./ft² (3000 g/m²) open weave cloth ("woven roving") is sometimes used instead of chopped strand mat for reinforced polyester linings in steel vessels.

FIGURE 5-24. Schematic of FRP system.

Note: The "mat and resin" systems described in this subchapter are just one of the many types of reinforced protective lining systems that are now available. For example, there are trowel-applied epoxy, polyester, and vinyl ester mortar systems containing fillers for added permeation resistance. There are also specialty systems that contain other types of reinforcement, such as orlon and carbon fiber. Further information on such systems can be obtained from References 1-4 (see Bibliography).

IV. INSPECTION OF JOB SITE CONDITIONS

The inspector's report should take the work area into consideration (Figure 5-25). It is imperative that there are no extraneous materials in the work area that could contaminate the lining. Fabrication is best done indoors. It is necessary to do any outside activities under a canopy under most instances. Cleanliness is of paramount importance, and the floor space and adjacent activities should be free from dusting. Clutter cannot be tolerated within the work area from either a contamination or safety standpoint.

V. INSPECTION OF MATERIALS

General procedures for inspection of materials are given in Chapter 4. The inspector should follow those procedures, and also verify that:

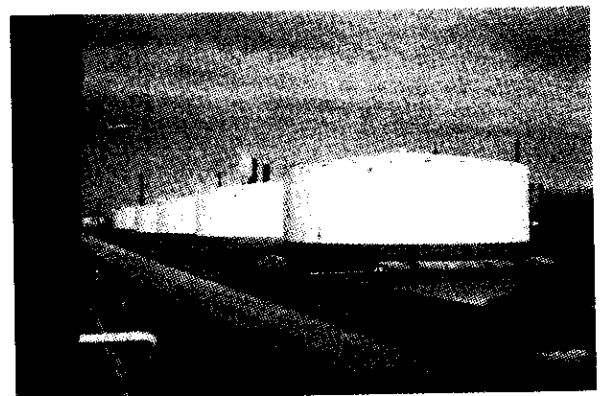
- There are no inadvertent mix-ups in the various materials being handled, and that the correct resins and fiberglass are used in the construction.
- All rolls of glass mat, woven roving, and veils are kept covered and free from foreign materials.
- All liquid resins and solvents are in containers that are readily identified, and kept in fire-proof closets when not being transferred to other vehicles for use at the job-site.
- Partly used buckets of resin or styrene that have been catalyzed and are not to be used in the immediate future are properly disposed of.

VI. SURFACE PREPARATION

A. SURFACES TO BE LINED

The inspector should verify that the vessels or surfaces to be lined meet the fabrication requirements of the specification and the surface condition requirement of the coating manufacturer. Specific requirements for welds, connections, etc. can be found in NACE recommended practice for fabrication of steel vessels (i.e., NACE RP0178-95) and in ASTM D 4618 for flue gas desulfurization linings.

The internal structure of the steel vessel should be examined to determine whether the construction is compatible with the laying-up of the fiberglass reinforced resin laminate. There should be no sharp edged, steel inner appendages that would contribute to disbonding of the lining

FIGURE 5-25. Chemical storage tank with FRP lining. Courtesy of Amoco Chemicals.

under service conditions. All such abrupt sharp edges should be beveled to permit the lining to follow a satisfactory, curved profile. All welds in the vessel should be ground smooth to provide uniformly even, continuous surfaces. There should be no apertures or structural voids under auxiliary installations, such as coil supports, thermowells, stand-pipes, etc., which could prevent the continuous lining of the wall of the vessel.

The inspector should examine and test the vessels or surfaces for contamination, as required by the specification, and should verify that any specification requirements for degreasing, cleaning, etc. are met.

B. ABRASIVE BLASTING

The inspector should verify that the specified level of surface preparation and profile are attained. It is common practice to require Near-White Blast Cleaning (SSPC-SP 10) and a 3 mil (76 micrometer) profile in preparing the surface of the steel before lining with the fiberglass reinforced polyester or vinyl ester overlay. After abrasive blast cleaning to the specified level, a vacuum cleaner should be used to remove any abrasive dust and metal particles to ensure the surface is free of such debris. The surface should then be wiped down with a toluene-wetted cloth to remove any oil on the surface that might interfere with the adhesion of the glass fiber reinforced resin lining. To minimize rapid oxidation of the newly abraded steel surface, a primer is often applied immediately over the blast-cleaned surface (see Section VII. D., below).

VII. LINING APPLICATION

A. AMBIENT CONDITIONS

The inspector should verify that ambient conditions are within the limits required by the specification and the manufacturer's instructions. It is of utmost importance that lining application not be done under high humidity conditions. It is advised that any activities be conducted at temperatures at least 10°F (6°C) above the dew point. (Note: This is stricter than the usual 5°F (3°C) because it is necessary to avoid moisture on both the steel surface and the mat or veil glass fabrics to be used in the lining.) Borderline dew point conditions slow down the catalytic curing of the resin. If the lining is exposed to moisture before it has been fully cured, it can result in an unsatisfactory and poorly performing overlay.

FIGURE 5-26. Resin being rolled onto glass mat.
Courtesy of Amoco Chemicals.



Under no circumstances should the resin application be done at temperatures below 50°F (10°C). Curing of the resin below that temperature is generally incomplete (it will remain tacky) and may result in a system that is not resistant to the environment. It is advisable not to attempt to apply the lining under situations in which it will be exposed direct sunlight. It may develop blow-hole blistering and non-uniform surface effects due to the degrading effects of ultraviolet (UV) radiation.

B. INSPECTION OF EQUIPMENT

The inspector should verify that mixing tanks for blending of the polyester resin, styrene, catalyst, or accelerators are completely free of contamination or previous solutions prior to new application. Hardened, or cured resin residues should not be left clinging to the outer surface of the blend tank, nor to its structural supports. Similarly, spray-guns, and auxiliaries must be kept free of any residual catalyzed resin materials.

The inspector should also verify that all brushes, applicators, and air removal rollers are kept absolutely clean. The practice of repeatedly soaking these items in old solvents in buckets should be discontinued whenever the solvent has picked up residual resins and glass fibers, which make for poor application and brush out of the lining.

C. MIXING AND THINNING

The inspector's prime concern during mixing and/or thinning of the resin, styrene, catalyst blend is to make certain that the proper materials are added together; that the correct resin system is used (same batch number of the same resin), and that the proper amount of each ingredients is added.

D. PRIME COAT APPLICATION

The inspector should verify that the proper thickness of the specified prime coat is applied to the abrasive blasted surface within the allotted time period to minimize oxidation to the steel substrate. The prime coat serves not only to prevent further oxidation of the steel surface, but to enhance the adhesion of the overlay fiberglass coating to the wall of the vessel. Occasionally the prime coat is simply a styrene-thinned version of the resin being used, without the fiberglass reinforcement. In these cases, the inspector should verify that the recommended dilution is used, as directed by the resin manufacturer. In many instances a proprietary formulation that is compatible with the specific resin system is employed.

E. EMBEDMENT OF FIBERGLASS MAT AND TOPCOATING

The inspector should monitor the embedment of fiberglass mat and topcoating (Figure 5-26). Before the prime coat has had time to set-up completely, the resin impregnated 1.5 oz./ft² (460 g/m²) fiberglass chopped strand mat is embedded into it. A top coat of the clear resin is applied, either by spray, brush, or roller to seal the glass mat, and provide a liner of approximately 40 mils (1 mm) minimum, smooth finish (Figure 5-27).

If additional thickness is desired to provide for severe environmental protection, a second fiberglass chopped glass mat, impregnated with the resin system is applied. The 40-80 mil (1-2 mm) thick fiberglass reinforced resin overlays are subjected to air-inhibition on the air-exposed surface, causing the surface to remain soft and tacky. To achieve tack-free curing, a top coating of the resin, containing approximately 0.4% paraffin wax is applied. Flotation of the wax to the surface permits the blanketed resin to cure completely. (NOTE: After curing of the substrate fiberglass reinforced resin, it is necessary to use solvent to remove the exuded paraffin surface layer and sandpaper

the surface to permit adhesion of any patch repair additions.)

F. SPECIAL CONSIDERATIONS FOR LININGS

In the lining of a steel vessel with a fiberglass reinforced resin system, the procedure is essentially the same as for the fabrication of a rigid, free-standing FRP vessel. One difference, however, is that a thinner layer of the fiberglass reinforced resin laminate is acceptable, inasmuch as the steel wall of the lined vessel serves as the structural member. In the free-standing structure, additional fiberglass filament winding, or woven roving are needed for structural strength. The fabrication problems and techniques associated with both types of construction are essentially the same, although a major concern with the lined steel vessel is that of the differences in thermal expansion of the steel wall and the FRP lining. Too thick of a lining can cause disbonding.

For steel vessels lined with FRP, it is imperative that the fiberglass laminate be thoroughly impregnated by the protective resin system. There can be no discontinuities ("holidays") that would allow penetration of the liquid environment to reach the substrate steel. This liquid permeation could rapidly result in serious corrosion, with attending undercutting and lifting of the lining.

FIGURE 5-27. Applicator applying resin-rich seal coat. Courtesy of Amoco Chemicals.



To accelerate curing, a warm 75- 80°F (24-27°C) air stream can be directed into the vessel for several hours.

VIII. HEALTH AND SAFETY

A. VENTILATION

The polyester and vinyl ester resins used in FRPs contain volatile monomers such as styrene. Although the monomers are completely reactive in the system, during the applications and initial curing some of the monomer evaporates into the work space. Proper ventilation should be provided to maintain the level of volatile monomers or solvents within safe working levels. The OSHA permissible exposure limit-time weighted average (PEL-TWA) for styrene is 100 ppm over an 8 hour period. In good engineering design, ventilating troughs are installed in the floor of the area that is used to construct the vessels. Styrene vapors are heavier than air, and thus gravitate to these ventilating troughs where an induced draft suction carries them to a scrubber and collects them.

B. PERSONAL PROTECTIVE EQUIPMENT

In addition to proper ventilation of the vessel, a respirator is a must for all workers entering the tank being lined with the FRP system. This is to protect workers against breathing the styrene or other solvents. Organic cartridge-type air purifying respirators may be used for personal protection against styrene under most conditions when it can be detected by its odor (1-10 ppm for most people). At higher concentrations, a supplied air respirator may be required. Persons sensitive to the resin should wear gloves or use protective cream on face, hands, and all exposed areas.

C. FIRE PROTECTION

These monomers used in FRPs and the solvents utilized for cleanup may be flammable or combustible and should be treated accordingly. Since FRP linings, until cured completely, contain flammable solvents, they must be kept free from sparks and open flames. All electrical equipment and installation tools should be grounded in accordance with the National Electric Code.

It is imperative that any spills of materials be cleaned up immediately, and that dirty rags be wet down with water

and be removed from the work area and disposed of as required by the specification.

IX. POST-APPLICATION INSPECTION

A. VISUAL INSPECTION

The inspector should verify that the cured fiberglass reinforced resin surface is free of the following:

1. Inadequate resin wetting of the fiberglass. This will be evidenced by resin-dry spots or areas.
2. Areas indicating lifting or delamination.
3. Entrapped air. This is evidenced by blistering, surface air bubbles, and sub-surface air bubbles.
4. Non-uniformity of laminal construction (ply-layup) or "fold-overs" or variations in laminal thickness. Laminal thickness is a measurement of the total thickness of the polyester or vinyl ester coating resulting from the number of plies used to line the vessel. A generally good rule of thumb is that laminal thickness will be 40-45 mils (1.0-1.1 mm) for each layup consisting of a resin-rich 1.5 oz./ft² (460 g/m²) glass mat and a 10-15 mil (250-380 micrometer) thick surfacing veil; and roughly 95-100 mils (2.4-2.5 mm) for each layup consisting of two 1.5 oz./ft² (460 g/m²) mats and one 10 mil (250 micrometer) surfacing veil.
5. Excessive porosity and/or crevices at junctures of nozzles
6. Inadequate reinforcement and support of nozzles and manways.
7. Excessively resin-rich areas, brittle sections, shrinkage cracks, high-temperature exotherms, or internal stress cracking.
8. Poor adhesion, unfinished areas, or careless, sloppy workmanship.
9. Contamination from foreign materials in the work area. Contamination may be embedded within the laminate or on the surface of the resin.

B. HARDNESS

The fully cured surface should be tested for hardness with a Barcol Hardness Tester. The hardness should be as required by the specification and the manufacturer's instructions. A reading of 35-40 is generally considered acceptable for the cured resin. There should be no evi-

dence of tackiness when an acetone-wetted cloth is impressed upon the surface.

C. HOLIDAY TESTING

It is often desired to test the FRP lay-up on the steel wall or floor for discontinuities that might allow aggressive liquids to contact the steel, and result in corrosion, and undercutting and lifting of the lining. Low voltage wet sponge holiday detectors are of little use in finding holidays in a coating this thick (100 mil (2.54 mm) or better), since permeation of the electrolyte from the wet sponge down to the steel surface may not readily occur. High-voltage holiday detectors are therefore most commonly employed for testing fully cured FRP laminates. The lining manufacturer should be consulted regarding which voltage to use for holiday testing. 100 volts per mil (4 volts/micrometer) is considered a good rule of thumb; however, the dielectric strength of the fiberglass reinforced resin laminate must be considered and a low enough voltage must be used so as not to burn through the lining. Changes in formulation (e.g., resin, catalyst, accelerator, fillers, or glass mat) can make a significant difference in the dielectric strength of the laminate, which could inadvertently cause arcing through the liner wall to the steel substrate.

X. SUMMARY

FRPs are specialty coatings consisting of an unsaturated polyester or vinyl ester thermosetting resin and an embedded layer (or layers) of fiberglass. The inspection of these coatings is therefore, up to a point, the same as the inspection of thermosetting resins. The hazards are essentially the same, too. However, there are several additional requirements related to the embedment of the fiberglass mat. For example, when working with FRPs, it is very important that equipment and materials be free from contamination by dust or debris. It is also imperative that the resin thoroughly impregnates the fiberglass.

Newly-applied FRP films are visually inspected for defects, such as resin-dry areas, entrapped air, non-uniformity, contamination, and excessive porosity. Holiday testing and hardness testing may also be required.

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BIOGRAPHICAL SKETCH

Otto H. Fenner is the president of Otto H. Fenner and Associates, a materials engineering consulting firm. He has extensive experience in the field of glass fiber reinforced resin chemical processing equipment and structures. For 43 years, Mr. Fenner was employed by the Monsanto Company, where he served in various capacities, including Chemical Operator, Research Chemist, Area Supervisor, Group Leader, Production Superintendent, Supervising Engineer, Operations Research Plant Manager's Staff, Corrosion Engineer, and Principal Engineering Specialist in Materials Engineering.

Mr. Fenner is a member of various professional societies, including the American Chemical Society; American Institute of Chemists, Inc.; NACE International; Society of Plastics Engineers; Society of Plastics Industry; American Society for Testing and Materials; Alpha Chi Sigma - National Professional Chemical Society; and the International Union of Pure and Applied Chemistry. In 1976, Mr. Fenner received the citation of recognition for outstanding contribution to NACE, and he is a NACE Certified Corrosion Engineer.

Mr. Fenner has served as a lecturer at Washington University, University of Utah, University of Missouri, Ohio State University, and Wayne State. He has written over 100 papers on various aspects of corrosion engineering and plastics applications. He is also author of a chapter entitled, "Chemical and Environmental Properties of Plastics and Elastomers" in the Handbook of Plastics and Elastomers (McGraw-Hill); and a chapter entitled, "Corrosion Engineering in Reinforced Plastics, of Fillers and Reinforcements for Plastics" in the ACS Advances in Chemistry Series (#134, American Chemical Society).

Mr. Fenner received his AB Degree in Organic Chemistry from Washington University, St. Louis, MO. He also did post-graduate studies in chemical, metallurgical, and materials engineering and studied for two years at Law City College of Law & Finance.

Chapter 5.6

Fluoroelastomeric Coatings

by Kenneth B. Lowrey

OUTLINE

- I. Scope
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- III. Properties and Typical Uses of Fluoroelastomeric Coatings
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- V. Materials
- VI. Surface Preparation - Steel
 - A. Cleanliness and Surface Profile
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 - A. Surface Cleaning and Sweep Blasting
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 - A. Mixing, Thinning, Other Preparation Steps
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 - H. Successive Coats
- IX. Safety
- X. Post-Application Inspection
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I. SCOPE

This sub-chapter provides some general information on the properties of fluoroelastomeric coatings. It also provides a basic outline of the inspection procedures that can be used to ensure that these coatings are successfully applied. Throughout this sub-chapter, it is assumed that the substrates to be coated are essentially new structures that have not been in service. (Note: Further information relevant to inspection of fluoroelastomeric coatings can be found in Chapters 3, 4, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 4285, Practice for Surface Cleaning Concrete for Coating

ASTM D 5162 Practice for Discontinuity (Holiday) Testing of Non-Conductive Coating on Metallic Substrates

SSPC: The Society for Protective Coating (SSPC)

SSPC-SP 5, White Metal Blast Cleaning (NACE No. 1)

SSPC-PA 2, Measurement of Dry Coating Thickness with Magnetic Gages

FIGURE 5-28. Inside chimney coated with fluoroelastomer. Courtesy of Colebrand Ltd.



III. PROPERTIES AND TYPICAL USES OF FLUOROELASTOMERIC COATINGS

Fluoroelastomeric coatings are chemical-resistant coatings that can be formulated to withstand elevated temperatures and attack by acids and alkalis, hydrocarbons, solvents, gases, and other harsh industrial chemicals (Figure 5-28). They are generally two-part, catalyzed systems that cure at room temperature. Physical properties can be controlled by varying the amount of catalyst. They are commonly used as heat and acid-resistant linings in power station flues and duct work. They have also been used in tanks, sumps, ditches, hazardous waste dikes and immersion zones.

IV. ABOUT FLUOROELASTOMERS

Fluoroelastomeric coatings are among the most expensive and highest performance coating materials in present day use. Thus, the inspection of surface preparation, material mixing and application, and assessment of the applied film are of paramount importance. If a coating of this type must be removed because it is wrongly or badly applied, it can be a very costly and time consuming exercise.

Fluoroelastomeric coatings are generally used by themselves as the sole protection media. However certain combinations, such as with vinyl ester or novolac epoxy primers, have been used successfully. Laboratory testing

may be needed to assess the compatibility between fluoroelastomers and other proposed coating materials.

V. MATERIALS

Fluoroelastomeric coatings usually have two components. These may be labeled:

- Base and Hardener or
- Base and Activator or
- Base and Curing Agent or
- Components A and B

(Note: The base is the major component, i.e., the uncrosslinked fluoroelastomer resin.)

All materials should be inspected. Certain conditions to look out for are:

1. Viscosity outside specification limits
2. Gelation or gel particles
3. Crystallization
4. Settlement that cannot be resuspended

If there is any doubt about the condition of the materials, a batch should be mixed and application trials should be carried out. If the material is not easily applied in a satisfactory film, the condition should be corrected following the manufacturer's instructions, or the manufacturer should be contacted for further information.

Fluoroelastomeric materials should be stored in a restricted area and stored according to specified conditions. The preferred temperature storage range is 50- 85°F (10-29°C). Storage temperatures between 40-85°F (4-29°C) may be acceptable, but temperatures exceeding 85°F (29°C) should be avoided wherever possible.

VI. SURFACE PREPARATION - STEEL

A. CLEANLINESS AND SURFACE PROFILE

Manufacturer's instructions for surface preparation should always be followed. Usually, steel surfaces to receive fluoroelastomeric coatings require blast cleaning to a white metal finish, in accordance with SSPC-SP 5/NACE 1, and a profile of 4-5 mils (100-127 micrometers). Abrasives that

can be used to achieve this include grades 2 or 3 flint abrasive, or equivalent gage iron or steel grit. Following the procedures outlined in Chapter 4, the inspector should verify that the specified level of surface cleanliness and surface profile are achieved.

The inspector should verify that all personnel involved with blasting and inspection wear hand protection to avoid contaminating cleaned surfaces prior to first coat application.

B. INSPECTION OF WELDS

All welds should be inspected and repaired if necessary. If satisfactory, and blasting for a shift has finished, all dust should be removed using a vacuum brush. The first coat should be applied as soon as possible after vacuum cleaning.

VII. SURFACE PREPARATION - CONCRETE

A. SURFACE CLEANING AND SWEEP BLASTING

Manufacturer's instructions for surface preparation should always be followed. Usually, concrete surfaces to receive fluoroelastomeric coatings are required to be free of oil, grease, and other surface contaminants prior to abrasive cleaning. ASTM D 4258 describes several methods for surface cleaning of concrete. In addition, the concrete should be lightly sweep blasted to remove any laitance or other loosely adherent materials. Care should be taken not to use excessive pressure at the nozzle as this could cause gouging of the cementitious matrix exposing the aggregate.

B. TREATMENT OF SURFACE IRREGULARITIES

Bug holes and fissures within the substrate that cannot be coated effectively by the airless spray technique should be filled prior to the spraying operation, as agreed upon by the owner and the applicator. It is sometimes difficult to decide on the minimum size of the cavity to be filled. The extent of affected areas should be considered rather than individual cavity size.

Any proposed filler should be compatible with both the original concrete and the coating to be subsequently applied. Bearing this in mind, cementitious fillers can be used that are mixtures of high alumina cement and pulverized fly ash (mixed either 1:2 or 1:3 by weight with a water:cement ratio of 0.3 to 0.4:1).

Once the irregular surface has been filled to an acceptable level, it should be vacuum brushed to ensure the final standard of cleanliness.

VIII. COATING APPLICATION

A. MIXING, THINNING, OTHER PREPARATION STEPS

The inspector should ensure that the coating materials is mixed properly, according to the specification and the manufacturer's instructions. In general, the base should be agitated for two (2) minutes, by the use of a variable speed, compressed-air operated mixer supplying no more than 100 rpm, prior to adding the curing agent. Care should be taken to avoid air entrapment in the final mix. The curing agent is added to the base material, with a further two (2) minutes agitation.

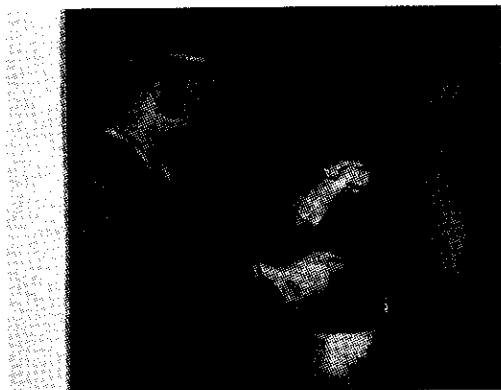
Care should be taken to prevent inclusion of foreign particles, oil or water into the mixed material. Temporary covers should be placed on all open containers until the time of use. Materials should not be mixed unless they can be applied within their pot lives.

If thinning is deemed necessary, the mixed material (not an individual component) should be thinned with the type and amount of thinner permitted in the job specification. The inspector should keep a complete record of mixing and thinning operations, including amounts of both base and curing agent, batch numbers and amount of thinner used.

B. BRUSH COATING OF WELDS

A brush coat is applied to the welds and edges before the first coat (Figure 5-29).

FIGURE 5-29. Brush coating welds. Courtesy of Colebrand Ltd.



C. SPECIAL APPLICATION EQUIPMENT

Generally speaking, most fluoroelastomeric coatings are applied by airless spray (Figure 5-30). Typical spray parameters are as follows:

Use a 3/8 inch (9.5 mm) minimum i.d. material line with an inline 60 mesh filter. Use a 0.023 - 0.027 inch (0.58-0.69 mm) reverse-a-clean tip with various fan sizes accommodate varying geometry. On large flat areas an 18 - 24 inch (46-61 cm) fan is recommended.

The equipment listed below has been found to be suitable. Equivalent equipment may be used as an alternative, if allowed by the specification.

TABLE 1. Suitable equipment for applying fluoroelastomeric coatings.

Manufacturer and Gun	Pump
De Vilbiss JGB-508	QFA-650
Graco 208-327	King 45:1
Binks model 620x2	B8-36

Teflon packings are recommended for the pump.

TABLE 2. Typical environmental limits for the application of fluoroelastomeric coatings.

	Material Temp.	Surface Temp.	Ambient Temp.
Normal	65-75°F (18-24°C)	70-80°F (21-27°C)	65-75°F (18-24°C)
Minimum	50°F (10°C)	50°F (10°C)	50°F (10°C)
Maximum	90°F (32°C)	100°F (38°C)	90°F (32°C)
Humidity			
Normal	50%		
Minimum	0%		
Maximum	85%		

D. APPLICATION TEMPERATURES

The inspector should verify that the correct application temperatures are maintained. Manufacturer's instructions should always be followed. In addition, material should not be applied when the surface temperature is less than 5°F (3°C) above the dew point. As a general guide, Table 2 lists typical environmental limits for the application of fluoroelastomeric coatings.

FIGURE 5-30. Spray application of a fluoroelastomeric coating. Courtesy of Colebrand, Ltd.



E. WET FILM MEASUREMENTS

Wet film thickness readings should be taken at a minimum frequency of at least once per 100 ft² (m²) depending on surface geometry. In areas of complicated geometry, three readings per 10 ft² (0.93 m²) are required. These measurements should be carried out immediately after the spraying operation, that is, before significant solvent evaporation has occurred.

F. SOLVENT ENTRAPMENT TEST

After each coat, a solvent entrapment test should be performed. An explosion proof heatlamp and a magnetic surface temperature thermometer are required to perform this test. The distance from the lamp to the substrate should be determined experimentally on a control sample prior to the inspection of the structure.

The solvent entrapment test involves raising the temperature of the coated surface to 120°C (250°F) over a period of approximately 10 minutes. If blisters appear, it means that the coating requires additional drying time. (Note: In the event that an application fails the solvent entrapment test, the blisters should be cut out and the area repaired.) If no blisters appear, the surface tested may be recoated.

G. DRYING AND CURING

The inspector should verify that the correct drying and curing times are maintained. Air flow should be sufficient to remove solvent vapors that evaporate from the coating as it dries. Manufacturer's instructions should always be followed. As a general guide, Table 3 lists typical drying and curing times for fluoroelastomeric coatings at different ambient temperatures.

H. SUCCESSIVE COATS

A brush coat is applied to the welds and edges immediately prior to spraying all subsequent coats. Any overspray and dust should be removed using abrasive cloth and a vacuum brush. Successive coats are applied to all low areas until the required dry film thickness has been achieved.

TABLE 3. Approximate drying times with proper ventilation.

	Between Coats	Final Cure
at 50°F (10°C)	32-48 hours	14 days
at 75°F (24°C)	16-24 hours	7 days
at 90°F (32°C)	10-12 hours	7 days

IX. SAFETY

The main hazards associated with spraying fluoroelastomeric coatings are:

- **Harmful solvent vapor.** All drums should be closed after use. A flow of air should be maintained through the workplace, to keep the level of solvent vapors down. Workers should wear the appropriate supplied air respirators as required by the specification. No eating, drinking, or smoking should be allowed in the workplace.
- **Fire.** Care must be taken to ensure that (1) there are no sources of ignition present in the workplace; (2) there is no danger of sparks from metal to metal contact; and (3) all potential sources of static discharge are grounded (i.e., the spray pump, metal containers, etc.).
- **Explosion.** The flow of air through the workplace should be sufficient to keep the level of solvent vapors at or below 10% of the Lower Explosive Limit (LEL).

X. POST-APPLICATION INSPECTION

A. DRY FILM THICKNESS

When the coating is sufficiently cured, a complete dry film thickness check should be carried out as specified (e.g., in accordance with SSPC-PA 2).

B. HOLIDAY TESTING

After full cure has been achieved, the whole coating system should be tested for continuity as required by the specification as described in ASTM D 5162 (Figure 5-31). For fluoroelastomeric coatings, this is typically done by using a high-voltage spark tester set at approximately 80 volts/mil thickness. A wire brush attachment may be used



FIGURE 5-31.
Holiday testing a
fluoroelastomeric
coating.
Courtesy of
Colebrand, Ltd.

Albert L. Hendricks - Wisconsin Protective Coatings
Corporation

Philip Lancello - Sentry Polymers, Inc.

BIOGRAPHICAL SKETCH

Ken Lowrey was formerly Technical Director of Colebrand, Ltd., London. Colebrand has been involved with the development, manufacture, and application of fluoroelastomeric coatings since 1973. Major contracts undertaken include the application of fluoroelastomeric linings to the flues at Drax Power Station (England), Bruce Mansfield Power Plant (Shippingport, PA), and Apache Power Plant (Cochise, AZ). Colebrand had also lined ductwork for U.S.A. Condensers in Norway, Germany, and South Wales.

to check the entire surface. Any defects produce a high pitched buzz from the spark tester.

Particular attention should be paid to areas of welds, angle brackets, and struts. Thin spots, or pin holes revealed by spark testing should be recorded and repaired as specified.

XI. SUMMARY

Fluoroelastomeric coatings are relatively costly, so their proper application is critical. These are generally two-component materials, thus the inspector should ensure that the components are properly mixed. He should also ensure that the application equipment is suitable for the job. The inspector also has the usual responsibilities for monitoring ambient conditions, surface preparation, coating application, time between coats, and dry film thickness. In addition, a solvent entrapment test should be performed on each coat. If required by the specification, the cured coating should be tested with a high-voltage spark tester.

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Chapter 5.7

High-Bake Phenolic and Epoxy Phenolic Coatings

by Albert L. Hendricks

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 - A. Baking
- IV. Inspection of Materials
- V. Surface Preparation Requirements
- VI. Coating Application
 - A. Mixing and Thinning
 - B. Application
- VII. Post-Application Inspection
 - A. Dry Film Thickness and Visual Inspection
 - B. Inspection of Baking
 - C. Holiday Testing
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I. SCOPE

This sub-chapter describes the unique properties, uses, and inspection requirements for high-bake phenolic and epoxy phenolic coatings. These coatings are applied by conventional techniques; however, they have some special inspection requirements because they must be baked in order to effect complete curing. (Note: Further information relevant to inspection of high-bake phenolic and epoxy phenolic coatings can be found in Chapters 3, 4, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

SSPC: The Society for Protective Coatings (SSPC)

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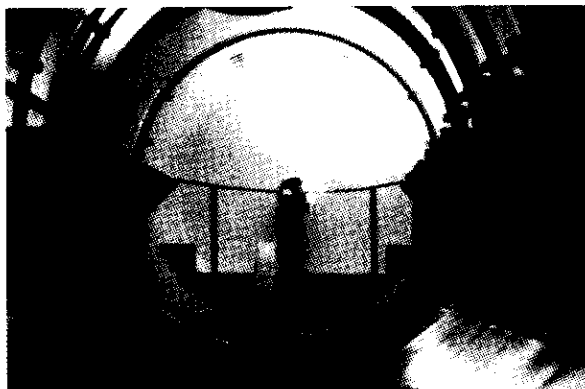
Jerry Truettner, "Baking Phenolics," Chapter 13, *Generic Coating Types*, L. Smith, Ed., Technology Publishing Company, Pittsburgh, PA, 1996 (SSPC 95-08).

III. PROPERTIES AND TYPICAL USES OF HIGH-BAKE PHENOLIC AND EPOXY PHENOLIC COATINGS

High-bake phenolic resins based upon the condensation reaction of phenol and formaldehyde are among the oldest synthetic resins used by the coatings industry. They are available in both unmodified compositions and in compositions modified with other resins, notably epoxy resins. Varying the composition significantly affects properties of the cured films, e.g., addition of epoxy resin improves the normally poor alkali resistance of high-bake phenolics.

Despite their relatively thin films (e.g., 4 to 8 mils (100 to 200 micrometers) applied in 2 to 5 coats), high-bake phenolic and epoxy phenolic coatings are hard and have good resistance to chemicals, solvent, and hot water. They are therefore used primarily as linings for vessels containing a variety of chemicals (Figure 5-32). They are also used extensively in the food and beverage industries, as well as for drum, pail, and pipe linings.

FIGURE 5-32. High pressure, high temperature chemical separator with baked phenolic lining. Courtesy of Tank Lining Corp.



A. BAKING

After the high-bake phenolic or epoxy phenolic coating is applied, the coated vessel must be baked. Recommendations of the coating supplier must be followed precisely. Smaller tanks are usually heated in an oven, while larger tanks require their exteriors to be insulated before their interiors are heated with a direct fire heater. Common heater fuels are natural gas and propane.

IV. INSPECTION OF MATERIALS

Because they are heat-activated, high-bake phenolic and epoxy phenolic coatings must be stored under conditions of controlled temperature. Their shelf life, typically six to twelve months, decreases significantly at higher temperatures.

The batch number and date of manufacture on each container should be recorded, and products that exceed the allowable shelf life should be removed from the jobsite. The inspector should also ensure that storage conditions meet specification requirements.

V. SURFACE PREPARATION REQUIREMENTS

All previously used vessels to be recoated with high-bake phenolic and epoxy phenolic systems should be preheated to a temperature 50°F (10°C) above the final-bake or operating temperature, whichever is higher. This helps remove surface contaminants that might adversely affect the new lining. Without this procedure, blistering may occur during the final curing.

The surface should then be abrasive blasted to the level of cleaning required by the specification. The inspector should verify that the required level is achieved. Procedures for inspection of surface preparation are given in Chapter 4.

It should be noted that pits on the cleaned surface may cause problems with these coatings, because they are applied in relatively low film thicknesses. If pits are present, it may be difficult to obtain a continuous lining.

VI. COATING APPLICATION

A. MIXING AND THINNING

High-bake phenolic and epoxy phenolic coatings are supplied as single-component solvent-based products. They require thorough mixing to redisperse pigment that has settled to the bottom of the container. The mixing equipment must be large enough to handle the operation and free of contaminants that would adversely affect the cured film. Any added thinner must be of the type and amount specified by the coating manufacturer. Insufficient thinning may result in blister formation during the intermediate or final bakes.

B. APPLICATION

The inspector should test the blasted surface with cellophane tape to ensure that all blasting debris has been removed prior to coating application. Welds and other irregular surfaces should be striped with coating, as described in SSPC-PA 1, before a full coat is applied to all surfaces, usually by conventional or airless spraying.

Wet film thickness measurements are usually taken periodically by the applicator to ensure that the desired dry film thickness in each coat is achieved. Otherwise, additional coats are necessary to achieve the specified total coating thickness.

VII. POST-APPLICATION INSPECTION

A. DRY FILM THICKNESS AND VISUAL INSPECTION

After drying of each coat, the inspector should measure the total dry film thickness using a magnetic gage, as described in SSPC-PA 2.

The inspector should also make a visual inspection for such surface defects as overspray, foreign particles in the film, pinholes, and blisters.

B. INSPECTION OF BAKING

After the coated vessel is inspected, it must be baked, first at an intermediate temperature (typically, between 180 and 250°F; 82-120°C) and then at a higher temperature (typically, between 350 and 450°F; 180-230°C). The inspector should monitor the temperatures using contact thermometers on the exterior. These thermometers should be widely distributed on the vessel exterior to ensure that all tank surfaces remain within the required temperature range during the curing period. There is no correlation between air temperatures in the tank and those on the tank itself.

During the baking process, the color of the lining undergoes a change (typically, from golden to a very dark reddish brown color). The inspector should use the color comparator supplied by the manufacturer to determine that all areas have been completely cured.

C. HOLIDAY TESTING

Most specifications require holiday testing with a low-voltage detector according to Test Method A of ASTM D 5162. Any holidays detected should be marked with a non-wax marker and repaired according to the manufacturer's recommendations. It is important to minimize defects in linings because they are difficult to repair.

VIII. SUMMARY

High-bake phenolic and epoxy phenolic coatings are used mostly for tank linings requiring special chemical, solvent, and/or heat resistance. They are heat activated. They must be baked to effect complete cure. The inspector is required to closely monitor the cleaning, application, and curing processes to ensure that a high-quality lining is obtained. In addition, because these coatings are heat-activated, the inspector must verify proper storage and handling temperatures.

After the coating is baked, proper curing is verified through the use of a color comparator. Holiday testing is usually required.

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The author and editors gratefully acknowledge the active participation of the following in the review process for this sub-chapter:

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Ronald R. Skabo - CH2M Hill
Lawrence J. Stanislow - Elf Atochem North America, Inc.

BIOGRAPHICAL SKETCH

A biographical sketch of Albert L. Hendricks appears at the end of Chapter 5.1.

Chapter 5.8

Powder Coatings

by Terry Brown

OUTLINE

- I. Scope
- II. References
- III. Properties and Typical Uses of Powder Coatings
 - A. Advantages and Limitations of Powder Coatings
- IV. Inspection of Materials
- V. Surface Preparation
- VI. Conversion Coatings
- VII. Coating Application
 - A. Equipment
 - B. Curing
 - C. Field Inspection of Coatings
- VIII. Post Application Inspection
- IX. Summary

I. SCOPE

This sub-chapter presents a brief description of powder coating materials. It also discusses the operations and items requiring inspection to ensure that quality applications are received. (Note: Further information relevant to inspection of powder coatings can be found in Chapter 6.2, and Chapters 3, 4, 7, and 8. Chapter 6.2 describes inspection of coatings on pipelines; Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 2794, Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

ASTM D 3359, Test Methods for Measuring Adhesion by Tape, Test Method A

ASTM D 3363, Test Method for Film Hardness by Pencil Test

ASTM D 4060, Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

NACE International (NACE)

NACE RP0188-90, Discontinuity (Holiday) Testing of Protective Coatings

SSPC: The Society for Protective Coatings (SSPC)

SSPC-PA 2, Measurement of Dry Paint Thickness with Magnetic Gages

III. PROPERTIES AND TYPICAL USES OF POWDER COATINGS

Powder coating films are obtained when finely pulverized plastic compositions (different than conventional coating resins) are applied to a metal or other surfaces and fused

together by heat. The powders used are of two distinct types: thermoplastics and thermosets.

Thermoplastics are high molecular weight products that melt, flow, and form a film without a change in their chemical compositions. Because they are difficult to grind, they are often applied in fluidized beds and used in thick films. Examples include polyethylene, polypropylene, nylon, polyvinyl chloride, and thermoplastic polyesters.

Thermosets are lower molecular weight polymers that cross-link during heat curing to form higher molecular weight products. They can be ground finer and thus be applied in thinner films (i.e., 1 to 3 mils (25 to 76 micrometers)). Examples include epoxies, acrylics, polyurethanes, and hybrids. Epoxy is the most commonly used type for corrosion protection, although it chalks on exposure to UV radiation. One type of product is the so-called fusion-bonded epoxy (FBE). There is a whole family of FBE coatings, each with very specific application and performance characteristics.

FBEs and other powder coatings provide a fully commercial method of obtaining tough, corrosion-resistant films. Their successful use, however, requires a thorough inspection of the various stages of this unique process. Uses of powder coatings include protection of appliances, outdoor furniture, farm implements/tractors, lamp housings, rebar, piping and building products.

A. ADVANTAGES AND LIMITATIONS OF POWDER COATINGS

Some of the advantages and limitations of powder coatings are listed below.

Advantages

- Hard, durable coating
- Many different chemical types
- Variety of properties/thicknesses available
- No VOCs released into atmosphere
- Low solid waste (99% of powder consumed)
- Ready to use (no mixing required)

Limitations

- Some processes restricted to shop application

- Limited to oven size
- Generally limited to metals and other non-heat sensitive substrates

IV. INSPECTION OF MATERIALS

The inspector should verify that the powder storage area is clean and dry with temperature maintained as recommended by the powder manufacturer. Powder identification and lot number should be recorded as the powder is added to the application system. Shelf life and storage conditions of materials should be determined and recorded.

Fresh powder and reclaim powder from any recovery system should be free of contaminants.

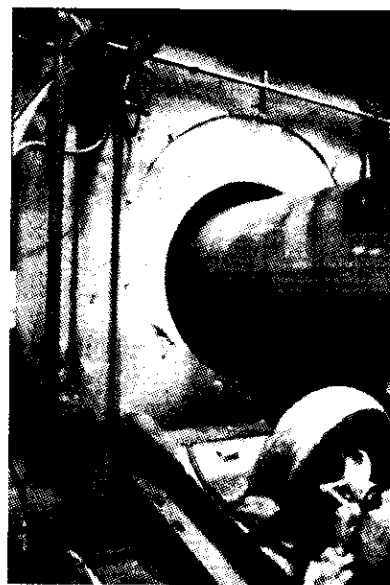
V. SURFACE PREPARATION

Whatever the surface preparation method, the inspector should verify that the required level of cleanliness and profile are achieved (Figure 5-33). Procedures for inspection of surface preparation are given in Chapter 4.

VI. CONVERSION COATINGS

Conversion coatings such as iron phosphate, zinc phosphate, and certain chromates can be used to promote adhe-

FIGURE 5-33. Automatic surface cleaning of a pipe prior to application of a powder coating. SSPC file photo.



sion of the powder coating and/or provide additional corrosion protection. The inspector may be required to monitor the application of conversion coatings prior to the application of the powder coating. Manufacturer's instructions should always be followed.

VII. COATING APPLICATION

A. EQUIPMENT

Powder coatings are applied by one of four methods: fluidized bed, electrostatic spray, hot flocking, and thermal spray. Each has its own advantages and limitations.

The fluidized bed method of application utilizes a porous membrane supported above the bottom of an open container to hold the powder. The powder is fluidized by a steady flow of clean, dry air through the plenum at the bottom of the container. A pre-heated item is immersed in the bed of fluidizing powder. The powder melts and clings to it. The coating may be completely fused/cured by this process or require further heating in an oven for complete fusing or curing.

The electrostatic spray method of application is more commonly used (Figure 5-34). This unit includes (1) a powder feeder unit, (2) an electrostatic powder spray gun, (3) an electrostatic voltage source, (4) a recovery unit for the powder that does not adhere to the metal, and (5) a ventilated spray booth. It is not necessary to pre-heat the item to be coated. Fusion/curing is accomplished by heating in an oven at a set temperature for a specific length of time for the particular powder (Figure 5-35). The parts being coated must be conductive and electrically grounded.

The hot flocking or hot spray method of application relies on a non-electrostatic spray of powder onto parts which have been preheated above the softening point of the powder. It is similar to the fluidized bed method, in that the powder melts and clings to the preheated parts. In some cases the coating is fused/cured by residual heat in the parts, while in others, a postheating step is required.

The thermal spray method of application is an alternative, relatively new technique that involves spraying plastic powder through an acetylene or propane flame to melt it. This allows it to flow freely on the prewarmed substrate to which it is applied. The cooled material forms a continu-

FIGURE 5-34. Electrostatic spray application of a powder coating. SSPC file photo.

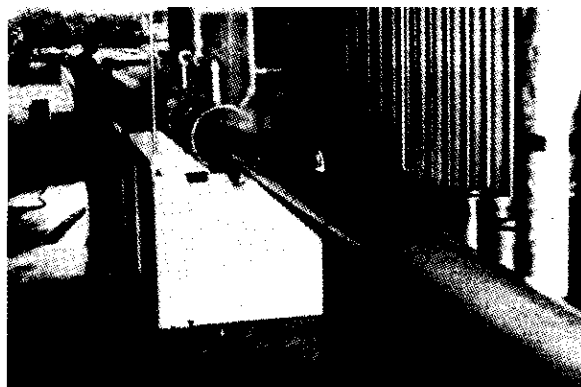
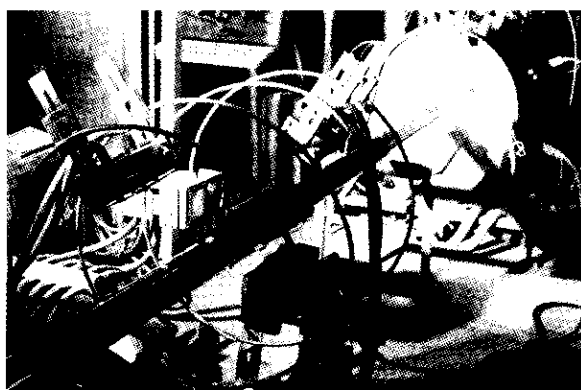


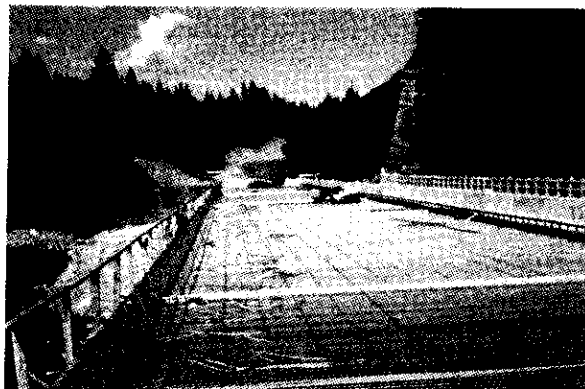
FIGURE 5-35. Post heating of a pipe coated with a powdered epoxy resin applied by electrostatic deposition. Courtesy of Bredero Price Co.



ous film of about 10 to 20 mils (250 to 500 micrometers) dry film thickness. Typical mechanical substrate preparation has been utilized during the development of this technology. Application procedures are currently specified by the equipment and powder coating manufacturers. This method is suitable for thermoplastic powders only.

Coating application equipment should be maintained as recommended by the equipment manufacturer. The type

FIGURE 5-36. FBE-coated reinforcing steel. Courtesy of S.G. Pinney & Associates, Inc.



and configuration of the application system should be recorded. Appropriate equipment settings should be verified and recorded per the job specification. If there is a powder application air supply, it should be inspected for appropriate oil and water traps, and the air drying system should be verified as functional.

B. CURING

The cure schedule specified by the manufacturer of the powder coating should be verified by the inspector. This includes dwell time, substrate description, oven temperature and part (substrate) temperature.

C. FIELD INSPECTION OF COATINGS

Items such as rebar and piping should be checked in the field for coating damage during transportation and installation (Figure 5-36). Any damage found should be repaired as specified.

VIII. POST-APPLICATION INSPECTION

The cured product may be inspected for:

- General appearance (color, gloss, texture, etc.)
- Film thickness - SSPC-PA 2
- Film adhesion - ASTM D 3359
- Holidays in film - NACE RP0188-90

- Hardness - ASTM D 3363
- Impact strength - ASTM D 2794
- Abrasion resistance - ASTM D 4060

IX. SUMMARY

Powder coatings are finely pulverized thermoplastics and thermosets applied to a metal surface and fused together by heat. The thermoplastics do not undergo chemical change during curing. The thermosets crosslink during heat curing to form higher molecular weight products. Powder coatings are ready-to-use, have a high transfer/recycle efficiency, and do not release VOCs.

There are four methods of applying powder coatings: the fluidized bed method, the electrostatic spray method (the one most commonly used), the hot flocking (hot spray) method, and the thermal spray method. In addition to the normal inspection requirements, the coating inspector must verify the cleanliness and proper operation of the application equipment being used. He must also verify the operation of ovens used for preheating, fusing, and curing.

Besides visual inspection, film thickness, and holiday testing, there are several other types of tests that may be required for powder coatings.

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Ronald R. Skabo - CH2M Hill

Chapter 5.9

Natural and Synthetic Rubber Linings

by John R. Lee

OUTLINE

- I. Scope
- II. References
- III. Properties and Typical Uses of Natural and Synthetic Rubber Linings
- IV. Inspection of Materials
 - A. Thickness
- V. Surface Preparation
- VI. Application of Primer and Cement
- VII. Inspection of Rubber Lining Before Cure
 - A. Visual
 - B. High Voltage Holiday Testing
 - C. Repairs
 - D. Curing
- VIII. Safety
- IX. Inspection of Rubber Lining After Cure
 - A. Visual
 - B. Holiday Testing
 - C. Hardness Testing
 - D. Adhesion
 - E. Repairs
- X. Summary

I. SCOPE

This sub-chapter covers recommended procedures for inspecting and testing prefabricated natural and synthetic rubber linings for steel tanks before and after cure. (Note: Further information relevant to inspection of natural and synthetic rubber linings can be found in Chapters 3, 4, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 413, Test Methods for Rubber Property - Adhesion to Flexible Substrate

ASTM D 429, Test Methods for Rubber Property - Adhesion to Rigid Substrates, Method D or E

ASTM D 2240, Test Method for Rubber Property - Durometer Hardness

ASTM D 3486, Practice for Installation of Vulcanizable Rubber Tank Lining and Pipe Linings (discontinued, 1994)

ASTM D 5162, Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metallic Substrate

SSPC: The Society for Protective Coatings (SSPC)

SSPC-SP 1, Solvent Cleaning

SSPC-SP 5, White Metal Blast Cleaning (NACE No. 1)

III. PROPERTIES AND TYPICAL USES OF NATURAL AND SYNTHETIC RUBBER LININGS

Natural and synthetic rubber linings are used in such industries as steel, chemical, paper, plating, mining, agricultural, and power. The physical properties of these linings allow them to protect steel from erosion, corrosion, abrasion, and chemical attack. These linings are applied to various types of equipment such as flue gas desulfurization systems, tanks, pipe, fittings, railway tank cars, truck tanks, rolls, and pulleys (Figure 5-37).

IV. INSPECTION OF MATERIALS

A. THICKNESS

The inspector should verify that the thickness and type of lining are as specified. The thickness can be measured with calipers. Prefabricated natural and synthetic rubber linings are typically 1/8 inch (3.2 mm), 3/16 inch (4.8 mm), or 1/4 inch (6.4 mm) thick.

V. SURFACE PREPARATION

The inspector should verify that the specified level of surface preparation is attained. General procedures for inspection of surface preparation are given in Chapter 4. When inspecting surfaces to be lined with rubber, the inspector should verify that:

- All metal surfaces to be lined conform to specifications and drawings.
- All joints over which lining is to be applied are continuous, solid welds. All welds must be smooth with no porosity, pinholes, high spots, lumps, or pockets. All sharp corners or edges should be ground to a minimum radius of 1/8 inch (3.2 mm) (Figure 5-38).
- All metal surfaces to be abrasive blasted are free from oil, grease, and chemicals. The surfaces should be cleaned in accordance with SSPC-SP 1.

- Compressed air used for abrasive blast cleaning is kept free of oil and water contamination. Inspector should check for properly functioning water trap or dryer.
- Blasting is done only when the metal substrate temperature is 5°F (3°C) or more above the dew point. Blasting should not be done under conditions of high

FIGURE 5-37. Top - Rubber lined structure at a power station. Courtesy of KTA-Tator Inc. Bottom - Rubber lined mixing tank. Courtesy of Blair Rubber Company.

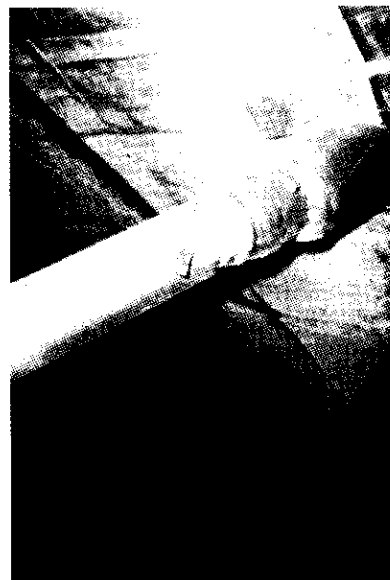


FIGURE 5-38. Grinding of welds. Courtesy of Colebrand, Ltd.



humidity. The inspector should check the ambient conditions for conformance with the job specification requirements.

- All metal surfaces to be lined are abrasive blast cleaned in accordance with the specification. For surfaces to be lined with rubber, White Metal Blast Cleaning (SSPC-SP 5) and a 2-4 mil (50-100 micrometer) profile are normally specified. The blasted metal should be free from all rust, mill scale, and any other foreign matter.
- After blast cleaning, sand and/or grit particles are removed by brushing, vacuuming or blowing with filtered compressed air.

VI. APPLICATION OF PRIMER AND CEMENT

The inspector should ensure that there is no sweating of the metal surfaces to be primed and cemented. For rubber linings, this is critical. To prevent condensation, the metal substrate should be a minimum of 5°F (3°C) above the dew point.

The inspector should verify that primer and cement are applied as specified, and following the manufacturer's instructions. In addition, the inspector should ensure that cemented surfaces are not exposed to direct sunlight and/or weather. If necessary, surfaces can be protected by covering with plastic while outdoors.

VII. INSPECTION OF RUBBER LINING BEFORE CURE

Before application of the lining and again before curing, areas to be lined should be checked against blueprints, sketches or any other special instructions to determine that they conform to the specification. The inspector should also monitor the installation of the rubber lining.

A. VISUAL

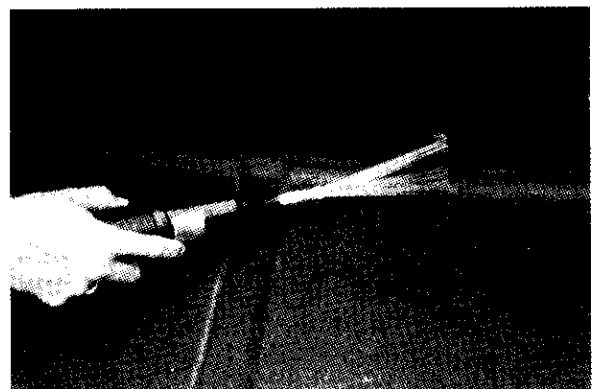
Once the rubber lining is installed, inspector should make a thorough visual inspection of it. Items to look for are surface imperfections, blisters, entrapped air, poor adhesion and loose seams.

B. HIGH VOLTAGE HOLIDAY TESTING (ASTM D 5162)

The lining should be inspected for continuity by spark testing all lined surfaces (Figure 5-39). The spark tester should be properly calibrated and operated according to the manufacturer's instructions.

1. Testing Equipment - There are various models of high frequency generators used for spark testing rubber lining. The one most commonly used has a tesla coil added to the circuit. Generally a tester that produces a spark with a

FIGURE 5-39. Holiday testing of a rubber lining. Courtesy of RJF International Corporation.



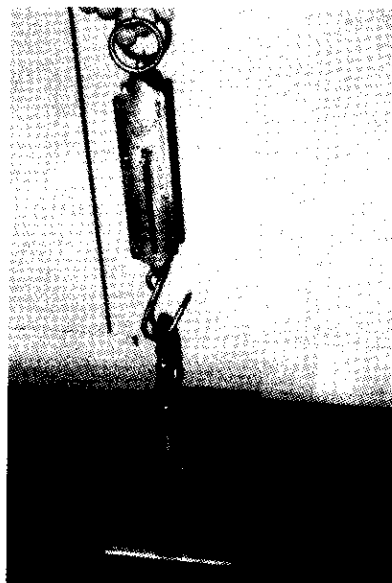


FIGURE 5-40. Adhesive pull test. Courtesy of RJF International Corporation.

magnitude of 0.04 inches (1 mm) at 1700 volts (measured in air) is acceptable. The spark length needed depends on the thickness of the lining to be tested. Some model of testers have adjustable gap assemblies that simulate the required spark gap. For further information on spark testing (high voltage holiday testing), see Chapter 8.

2. Testing Procedures - No moisture should be present at the time of spark testing and all surfaces should be free of dirt, grit and foreign matter. After the tester has been calibrated, the lining should be tested by passing the tester probe over it in an uninterrupted constant stroke. The probe should be kept in light contact with the lining, moving back and forth at the rate of 1 foot per second (0.3 meters/second). Strokes should be overlapped so that no surface is missed. In order to prevent dielectric breakdown of the rubber lining, excessive voltage should not be used. All faults or pinholes detected should be marked for repair.

C. REPAIRS

If any repairs are required, they should be made before curing using the same lining material. In general, repairs are made using the same application technique and the same overlap as for the original lining. However, the rubber manufacturer's recommended procedures should always be followed when making repairs, since there are

various types of rubber linings that require a specific repair method.

D. CURING

The lining then should be cured in accordance with the rubber manufacturer's recommended procedures.

VIII. SAFETY

The application of natural and synthetic rubber linings can involve hazards such as oxygen deficiency, toxicity, fire, and explosion. Safety precautions adequate to avoid these hazards must be observed at all times. MSDSs, safety instructions, and warnings for the use of materials and equipment should be consulted and followed (see Chapter 7). Elastomeric materials such as rubber may present a severe respiratory hazard when they undergo thermal decomposition, such as occurs in emergency conditions involving fire or explosion. To protect against such hazards, the appropriate NIOSH-approved respirator should be worn.

IX. INSPECTION OF RUBBER LINING AFTER CURE

A. VISUAL

Upon completion of the recommended cure, the lining should be given another complete visual inspection for imperfections such as blisters, poor adhesion, loose laps and feather edges. The lining should also be checked for proper overlap. Normally, a 2 inch (5 cm) minimum overlap is acceptable.

B. HOLIDAY TESTING

Upon completion of the recommended cure, the lining should be spark tested again as outlined above.

C. HARDNESS TESTING

After the cured lining has cooled, the hardness should be checked with a Shore "A" or Shore "D" Durometer. Hardness indicates the state of cure of the lining. A Shore "A" Durometer should be used for soft rubber linings and Shore "D" for hard rubber linings. Standard test method, ASTM D 2240 is applicable.

The temperature of the lining during durometer readings is very important, and should be recorded. The lining should be tested when it is at ambient temperature, preferably in the range of $72^{\circ} \pm 5^{\circ}\text{F}$ ($22^{\circ} \pm 3^{\circ}\text{C}$).

Durometer readings should be made at representative locations throughout the lined surfaces, approximately one in every 100 square feet. Testing should be avoided on uneven, irregular and rough surfaces. Also, some linings and configurations do not lend themselves to be tested for hardness. In this situation it is acceptable to use test plates. These test plates must be prepared in the same way as the primary lined surface. They should also be located in such a manner as to simulate the same environmental conditions as the primary lined surface.

When making a durometer reading, the pressure on the durometer should be enough to insure a firm contact between the flat bottom of the durometer and the lined surfaces. The durometer readings are recorded one second after the flat bottom of the durometer is pressed on the lined surface. After obtaining the initial one second hardness reading, the durometer needle may slowly recede, especially on soft rubber linings. In this situation the initial reading should be recorded along with a ten second reading.

The inspector should verify that all hardnesses are in accordance with the specification and the manufacturer's instructions. If readings are taken at other than ambient temperature, then the readings along with the temperatures should be recorded.

D. ADHESION

If test plates are prepared, and adhesion testing is specified, adhesion pull tests should be run on the plates only in accordance with ASTM D 413 and/or ASTM D 429, Method D or E (Figure 5-40).

E. REPAIRS

Any repairs required after cure should be made in accordance with the rubber manufacturer's recommended procedures. Repairs should be inspected and tested as required by the specification.

X. SUMMARY

Natural and synthetic rubber sheet linings can be applied to structural steel for a variety of uses. When such linings are installed, the inspector has the usual responsibilities for monitoring ambient conditions and surface preparation. He also must inspect the lining materials and monitor the application of primer and cement. If required by the specification, test plates should be prepared. Once the lining is installed, but before it cures, it should be visually inspected and spark tested. After curing, the lining should again be visually inspected and spark tested. In addition, the hardness should be tested with a durometer.

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Henry R. Stoner - Henry R. Stoner Associates, Inc.

Rufus F. Wint - Consultant

BIOGRAPHICAL SKETCH

John R. Lee is a Field Application Engineer for Polymeric Protective Linings, a Division of RJF International Corporation (formerly B.F. Goodrich Company). He has been in the protective lining business since the 1950s, serving in various capacities at The B.F. Goodrich Company and RJF International Corporation. His experience has included actual hands-on application of rubber linings; setting up and managing field jobs; estimating and quoting all types of rubber lining applications; and managing The B.F. Goodrich rubber manufacturing facility at Tuscaloosa, Alabama. He is still involved with all phase of protective linings, including sales, specification writing, making recommendations, inspections, and application of linings in the US and abroad.

Mr. Lee is a member of SSPC and NACE International. As a member of NACE, he has conducted lining and inspection seminars for local NACE chapters, as well as for many design engineering firms and end users of rubber lin-

ings. As a member of the Rubber Manufacturers Association, he served as Technical Committee Chairman of the Protective Linings Applicators Sub-Division.

Mr. Lee is a graduate of the University of Alabama at Tuscaloosa.

Chapter 5.10

Shotcrete

by Gregory D. Maloney

OUTLINE

- I. Scope
- II. References
- III. The "Art" of Shotcreting
- IV. Inspection of Materials
- V. Surface Preparation and Primer Application
- VI. Anchoring Systems
 - A. Wire Mesh
 - B. "T" Type Anchors
- VII. Shotcrete Installation
 - A. Ambient Conditions
 - B. Equipment Requirements
 - C. Predampening
 - D. Shotcreting Process
- VIII. Post-Installation Inspection
 - A. Cracking
 - B. Soundness
 - C. Hardness
- IX. Summary

I. SCOPE

This sub-chapter gives inspectors, engineers, and specifiers of materials a general overview of the shotcreting process. It should serve as a guide for inspectors to ensure proper techniques and procedures. It covers preliminary inspection; inspection of surface preparation, anchoring, and installation; and final inspection. (Note: Further infor-

mation relevant to inspection of shotcrete can be found in Chapters 3, 4, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM C 805 Test Method for Rebound Number of Hardened Concrete

ASTM C 1140 Practice for Preparing and Testing Specimens from Shotcrete Test Panels

American Welding Society (AWS)

AWS/ANSI D1.1 Structural Welding Code, Steel

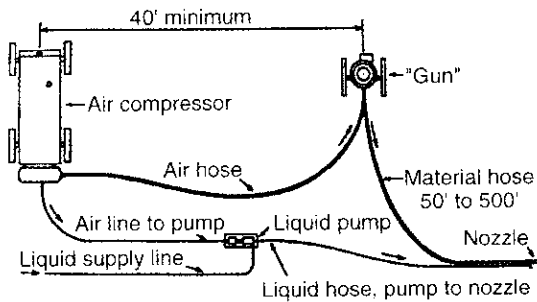
SSPC: The Society for Protective Coatings (SSPC)

SSPC Surface Preparation Specifications

III. THE "ART" OF SHOTCRETING

Shotcreting, also commonly called "guniting," is the pneumatic application of mortar or concrete at a high velocity. It offers a rapid, economical way to apply inorganic protective linings; however, shotcreting is not a simple matter of picking up the shotcrete nozzle, turning on the machine and spraying. The art of shotcreting requires using the proper equipment, specially formulated materials, the

FIGURE 5-41. Schematic of set-up of shotcrete rig with compressor and other components. Courtesy of Sauereisen.



proper anchoring system and a well-trained crew. In addition, it cannot be overstated that individual materials have their own special characteristics, and communication with the material manufacturer must be established. The material manufacturer should be able to assist in establishing the requirements that are not already detailed in the job specification. This process will help to give all parties a better understanding of what is required for the application, and to eliminate any questions or confusion about the application before work begins.

The job specification should require that the members of the shotcrete crew demonstrate their ability to shotcrete before any material is applied to the work area. This prequalification can be accomplished by testing according to ASTM C 1140. The material manufacturer should be consulted as to the acceptability of this test method. Many manufacturers have their own methods and test for prequalification.

IV. INSPECTION OF MATERIALS

All materials should be stored in an environment recommended by their manufacturer, and the following steps should be taken to ensure the quality of the material:

1. The inspector should examine all materials to ensure that no damage has occurred during shipment or storage at the job site. Bags of material that are broken or

water stained, or pallets that are in disorder, should be suspect as to their quality.

2. The inspector should investigate if there are special precautions for handling or shipping of the raw materials. For example, if a liquid is being used that can be adversely affected by freezing, the inspector should ensure that the material was not damaged by freezing during shipment to the jobsite.

3. The inspector should check and record the date the material was manufactured, lot numbers, and expiration date, and verify that shelf life has not been exceeded.

V. SURFACE PREPARATION AND PRIMER APPLICATION

As required by the specification, the inspector should verify that any surface preparation, primer application, and membrane application meet the requirements of the job specification. General procedures for inspection of surface preparation are given in Chapter 4. Procedures for inspection of primers and various types of membranes are given in some of the other sub-chapters of this chapter. The inspector should also be completely familiar with the requirements and purposes of these systems.

VI. ANCHORING SYSTEMS

There are two major methods of securing a shotcreted material to a steel substrate: wire mesh and "T" type anchors. The choice of anchoring system is generally based on the temperature and the chemical and physical environment. Many material manufacturers recommend specific criteria and type of anchoring system for their materials. The manufacturer's recommendations for anchoring system should always be followed.

Before the anchoring system is installed, the inspector should verify that the steel surface is cleaned of any contaminants that could inhibit a good weld. The installation of the anchoring posts for the wire mesh or the "T" type anchors should precede abrasive blasting. Any weld spatter or other contamination caused by welding should be removed by the final surface preparation (after welding, before shotcreting).

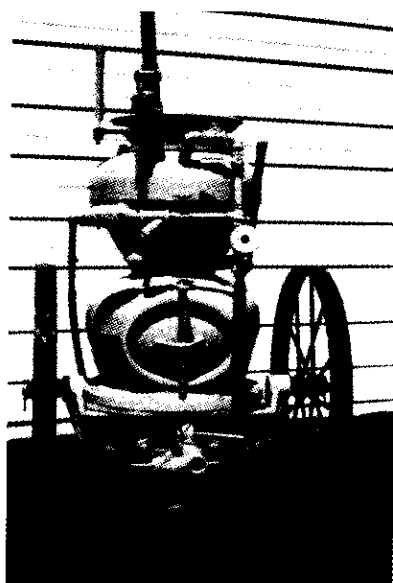


FIGURE 5-42.
Double chamber
shotcrete
machine.
Courtesy of
Sauereisen.

A. WIRE MESH

When inspecting a wire mesh type anchoring system, the following criteria should be met:

1. The anchoring posts for the wire mesh should be soundly attached to the steel substrate. Lightly striking the anchor post with a hammer can give an indication as to the strength of the weld. If the post bends or breaks at the weld, then it must be replaced. The weld joints should be inspected for full weld fillets per AWS specification (AWS/ANSI D1.1).
2. The distances between the anchoring posts should be measured to make certain they conform to the specified centerlines.
3. The wire mesh should be tied to the anchoring posts with wire that will not hinder the performance of the wire mesh or the shotcreted material, and be of sufficient strength to keep the wire mesh in place.
4. The sheets of wire mesh should overlap each other a minimum of three (3) squares.
5. The wire mesh, once placed, should be firmly and tautly secured to the anchoring posts and be taut. There should be no more than a 0.5 inch (1.3 cm) play in the wire mesh when pulled or pushed between anchor posts.

B. "T" TYPE ANCHORS

1. The "T" type anchors should be soundly attached to the steel substrate. Lightly striking the anchors with a hammer can give an indication as to the integrity of the weld. If the anchor bends or breaks at the weld, then it must be replaced. The weld joints should be inspected for full weld fillets per AWS specification (AWS/ANSI D1.1).
2. The distance between the anchors should be measured to make certain they conform to the specified centerlines.
3. The inspector should verify that the anchor pattern, tine direction, and height of the tine from the substrate conforms to the specification.

VII. SHOTCRETE INSTALLATION

A. AMBIENT CONDITIONS

To ensure proper installation and curing of the material, it is important to verify that ambient conditions conform to specification or manufacturer's requirements. Not only can these conditions adversely affect the application of shotcrete materials, but they can also impair the performance of the materials being applied.

B. EQUIPMENT REQUIREMENTS

The inspector should be completely familiar with the manufacturers' recommendations regarding application equipment for their materials (Figure 5-41). Each manufacturer may have unique equipment requirements to achieve the desired physical and chemical properties of their installed products.

1. Shotcrete Machines: There are two basic shotcrete machines available: the double chamber gun (Figure 5-42) and the rotary gun. Different jobsite conditions and materials may dictate which model should be used. The inspector should be sure the shotcrete machine is proper for the material and the job. The material manufacturer should be consulted to suggest the proper machine for its materials. The equipment should be clean of previously shotcreted materials, which may

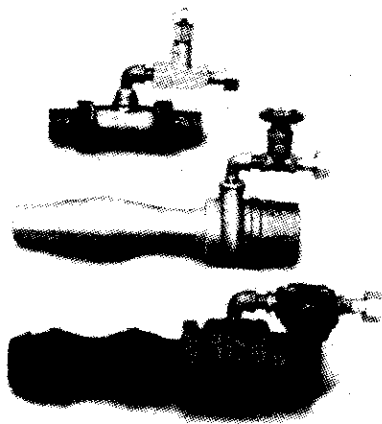


FIGURE 5-43.
Nozzles and
liquid bodies.
Courtesy of
Sauereisen.

restrict the flow or contaminate the materials to be shotcreted. The inspector should ask the applicator to operate the equipment to ensure its workability.

2. Liquid Transfer Pump: The liquid that will be mixed with the powder should be supplied to the shotcrete nozzle at a constant pressure. The inspector should verify that the applicator uses the pressure recommended by the materials' manufacturer. The liquid should be transferred by use of a liquid transfer pump, preferably one that is airless and is able to maintain a constant pressure through the pump cycle.

3. Air Compressors: The requirements on the size of the compressor are dictated by jobsite conditions, distance the material will be moved, the material, and the type of shotcrete machine. The material manufacturer should be consulted for its recommendations. The compressor should be inspected to ensure that it is working properly and is producing the pressure and volume (cfm) required.

Shotcrete materials are generally very susceptible to moisture, and compressors can generate large amounts of water. This water can infiltrate the air stream and eventually end up in the shotcrete equipment and material stream. The compressor should have a water trap or a dryer attached to the outlet to prevent the water from getting into the air line. It may also be advisable to have a water trap just before the air line enters the shotcrete machine.

4. Hoses: All hoses should be in good condition, free of worn spots, dry rot and other imperfections. Hoses should be clean and free of previously used materials. Material hoses must be designed specifically for use with shotcrete materials. Using another type of hose may cause problems.

Liquid hoses should be of a design and capacity to transport water or liquids long distances under high pressure. Use of any other type of hose, such as a garden hose, can cause losses of material, inconsistency in pressure at the nozzle, inconsistency in the shotcrete mixture, and can be a serious safety hazard.

The diameter of the hoses is dictated by the materials being shotcreted, the pressures being employed, and the experience and desire of the nozzleman. The material manufacturer should be consulted for his recommendations.

5. Nozzle Bodies: The nozzle body should be inspected to ensure that liquid passage is uninhibited. The liquid distribution device (the part of the nozzle body that controls liquid entry into the nozzle) should be in good condition, not clogged, and operating properly. Faulty liquid distribution devices must be repaired, cleaned, or replaced as required. The material manufacturer should be consulted for recommendations on the type of nozzle body to be used (Figure 5-43).

6. Nozzle Tips: The nozzles should be visually inspected to ensure there is no build-up of previously shotcreted material, which could inhibit the flow or contaminate the materials. They should be in good condition and not show signs of irregular wear. Nozzles with irregular wear patterns could cause problems in the mixing of the liquid and powder at this location.

7. Communication System: Coordination between the nozzleman and the shotcrete machine operator is one of the most critical factors in a shotcrete application. This is accomplished through good communication, using either hand signals (if the two parties are within sight of each other) or a two-way radio head set (if the two parties are not within sight of each other). This communication should be established before any work begins.

8. Thickness Controls: The thickness of installed shotcrete can be measured in several ways. The two best methods are to set screed strips or shooting guide wires. Another method often used is rodding the shotcrete, but it results in a permanent hole.

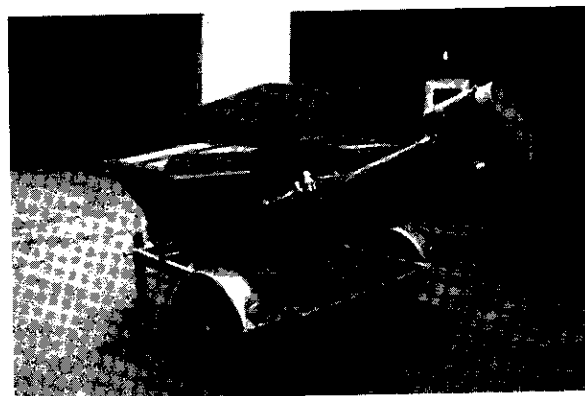
a) **Screed Strips:** A screed strip is a piece of material (such as wood or metal) that has been cut or fabricated to the thickness of the specified lining. It is positioned in a such a way that the nozzleman can judge the thickness of the lining as he is applying the material. If screed strips are employed, provisions must be made on the screed strips to ensure that rebound (shotcrete material that has not adhered to the surface) passes under them and is not entrapped. Also, it is suggested that an "alternate bay sequence" be used in applying the shotcreted materials. This means that 4 foot (1.2 meter) wide sections are shotcreted, leaving a space of approximately the same width between one section and the next section of work. After the alternate sections are installed, they are best allowed to cure before removing the screed strips and shotcreting the unfinished sections. Note: Using the alternate bay sequence creates more "cold joints" than applying the material in one continuous placement.

b) **Shooting Guides:** Shooting guides are made from a strong wire, such as piano wire. The guides are affixed to supports in the area to be shotcreted and the wire is set at the specified depth for the lining. Strong wire is needed, because it must be stretched very tight and there must be little or no play in it. The shooting guide must maintain its position under the high pressure and force of the shotcreting operation.

c) **Rodding:** Rodding involves prodding a measuring stick or piece of wire into the wet shotcrete in order to determine the thickness. This practice can be detrimental to many corrosion-resistant linings because the rod leaves a hole in the shotcrete that does not heal, and will act as an open path for corrosive media to reach the substrate. Also, if the specification calls for a membrane to be applied over the substrate before the application of the shotcrete, then this prodding may damage the membrane, defeating its intended purpose.

9. Blow Pipes: A blow pipe is an instrument used by the nozzleman assistant to remove any rebound that has been deposited in areas yet to be shotcreting. This piece of equipment is critical to avoiding the possibility of entrapping rebound.

FIGURE 5-44. Predampening machine. Courtesy of Sauereisen.



C. PREDAMPENING

Predampening incorporates a small amount of water or liquid into the dry powder before shotcreting. There are three purposes for predampening:

1. To reduce the amount of dusting as the material is placed into the shotcrete machine and as the material is dispensed from the nozzle.
2. To help reduce the amount of rebound during shotcreting.
3. To start the chemical activation of the material. The manufacturer should be consulted for any special requirements for activation.

Insufficient or excessive predampening of the powder has an adverse effect on shotcrete characteristics. (Note: For application of some materials, such as Portland cement, a larger amount of water is incorporated into the dry powder before shotcreting.)

One method of predampening involves the use of a predampening machine (Figure 5-44). This machine consists of a material feed chamber equipped with an auger to feed the material into an attached conveyer mechanism. The conveyer/auger mechanism is equipped with a water or liquid metering system and spray bar, which introduces the liquid into the dry powder, thoroughly mixes the components, and then transports the mixture directly to the hop-



FIGURE 5-45. Installation of shotcrete. Courtesy of Sauereisen.

per of the shotcrete machine. This method of predampening is efficient and does not take much manpower; however, the operator of the predampening machine must be skilled in its workings and must be able to coordinate the dry powder flow with the amount of liquid being dispensed.

Another method of predampening involves the use of a paddle-type mixer equipped with rubber-edged paddles and a water or liquid metering system. Exact amounts of powder and liquid are placed in the mixer, and they are mixed until they are well distributed. The materials are then transported to the shotcrete machine. This method takes less skill than the use of a predampening machine, but it is also more labor-intensive.

The inspector should be familiar with the predampening method to be used. He should ensure that all predampening equipment is clean, free of any contaminants, and in good working condition. The inspector should also ensure that:

- The method of transporting the predampened material is continuous.
- The material is not in danger of contamination during the process.
- Predampened materials are used within the time interval recommended by the manufacturer. Because pre-

dampening starts the chemical activation of the material, predampened materials that are not shotcreted within this time interval may start to prematurely set, and this can have an adverse effect on their characteristics and physical and chemical properties.

- Any predampened material older than this recommended length of time is discarded.

D. SHOTCRETING PROCESS

During the shotcreting process (Figure 5-45), the inspector should observe the following techniques and parameters:

1. Accessibility. Insofar as possible, the area to be shotcreted should be accessible to the nozzleman, with no obstruction that may inhibit his ability to apply the material using proper technique. The area where the nozzleman stands should be firm and secure so as not to affect the shotcrete pattern (for example, a swinging platform should be firmly secured to prevent any swaying).

2. Liquid Pattern. The nozzleman, when starting to shotcrete, should examine the liquid pattern produced by the liquid distribution device to ensure that it is producing the desired pattern. The nozzleman should then examine the liquid pattern produced with the air pressure adjusted as required.

3. Liquid/Powder Mix. Before any material is placed on the substrate to be shotcreted, the nozzleman should direct the nozzle into a waste area to adjust the liquid/powder mix. (If the material is too dry, the amount of liquid should be increased; if the outside of the material stream is wet but the inside is dry, the liquid pressure should be increased.)

4. Feed of Powder or Liquid. If any irregularity occurs in the feed of the powder or liquid during shotcreting, the nozzle should be directed away from the work area into a waste area. Should the stream of material from the nozzle suddenly become irregular, or the liquid fan become one-sided, work must be stopped and the situation corrected.

5. Nozzleman's Motions. The nozzleman should be positioned so that the nozzle is 3-4 feet (0.9-1.2 meters) from the area to be shotcreted. The nozzle should be directed at a 90 degree angle to the substrate. The nozzlemen should move the nozzle rhythmically in a series of overlapping, oval-shaped loops in order to apply the shotcrete evenly. The overlapping, oval-

shaped loops should be vertically 6 to 9 inches (15-23 centimeters) and horizontally 9 to 12 inches (23-30 centimeters).

The material should be deposited to the specified full thickness before the nozzleman moves on. This practice helps eliminate the possibility of trapping rebound, layering and laminations.

It is recommended the shotcrete work start at the bottom of the unit and proceed upwards. This procedure allows most rebound and overspray to be deposited on the surface of already shotcreted material and not areas yet to be shotcreted.

6. Nozzleman's Assistant. The nozzleman's assistant should precede the nozzleman, utilizing the blow pipe to remove any rebound or overspray that has been deposited on the surfaces yet to be shotcreted.

VIII. POST-INSTALLATION INSPECTION

The inspector should verify that proper drying and curing times are maintained. As they dry and cure, shotcreted materials tend to take a "skin set" first, that is, the surface layer hardens first. The skin should not be disturbed or broken. When the surface is cut or troweled, it is impossible to avoid microcracking. If the shotcrete liner is under thermal and physical stresses, the cracks can easily grow in size and depth. These microcracks are an easy pathway for the corrosive media to pass through the liner to the substrate. The material manufacturer should be consulted for specific recommendations. Finishing of shotcreted products is generally not a recommended practice.

The following procedures are suggested for a final inspection of a shotcreted liner before it is placed into service. They are non-destructive tests and are not intended to be totally comprehensive, but capable of detecting areas of concern or areas that need to be repaired. Repair procedures for these liners are also recommended. Note: In the final inspection of a shotcrete liner, it is assumed that the previous instructions in this section have been followed, i.e., that the shotcreted materials were verified to be those specified; that the surface was properly prepared and inspected; that the anchoring system was properly installed and aligned; and that a final cure schedule (if required) was completed properly as specified.

A. CRACKING

Shrinkage, high temperatures, and insufficient support of the substrate will cause stress cracks. The liner should be inspected for the formation of these cracks. Areas of high probability that should be closely inspected are cold joints, changes in planes, external stiffeners, and expansion joints. When cracks are more than 0.125 inch (3.18 mm) wide at the bottom, they generally require repair regardless of length (see sidebar, Part D, "Repair Method for Damaged or Aged Shotcrete").

If cracks are found, it is prudent to identify the cause of the crack before implementing the repair. In determining the cause, it may be necessary to institute appropriate precautionary measures to help eliminate the source of the cracking. These measures may reduce the chances of the cracks becoming more severe or other cracks appearing while the liner is in service.

B. SOUNDNESS

The shotcrete liner should be sounded by tapping lightly with a hammer. This process helps determine areas of non-continuity, such as delaminations, entrapped rebound, spalling or layering. A properly shotcreted material gives a solid uniform ring. Areas that are not continuous give a sound that is indistinct. This tapping method is also useful for determining loss of bond of materials to the substrate.

C. HARDNESS

The Schmidt hammer (ASTM C 805) can be used as a tool to determine the hardness of the liner; however, the accuracy of this tool can depend on the configuration of the liner and the type of material used. The material manufacturer should be consulted as to the effectiveness of this test for their material.

IX. SUMMARY

Shotcreting is a spray application method for inorganic coatings such as those containing cement. Although it is economical, it is not necessarily simple, requiring specialized equipment, specially formulated materials, the proper anchoring system, and a well-trained crew.

The anchoring systems for shotcreted linings consist of wire mesh or "T" type anchors welded to the steel surface. The anchoring system is installed prior to abrasive blasting. The inspector monitors the installation of the anchoring system, and verifies that it has been done properly and according to the specification. The inspector also has the usual responsibilities for monitoring ambient conditions and any final surface preparation.

The inspector should verify that all necessary equipment for the surface preparation and shotcreting process is clean and working properly. This includes shotcrete machines, the liquid transfer pump, air compressors, hoses, nozzles, thickness controls, and blow pipes. The inspector should also verify that a communication system is established between the nozzleman and the shotcrete machine operator.

Before a coating is shotcreted, the powder must be predampened. The inspector monitors this process, which may be accomplished through the use of a predampening machine or a specially-equipped paddle-type mixer. The inspector then monitors the shotcreting process. In the final inspection of a shotcrete liner, the inspector visually inspects the liner and looks for cracking. The liner may also be tested for soundness and hardness.

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Mr. Maloney is a member of SSPC, NACE International, the American Ceramic Society, and the American Chemical Society. He is the author of "Corrosion-Resistant Refractories used in Air Pollution Control Equipment" and "Chemical-Setting Ceramic Linings," chapters in Volume 13 of the Metals Handbook: Corrosion (ASM International).

Mr. Maloney received his Bachelor of Science degree in Chemistry from the University of Pittsburgh.

INSPECTION AND REPAIR OF AGED SHOTCRETE LININGS

A. INSPECTION SCHEDULE

Shotcreted linings should be inspected on a regular basis, and whenever unscheduled outages permit sufficient time to conduct such inspections. The following two schedules have been shown to be effective inspection periods.

Normal Service: 6, 18, 30, 42 months, and every two years thereafter. Defined as service conditions not involving abrasion, flexing, "oil-canning" (bowing of edges due to thermal expansion and contraction), potentially destructive environments, temperature fluctuations to thermal shock.

Severe Service: 6 months, 12 months and yearly thereafter. Defined as service conditions involving one or more of the conditions in the above paragraph.

The following are offered as suggestions of items to be checked in an inspection after the liner has been in service. There are non-destructive and destructive tests, the use of these tests should be judiciously chosen based upon the condition of the liner and information that is needed for the evaluation of the liner.

B. VISUAL OBSERVATIONS

1. Evidence of Chemical Attack: Characterized by an irregularly occurring softness of the shotcrete matrix, loose aggregate, flaking of surface, or delamination.

2. Thermal Spalling: Characterized by cracks parallel to air flow, or expanding reinforcement. Spalling may occur in hot spots (areas of high temperature due to the process).

3. Incomplete or Improper Dry-out of Lining: Characterized by delamination as spalls of the liner from itself. Hollowness of the liner that appears to be within the matrix of the material. Shear planing of the material from the reinforcement.

4. Cracks from Substrate-Induced Stresses: These cracks may be caused by oil-canning, flexing, bending, or severe thermal expansion. These cracks generally appear near external stiffeners, expansion joints, and changes in planes of the substrate. In the case of flexing or oil-canning, the cracking occurs first at the point of maximum deflection. Harmonics may also produce severe cracking.

5. Abrasion: Usually localized and well-defined; worn areas of the liner. Generally found in areas opposite inlets of the corrosive media. Areas of abrasion will be identified by worn

spots where some aggregate has been pulled out but the surrounding aggregate is still firmly bonded.

C. NON-DESTRUCTIVE TESTING

1. Soundness: Soundness of the lining may be tested by a few quick taps with a hammer, randomly done over accessible areas. Some loss of bond may be found but unless other problems are also present, these areas generally do not require repair.

D. DESTRUCTIVE TESTING

In evaluating the quality of the liner, destructive testing is done by core sampling. This procedure should be done judiciously. All areas where testing samples have been taken must be examined to ensure no harm has been done to the surrounding materials, such as any organic membrane that may have been applied under the shotcrete material. These areas must then be repaired. Repaired areas are non-continuous, and should be considered weak spots, due to the resulting cold joints.

The following, physical, and chemical tests should be completed on the core samples to determine the quality of the liner.

1. Uniformity: The liner is visually inspected for uniform distribution of aggregate throughout the thickness of the core. The sample should also be visually inspected for laminations, entrapped rebound, and evidence of chemical attack.

2. pH Readings: pH readings are made to determine if corrosive media have penetrated into the liner. The core section can be dry saw cut from the working face to the substrate surface to expose an inner cross section. Then the pH can be measured at different levels of the core. The acceptable pH ranges for the materials should be obtained from the manufacturer.

3. Petrographic Analysis: The material is systematically described based on visual inspection, microscopic examination, and testing. By describing the appearance and properties of the interspatial matrix, the effect of the corrosive media on the corrosion resistant material can be determined.

4. Compressive Strength: The sample can be tested to determine the physical strength of the liner.

5. Chemical Analysis: The sample can be analyzed by special analytical techniques to determine the chemical composition of the corrosion-resistant material.

E. REPAIR METHOD FOR DAMAGED OR AGED SHOTCRETE

1. Spalled areas that extend to within 0.5 inch (13 mm) of the substrate, regardless of size, should be repaired. The repair procedure is as follows:

- The entire spalled area should be cut out. Slight undercutting should be attempted at the edges.
- If a membrane has been used over the substrate, it should be inspected. If damage has occurred it should be repaired.
- Reinforcement should be reinstalled as needed.
- Repairs should be made with the appropriate material by troweling, casting, or shotcreting.

2. Chemically attacked areas should be repaired when less than 1 inch (25 mm) thickness of lining is left, or when it is anticipated that there will be less than 1 inch (25 mm) left at the next scheduled inspection. These areas should be cut out and repaired as described for spalled areas.

3. Abraded areas should be repaired when less than 1 inch (25 mm) of the lining thickness is left or when it is anticipated that there will be less than 1 inch (25 mm) left at the time of the next scheduled inspection. The repair procedure is the same as that for spalled areas.

4. Cracks may or may not require repair. The crack width should be measured when the lining temperature is between 60-90°F (16-32°C). When the crack is more than 0.125 inch (3.18 mm) wide at the bottom (substrate), it generally requires repair regardless of length. Cracks narrower than this are considered hairline and do not generally require repair. To repair a crack, it is first cut out along its full length to a width of at least 1 inch (25 mm). These areas are then repaired as described for spalled areas.

Chapter 5.11

Tapes

by Thomas Weber

OUTLINE

- I. Scope
- II. References
- III. Typical Uses of Tapes
- IV. Ensuring Proper Application of Tapes
- V. Materials
- VI. Surface Preparation
- VII. Coating Application
 - A. Special Application Equipment
 - B. Priming
 - C. Tape Application
- VIII. Post Application Inspection
 - A. Electrical Inspection
- IX. Summary

I. SCOPE

This sub-chapter describes procedures for the inspection of various types of tapes installed in the field. It includes plastic tapes, as well as petrolatum or petroleum wax impregnated tapes. Other types of tape coatings that are applied in the field to essentially completed pipelines for below ground or sub-sea services are discussed in Chapter 6.2, Pipelines.

II. REFERENCES

American Water Works Association (AWWA)

AWWA/ANSI C-209-90, Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines.

AWWA/ANSI C-217-90, Cold-Applied Petrolatum Tape and Petroleum Wax Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Buried Steel Water Pipelines.

NACE International (NACE)

NACE RP0375-94 Wax Coating Systems for Underground Piping Systems

III. TYPICAL USES OF TAPES

Tapes may be either thermoplastic or felt impregnated with petrolatum or petroleum wax (Figure 5-46). Thermoplastic tapes are applied both in the shop and in the field (see Chapter 6.2), whereas petrolatum or wax tapes are most frequently applied at the jobsite.

FIGURE 5-46. A petrolatum paste/tape system cut open for inspection. US Navy photo.



IV. ENSURING PROPER APPLICATION OF TAPES

As with any other coatings, the success of tape systems is dependent on application. The most common problem with tape application is improper overlapping. This problem may prevail in both the thermoplastic tapes and the petrolatum and petroleum wax impregnated varieties. The consequences of this in underground installations can be severe because water migrates inward at the overlap and eventually leads to entrapment of water underneath the tape. The tape can then act as a shield to cathodic protection, which accelerates the corrosion process and can create metal failure on the pipe.

One of the failure prone areas of tapes is in above ground areas, such as soil to air pipe transition zones. Before applying any tape above ground, the applicator should confirm that the product they are applying is specifically designed to use above ground where it will be exposed to ultraviolet light and weathering. Petrolatum and petroleum wax tapes, for example, are suitable for this application.

The above mentioned application problems can be eliminated through the using of experienced tape applicators. The application technique, although not difficult to learn (Figure 5-47), should be practiced by inexperienced applicators on non-essential or scrap piping to avoid inspection failures in actual installations.

V. MATERIALS

The inspector should inspect product packaging to ensure that there is no damage to the integrity of the materials.

VI. SURFACE PREPARATION

The inspector should verify that pipe surfaces are free from moisture (when using thermosetting tapes), mud, mill lacquer, paint, coal tar, asphalt, oil, grease or any other foreign material. Before any wire brushing or blast cleaning is done, the inspector should inspect surfaces for welding slag, spatter and scale, and verify that the pipe is cleaned according to SSPC-SP 1 for petrolatum and petroleum wax tapes and SSPC-SP 2 for plastic tapes. If present, metal surface imperfections should be removed by grinding or filing in order to avoid the puncture of the tape being applied.

VII. COATING APPLICATION

A. APPLICATION EQUIPMENT

The inspector should check all of the equipment to be used for application of the tape system to ensure that it is in working order. This includes tape wrapping machines, and other miscellaneous materials, such as wire brushes, abrasive blast equipment, brushes, and spray equipment.

FIGURE 5-47. Proper overlap in tape application. Courtesy of the Trenton Corporation.



FIGURE 5-48. Applying tape in the field. SSPC file photo.



B. PRIMING

The inspector should verify that primer is applied in accordance with the manufacturer's instructions. The inspector should visually inspect for uniform coverage of primer. In the case of petroleum wax or petrolatum primers, drying or curing of the primer does not occur.

C. TAPE APPLICATION

The inspector should verify that the application of tape follows immediately after priming in accordance with manufacturer's instructions. After application, the inspector should visually inspect the tape for damage or mis-application (Figure 5-48). This inspection should include checking for proper seal and width of the overlap, nicks or cuts on the outer film of the tape, excessive or severe wrinkling, or any other obvious mis-application. The inspector should ensure that any application deficiencies are corrected.

VIII. POST APPLICATION INSPECTION

A. ELECTRICAL INSPECTION

Because of their semi-solid nature, it may not be necessary or feasible to electrically inspect petrolatum and petroleum wax tapes; however, plastic tapes should always be inspected for continuity. The inspector should conduct the continuity test on the applied tape using the instrument

and procedure recommended by the supplier of the tape. Holidays should be marked with an appropriate marking crayon or chalk and should be repaired. AWWA/ANSI C-217-90 describes the recommended method for detection and repair of holidays in petrolatum and petroleum wax tapes.

IX. SUMMARY

Tapes require a specialized application technique and, sometimes, specialized application equipment. For this reason, application should be confined to contractors that are experienced with the specified product.

Special attention must be paid to proper overlapping and overlap sealing. Visual inspection and electrical inspection may be used to detect deficiencies in the application. When deficiencies are found, they must be corrected using the proper procedure recommended by the supplier.

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 Harold G. Clem, Jr. - Union Carbide Corporation
 Albert L. Hendricks - Wisconsin Protective Coatings Corporation
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Tom Weber is International and Western Regional Sales Manager for the Trenton Corporation. He has been involved in the marketing of coatings since 1984, with emphasis on coatings for underground corrosion protection.

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update of ANSI/AWWA C217-90 Cold Applied Petroleum and Petroleum Wax Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Buried Steel Water Pipelines.

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Chapter 5.12

Thermal Spray

Metallic Coatings for Steel

by Robert A. Sulit and Jack Blasingame

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I. SCOPE

This sub-chapter presents a brief description of thermal spray metallic coatings used for corrosion protection. Although these coatings may be applied to a variety of substrates, this sub-chapter is solely about their application to steel. Inspection requirements are summarized and industry and military standards are cited for amplifying information. (Note: Further information relevant to inspection of thermal spray metallic coatings can be found in

Chapters 3, 4, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American National Standards Institute (ANSI)

ANSI Z87.1 Practice for Occupational and Educational Eye and Face Protection

ANSI Z89.1 Personnel Protection - Protective Headwear for Industrial Workers

American Society for Testing and Materials (ASTM)

ASTM B 833, Specification for Zinc Wire for Thermal Spraying (Metallizing).

ASTM D 4541 Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

American Welding Society (AWS)

ANSI/AWS C2.18, Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum, Zinc, and Their Alloys and Composites

ANSI/AWS Z49.1, Safety in Welding and Cutting

TS-85 Thermal Spraying: Practice, Theory, and Application, American Welding Society, Miami, FL

British Standards Institution (BSI)

BS 5493 Code of Practice for Protective Coating of Iron and Steel Structures Against Corrosion

BS 2569 Sprayed Metal Coatings Part 1: Protection of Iron and Steel by Aluminum and Zinc Against Atmospheric Corrosion

Canadian Standards Association (CSA)

CSA G-189 Sprayed Metal Coatings for Atmospheric Corrosion Protection

Code of Federal Regulations (CFR)

29 CFR 1910.134 Respiratory Protection

European Committee for Standardization (CEN)

CEN EN 22063/ISO 2063, Metallic and Other Inorganic Coatings - Thermal Spraying - Zinc, Aluminum, and Their Alloys

Military Specifications

MIL-P-85856, Powder Materials for Flame and Plasma Sprayed Coatings

MIL-STD-2138A(SH), Metal Spray Coatings for Corrosion Protection Aboard Naval Surface Ships (Metric)

MIL-W-6712C, Metallizing Wire

National Fire Protection Association (NFPA)

NFPA 58, Standard for the Storage and Handling of Liquefied Petroleum Gases

SSPC: The Society for Protective Coatings (SSPC)

SSPC-AB 2 Mineral and Slag Abrasives

SSPC-PA 2 Measurement of Dry Coating Thickness with Magnetic Gages

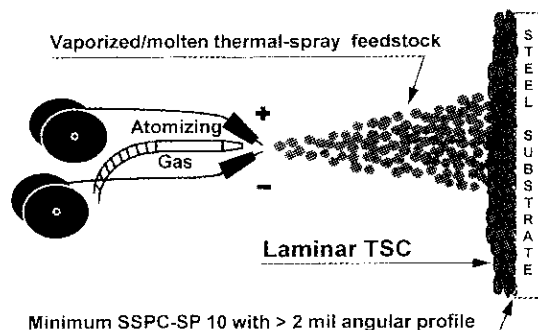
SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-CS Guide 23.00, Guide for Thermal Spray Metallic Coatings

III. PROPERTIES AND TYPICAL USES OF THERMAL SPRAY COATINGS

Thermal spray coatings (TSC) are produced by flame or electric heating of powder and wire feedstock materials and spraying the finely divided molten or semi-molten material on properly prepared substrates (Figure 5-49). The substrate must be prepared to at least near-white metal finish with a 2-4 mil (50-100 micrometers) angular profile.

FIGURE 5-49. Schematic for thermal spraying process.

White metal finish should be specified for critical components and for seawater service. The molten particles flatten, solidify, and interlock to form a laminar coating on the prepared substrate.

Aluminum, zinc, and their alloys, in wire form, are the metals normally used for arc and flame spraying TSCs on steel. TSCs emit no volatile organic compounds during application, need no drying time, and can be applied in low- and high-temperature environments.

The porosity of aluminum and zinc TSCs depends on the spraying parameters, typically ranging from 3-15% porosity. When applied in a non-through-porosity thickness (no interconnected path from the surface of the coating to the substrate), these TSCs provide both barrier and galvanic protection to the steel. When zinc is alloyed with aluminum, the zinc-rich spray material forms an effective corrosion-resistant coating, having the attributes of both elemental components. Zinc's greater electrochemical activity provides greater cathodic protection than aluminum. Aluminum, with its lower chemical activity and adherent oxide film, provides long-term protection at non-through porosity thickness and improved wear and abrasion resistance as compared to zinc. Aluminum, however, produces adequate cathodic protection in seawater immersion, and has been shown to be capable of protecting (through cathodic protection) up to 5% bare steel over long periods up to 30 years (see Bibliography).

A. SEALING/TOPCOATING

The natural texture of TSCs provide an excellent base for sealer and powder coatings. TSCs should normally be sealed except for service intended to expose the metal as anodes for cathodic protection.

Metallic TSCs may be sealed naturally by the oxidation (corrosion) products in the pores of the coating or by applying low viscosity sealer paint to fill the porosity. If a sealer paint is specified, it should be applied immediately after spraying before significant natural sealing occurs.

Paint-sealed TSCs should be topcoated only when: (1) the service environments is very acidic or alkaline, (2) the metal is subject to direct attack by specific chemicals, (3) a decorative finish is desired that can only be obtained with paint, or (4) additional abrasion resistance is required. The topcoat components should be compatible with the sealer and the substrate and the requirements for durability, maintenance, and resistance to the intended service environment. Note: Topcoating will be less effective, and is not recommended after natural sealing of the metallic TSC.

B. USES OF TSCs

Aluminum, zinc, and their alloys provide corrosion protection for steel and iron in a broad range of environmental conditions. TSCs are used extensively to provide corrosion protection in industries such as automotive, civil works, infrastructure, marine, paper and pulp, petroleum, and power generation.

Aluminum and zinc TSCs, when properly applied and inspected, will provide many years protection to first maintenance in industrial and marine environments. Sealed aluminum and zinc TSCs will give such protection in sea water immersion and splash zones. Aluminum TSCs sealed with an inorganic material will provide corrosion protection in high temperature environments up to 1000°F (540°C).

IV. QUALITY AND ACCEPTANCE ISSUES

The job specification should include the measurement criteria, instruments, method, and sampling schedule for the major job elements, such as surface preparation, TSC quality and thickness, sealing, and topcoating. In addition, a job reference standard, mutually agreeable to the owner

and the TSC applicator, may be prepared: (a) from a steel sample representative of the steel of the whole job (or job section), (b) using the actual field equipment and materials, and (c) using the method for surface preparation, thermal spraying, and quality control required by the job specification. The inspector should use the job reference standard to compare and resolve TSC quality and acceptance issues. If the specification does not include sufficient information to resolve quality and acceptance issues, the inspector should prepare such information himself and submit it to the owner to include in the specification.

V. CONSIDERATION OF DESIGN AND WORKING CONDITIONS

A. DESIGN

The inspector should recognize and note the limitations some design details impose on the coating and the coated products. The design should provide that all surfaces are fully accessible for surface preparation, for the subsequent removal of abrasive, and permit complete and uniform application of TSCs. Best results are obtained if the design permits spraying as close to normal to the surface as possible. The spraying angle should be less than 30 degrees normal to each surface. Unless special equipment is used, at least 12 in. (300 mm) are needed to provide access for the abrasive blasting hose and spray gun. Light gauge steel sheet, particularly in unsupported structures may require special attention to minimize distortion.

B. WORKING CONDITIONS

Grit blasting is a dust-producing operation that unless controlled may result in dust contamination. The following working conditions are essential to obtain clean surfaces for TSC application:

- Good ventilation
- Good quality abrasive - low dust and low breakdown properties
- Efficient removal of fines resulting from the breakdown of the grit
- Clean handling
- Shielding from other work in progress
- Covering of work in transit or awaiting spraying
- Clean stacking and storage

VI. INSPECTION OF MATERIALS

A. GRIT CLEANLINESS

Grit contaminated by oil and grease must be discarded. Such grit will contaminate freshly prepared surfaces and degrade coating adhesion. Prior to use of the grit blasting media for final anchor-tooth blasting or brush blasting, the inspector should:

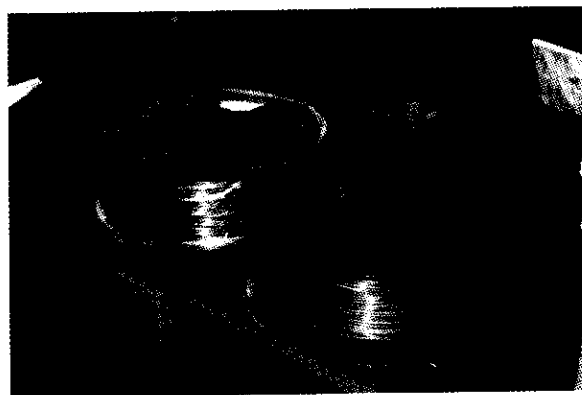
1. Visually inspect the surface for the absence of contamination and debris using 10X magnification.
2. Test for the absence of oil contamination using the procedure described in SSPC-AB 1. If any oil contamination is detected, the blasting media should not be used. Blasting equipment, especially the pot and hoses, should be cleaned prior to use, then the blasting media should be replaced and retested.

B. TSC FEEDSTOCK

The chemical and physical properties of the TSC feedstock should be in compliance with the job specification. Additionally, the feedstock should be inspected visually (Figure 5-50):

1. Wire feedstock should be clean, with a smooth finish that is free from slivers, depressions, scratches, scale, laps, and other foreign matter that would adversely affect wire feed. Thermal spray wire on spools and in coils (including reels and drums) should be wound so

FIGURE 5-50. Wire feedstock for thermal spraying.
Courtesy of Platt Brothers & Company.



that there are no kinks, waves, sharp bends, and overlapping or wedging wires, leaving the thermal spray wire to unwind without restriction. Note: A very small amount of lubricant, such as silicone spray, that will not degrade the deposited coating may be applied to the thermal spray wire to permit smooth and low-friction feeding through the thermal spray equipment.

2. Powder feedstock should be of uniform shape and color, clean, dry, non-packing, and free of contaminants. Note: Visual inspection for uniformity and contaminants should be conducted at magnification up to 40X.

TSC feedstock should be stored in accordance with the manufacturer's instructions.

VII. SURFACE PREPARATION

A. OIL OR GREASE

Oil or grease may be present on the surface of the steel, resulting from fabrication, handling, and/or transport. The substrate should be degreased as required to meet the SSPC 10/NACE 2 cleanliness standard. Large work may be degreased in a tank containing alkali or a clean solvent. Small areas may be hand-swabbed with a clean solvent. Alternatively, steam cleaning may be used.

The absence of oil and grease may be verified by visual inspection or by conducting a qualitative solvent evaporation test or heat test:

1. The solvent evaporation test is made by applying several drops or a small splash of residueless solvent such as trichloromethane, on areas suspected of oil or grease retention (e.g., pitting and crevice corrosion areas, depressed areas, especially those collecting contamination, etc.). The evaporating solvent will draw oil or grease contamination to the surface and appear as an oil sheen.
2. The heat test is made by using a torch to heat the degreased metal to approximately 225°F (107°C). Residual oil/grease contamination is drawn to the metal surface and is visually apparent. The surface temperature may be measured with a contact or infrared pyrometer.

Rejection of oil or grease-contaminated surface is subject to agreement. Remedial actions when a surface is contam-

inated with oil or grease may include degreasing, pretreatment or disposal of contaminated blasting media.

B. SHARP EDGES AND WELDING RESIDUES

Surfaces to be cleaned for TSC coating should be examined visually for sharp edges and welding residues such as weld spatter. Such defects may be the result of poor design or poor fabrication workmanship. Rejection of surfaces with sharp edges and welding residues is subject to agreement. Remedial actions may include radiusing edges and removing slag and weld spatter (or the specification may just allow for roughness). The specification should clearly describe the allowable defects which will affect the quality of the TSC.

Weld flux residues may cause local corrosion. They should be removed by detergent washing or by cleaning with a residueless solvent such as trichloromethane.

Weld spatter should preferably be removed mechanically. The inspector should note the position of any firmly adherent residual lumps so that the uneven coating at these locations after spraying is not confused with coating defects.

C. SURFACE PREPARATION EQUIPMENT

Filters and water traps in compressed air equipment should be drained, cleaned, and renewed regularly to prevent oil and water from reaching the grit blasting media through the air hoses.

D. AMBIENT CONDITIONS

A freshly abrasive-blasted steel surface may rust quickly (humidity over 70% promotes corrosion of steel). Unless in an environmentally controlled enclosure, no blasting should be done: (1) in bad weather, (2) when dew is on the steel, and (3) when humidity caused moisture to condense at the nozzle of the blast hose.

E. SURFACE PREPARATION REQUIREMENTS

The steel surfaces should be abrasive blast cleaned to at least near-white metal finish per SSPC-SP 10/NACE No. 2. Critical surfaces should be cleaned to white metal finish,

(SSPC-SP 5/NACE No. 1). A 16-24 mesh angular steel grit or 16-30 mesh aluminum oxide should be used. The inspector should pay particular attention to shaded areas (areas which cannot be blasted with a blasting angle $90^\circ \pm 30^\circ$ to the steel substrate at the proper nozzle-to-substrate distance). SSPC-Vis 1 should be used to verify the level of cleanliness. (Note: The specific surface preparation and thermal spray processes should always be validated on representative steel components or on the surface itself. Specific surface preparation and thermal spray processes can be developed and refined by repetitive test and evaluation leading to an acceptable coating structure (thickness, density, and surface texture) and tensile bond strength for the intended service. As described in Section IV, a job reference standard should be prepared and used by the inspector to resolve quality and acceptance issues.)

F. SURFACE PROFILE

For TSC application, the blasted surface is usually specified to have a 2-4 mil (50 - 100 micrometer) angular (not peened) profile. Profile tape and/or a depth gage micrometer should be used to determine the surface profile. (See Chapters 4 and 8 for further information on measuring profile.)

If the blasted surface profile depth is too smooth, it may be due to one or more of the following causes: (1) incorrect grit size/type, (2) worn or rounded grit, (3) inadequate removal of fines, (4) low air pressure, and (5) shaded or inaccessible areas. For a surface that is too smooth, the specification may call for rejection and require the following remedial actions: (1) changing grit and reblasting, (2) overhauling separators and dust extractors and reblasting, (3) increasing pressure and reblasting, and (4) giving special treatment to shaded and inaccessible areas.

If the blasted surface profile depth is too great, it may be due to using too large a grit size. In such cases, the specification may call for reblasting the surface with a smaller grit size/type. For aged, heavily corroded steel, the surface roughness will often exceed the 2-4 mil (50-100 micrometer) profile depth required for TSCs. This is not important, but the final TSC thickness must be at least two times the profile depth.

VIII. INSPECTION AFTER SURFACE PREPARATION AND BEFORE THERMAL SPRAYING

A. OIL, DIRT, WATER, OR RUST

After surface preparation and before thermal spraying, the surface should again be inspected visually for oil, dirt, water, or rust. Such surface contamination (which may result from poor working conditions, media contamination, or compressed air contamination), may be grounds for rejection, and the specification may call for remedial actions such as: (1) covering and protecting the work piece during transit and while spraying, (2) discarding contaminated grit and reblasting with clean grit, (3) cleaning or changing air filters and reblasting.

B. RESIDUAL RUST

A grit blasted steel surface with residual rust (due to inadequate blasting) should be rejected. The surface should be reblasted where necessary to remove this rust.

C. LOOSE FILM OR DUST ON GRIT-BLASTED SURFACE

A loose film or dust on the surface can be detected by visual inspection or by the tape test method described in Chapter 8. Dust or film may result from one or more of the following: (1) inadequate removal of fines, (2) inadequate ventilation, (3) dust settling from other blasting operations. The surface may be accepted if the dust is removed by air blow-down, brush down with a soft bristle brush, and/or vacuum cleaning.

IX. THERMAL SPRAYING

A. THERMAL-SPRAY EQUIPMENT SET-UP

The inspector should verify that equipment is set up per the manufacturer's instructions. The bend test should be used (see XI. C.) to confirm the equipment set-up and spray parameters prior to daily and crew change for production work. For good quality coatings, both hand-held and mechanized equipment should be adjusted per manufacturer's instructions. For hand-held spray guns, the operator's skill is especially important.

B. HOLDING PERIOD

The holding period between completion of surface preparation and completion of thermal spraying should not be more than 4 hrs. Shorter holding periods should be used for high humidity. Longer periods may be used in controlled humidity environments. A job site reference standard for surface condition should be used to confirm acceptable time intervals.

C. TSC APPLICATION PROCEDURE

Before TSC application begins, the inspector should measure surface temperature and verify that it conforms to the specification. For surfaces to be thermal sprayed, the surface temperature should be at least 10°F (6°C) above the dew point. As application proceeds, the inspector should observe the following (Figure 5-51):

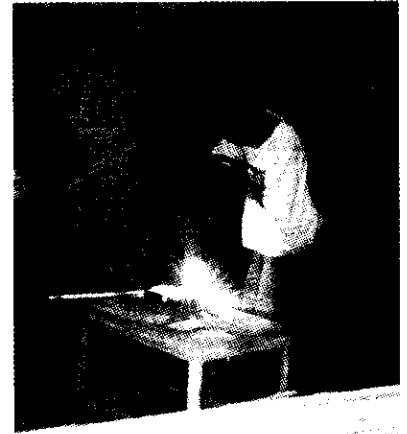
1. That 1 ft² (0.1 m²) of the initial area is preheated to remove residual non-visible moisture and to reduce the temperature differential between the sprayed metal and the substrate.
2. That the applicator sprays 2-3 mils (50-75 micrometers) per pass in crossing passes until reaching contract specified coating thickness. Note: For high humidity conditions, it may be necessary for the applicator to quickly apply a thin holding coat (1 mil (25 micrometer)) all over the surface, then build it up to the specified coating thickness.

X. HEALTH AND SAFETY

Personnel involved in thermal spray work face a number of potential health hazards. These include exposure to hot work, organic vapors, metal fumes, dust, excessive noise, infrared (IR) and ultraviolet (UV) radiation, and the danger of electrical shock (from thermal spray or other equipment and charged wire spools). In addition, with fuel and carrier gases being used, there is the potential for fire or explosion from improper use of the equipment.

The basic precautions for thermal spraying are described below. These are essentially the same as for welding and cutting. Further information on safety precautions can be found in Chapter 7 of this book and in the following sources:

FIGURE 5-51. Application of a thermal spray coating. Top - In the shop. Bottom - In the field. Both SSPC file photos.



- AWS Thermal Spraying: Practice, Theory, and Application, Chapter 11
- ANSI/AWS Z49., Safety in Welding and Cutting
- NFPA 58, Standard for the Storage and Handling of Liquefied Petroleum Gases.

A. VAPORS, DUSTS, AND FUMES

Paint sealers and solvents used for surface cleaning may have vapors that are harmful upon inhalation or skin contact. They should be used only with adequate ventilation or proper respiratory protection and other personal protective equipment. Material Safety Data Sheets (MSDSs) should be consulted for information on the hazards of the specific materials used.

Both grit blasting and thermal spraying generate dust and fumes that may pose a respiratory hazard. Appropriate personal respiratory protection should be worn during grit blasting and thermal spraying. Respirators should be those currently approved and certified by NIOSH and MSHA (29 CFR 1910.134). Personnel in or near blasting operations should also wear helmets, handshields, faceshields, or goggles conforming to ANSI Z87.1; eye protection conforming to ANSI Z89.1.

B. FIRE AND EXPLOSION HAZARDS

All welding, oxyfuel cutting and heating, and thermal spraying equipment should be kept 50 ft (15 m) away from solvents and flammable materials. In addition, all paper, wood, oily rags, cleaning solvents, sealers, and paints should be moved away from the thermal-spraying area. Solvents used for surface cleaning may be flammable. All solvent tanks should have lids and be covered when not in use.

Before opening any gas valve, it should be verified that the ventilation of the work area is adequate. All gas equipment should be examined regularly for leaks and loose connections, and defective parts should be replaced as necessary. Gas cylinders should be secured in place to keep them from falling. Gas cylinders in use should be kept away from the thermal spray operations so that molten spray or flame cannot reach them. (Alternatively, fire resistant shields may be used.) When not in use, gas should be shut off, with regulators removed and valve caps placed on the cylinders.

Thermal spray guns should be maintained in accordance with the manufacturer's instructions. The flame-wire guns should not be lit without wire in the nozzle as flames may shoot back into the gun causing operator injury and equipment damage. A friction lighter (never matches) should be used to light the flame gun.

Flame resistant clothing and leather or rubber gauntlets may be required during thermal spray operations to keep harmful flying particles and thermal spray materials from skin contact. Aluminized clothing may be used with the following precautions (1) that IR and UV radiation are not to be reflected on unprotected skin and (2) that there is no danger of electrical shock.

Airborne metal dusts, finely divided solids, or their accumulations should be treated as explosives. There should be adequate ventilation in the thermal spray work area and overspray should be collected to minimize the danger of dust explosions and fires. In shop environments, wet-, bag-, and filter-cartridge collectors may be used to collect the fine overspray particles, thus minimizing the explosion and fire hazard and release of controlled and hazardous materials. Bag- and filter-cartridge collector units should be kept at least 50 ft (15 m) away from the spraying area to preclude ignition from the flame or heat of thermal spray guns.

C. NOISE

Noise levels generated in thermal spray operations can cause fatigue and temporary or permanent loss of hearing. Properly fitted earplugs should be worn when thermal spray operators and personnel are in the immediate vicinity of flame and arc spray operations to reduce the high intensity noise levels to acceptable conditions.

D. RADIATION

Infrared (IR), visible, and ultraviolet (UV) radiation from the various thermal spray processes can cause eye and skin damage. When arc spraying, thermal spray operators and personnel viewing the thermal spray work should wear Shade 5 protection goggles or a face shield; when flame spraying, they should wear Shade 2-4 protective goggles (see ANSI Z87.1).

To protect personnel working outside the immediate thermal spray work area and personnel passing nearby, suitable opaque or arc-radiation protective screens should be used.

E. CLEAN-UP AND CONTAINMENT

Good housekeeping in the shop and field work areas should assure proper storage of hazardous materials and to

avoid accumulation of combustible materials and metal dusts. Particular attention should be given to dust on beams, rafters and booth tops, and in floor cracks.

Field work may require partial or complete containment of the work site for surface preparation and thermal spraying and the collection and safe disposal of the used blasting media and thermal spray overspray. If he has been given that responsibility by the job specification, the inspector should verify that all operations are in compliance with the owner's requirements and government agency requirements for air-quality and hazardous-materials control and disposal.

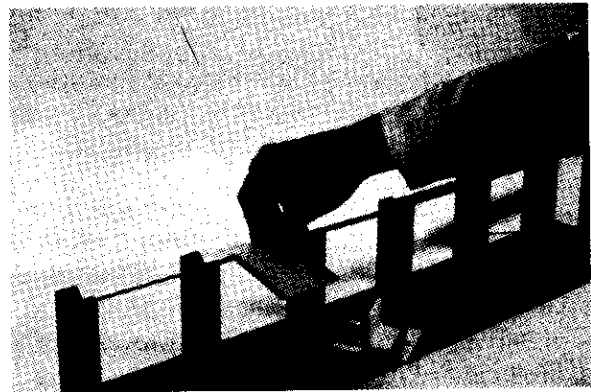
XI. POST-APPLICATION INSPECTION

A. VISUAL INSPECTION

The coated surfaces should be inspected visually and by touch (using clean gloves if it is to be subsequently painted). They should be smooth and uniform without blisters, cracks, or loose particles. Blisters and cracks decrease the effective coating thickness and laminar structure and expose the substrate. Loose particles decrease the effective coating thickness and laminar structure. Such defects may have the following causes: (a) improper equipment set up: gas pressure and flow rates, excessive wire feed, and/or incorrect air cap; (b) improper spray standoff, over 30-degree spray angle, and/or speed over surface. All of the above-mentioned defects are usually cause for rejection. The remedial actions that may be specified are: (a) Adjust equipment and validate with bend test and (b) spray as near to normal as possible.

The coated surfaces should also be examined for signs of oxidation or powdery deposits. On TSCs, oxidized, powdery, coarse, or generally lumpy areas will not provide the intended corrosion resistance and also may not have sufficient adhesion. These are detected when light scraping or wire brushing fails to produce a silvery surface. Possible causes of these defects are: a) Incorrect gas pressure and flow rates and b) Incorrect mesh analysis of powder feedstock. Surfaces found to have oxidation or powdery deposits should be rejected (although by prior agreement, isolated lumps may be tolerated or removed by sanding). Remedial actions may include changing powder or receiving or adjusting equipment, in each case validating results with the bend test.

FIGURE 5-52. Mandrel for bend testing. SSPC file photo.



B. TSC THICKNESS

The nominal TSC coating thickness should not be less than 4 mils (100 micrometers). Measure and record the TSC thickness per SSPC-PA 2. Take the average of 5 readings per measurement spot. Use an agreed upon dry film thickness gage. When TSC are manually applied, thickness uniformity depends largely on the skill and experience of the operator. For mechanized spraying, random measurements are sufficient. TSC thickness should also be measured and recorded in surface plane changes and around welded and bolted attachments.

If the coating is found to be too thin, it may be due to improper spray-gun manipulation. Areas in which the coating is too thin should receive additional spraying, provided the initial deposit is uncontaminated. It should be noted that rust staining from the underlying steel will readily occur when the TSC thickness is less than 1 mil (25 micrometer). Rust stains under TSCs will degrade adhesion and thus should never be permitted.

Improper spray-gun manipulation can also result in a coating that exceeds the specified thickness. The specification should state the required corrective actions for thicknesses outside the specified range.

C. ADHESION

The adhesion of TSCs depends primarily on the quality of the surface preparation immediately prior to spraying.

equipment spray parameters, and application method. Adhesion should be measured with a portable adhesion tester as described in ASTM D 4541.

A qualitative adhesion test is made with a coupon bend test, such as those described in ANSI/AWS C2.18-93, Section C.6.1 and MIL-STD-2138(SH), Section 5.3.3.2 (Figure 5-52). The coupon bend test is a ductility test that can be used for qualitative evaluation of the laminar coating structure of the TSC and its adhesion to the substrate. An approximately 2 in. x 6-8 in. x 0.050 in. (5 cm x 15-20 cm x 0.13 cm) steel coupon is cleaned, grit blasted, and thermal sprayed per specification equipment, materials, and method. It is then bent 180° around a 0.50 in. (1.3 cm) cylindrical mandrel. The specimen passes if there is no cracking or only minor cracking observed on the bend-radius. The specimen fails if the coating disbonds so that it can be picked off with a knife blade.

If the TSC does not meet the specified adhesion requirement, the inspector should recommend remedial action such as removing the coating and reblasting and reapplying.

XII. SEALING

1. The inspector should verify that sealing is done as soon as possible after thermal spraying using the specified material.
2. He should visually inspect for complete wetting and coverage during sealing.
3. Wet or dry film thickness gages cannot be used on the textured TSC. If required by the specification, the inspector should use a clean unprofiled companion coupon (clean steel coupon similarly painted alongside the production area painted) during sealing to measure the film thickness per SSPC-PA 2.

XIII. INTERMEDIATE/TOPCOAT THICKNESS

1. The inspector should verify that intermediate and topcoats are applied per the specification thickness requirement.
2. He should use a clean, unprofiled steel specimen during intermediate/top coating to validate the film thicknesses per SSPC-PA 2, if required by the specification.

XIV. INSPECTION AFTER STORAGE OR TRANSPORT

A. WHITE DEPOSITS

The natural oxides of aluminum and zinc are white and are normally adherent and protective, aluminum oxide being more adherent. Non-adherent and bulky white deposits of these oxides (wet storage stains or "white rust") often form when closely packed thermal spray coated articles become dampened or are poorly ventilated during storage and transit. Corrosion is accelerated by the retention of films of water between the contacting surfaces.

To prevent the formation of oxide deposits, thermal spray coated articles should be stored and shipped in dry, well-ventilated containers or in such a way that water runs off them. Dry separators should be used and the articles should be kept off the ground.

B. MECHANICALLY SCORED OR OTHERWISE DAMAGED COATING

Coated surfaces may become damaged during handling. Scored and damaged areas may be repaired by solvent cleaning to remove oil and grease; scraping, power tool cleaning, or grit blasting of the degraded TSC; respraying; and sealing/topcoating. Damaged areas should be touched up to the same thickness as adjacent areas. To prevent damage to coated articles, wrapped slings and wooden separators should be used.

XV. SUMMARY

Metals such as aluminum, zinc, and their alloys can be applied to steel structures by a thermal spray technique to provide corrosion protection. The resulting coatings (TSCs) have a proven record of (a) very long, greater than 20 year service life in severe industrial and marine environments and (b) toughness and resistance to handling, transport, and mechanical damage. They provide both barrier and cathodic protection to the steel. Although metallic TSCs may be sealed naturally by oxidation, low viscosity sealer paints are normally applied as soon as possible after TSC application. TSCs can also serve as a base for powder coatings.

The inspector of TSCs is required to monitor ambient conditions, surface preparation, and the thermal spraying process. Film thickness must be monitored throughout the thermal spray application process. The companion coupon bend test and the knife-peel test are used to confirm the adhesion and quality of the coating. The inspector must also monitor any specified sealing process.

The inspector should observe and validate that the surface preparation and TSC application thickness and quality requirements of the job specification are met. The inspector should use the job reference standard to compare and resolve TSC quality and acceptance issues.

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Tim Race - US Army Corps of Engineers, Construction Engineering Research Laboratories
Bob Unger - TAFA, Inc.

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Mr. Sulit is a member of AWS, NACE International, and SSPC. He is Chairman of several thermal spray committees: AWS A5U (Thermal Spray Feedstock Materials),

AWS C2F (Thermal Sprayer Training and Certification), ASTM B08.14, SSPC C.1.2.b, and ISO/TC 107/SC 5. He is also Past Chairman of AWS C2 Committee for Thermal Spraying (1990-1993).

He is also the author/coauthor over 100 technical papers and reports, and a book entitled "Principles of Radiation and Contamination Control." He received the Navy Commendation Medal in 1986 for advancing thermal spray technology for corrosion control in US Pacific Fleet; and a Federal Leadership Award in Information Technology in 1992. He also received the Civil Service Civilian Meritorious Award in 1968 for development of Navy nuclear warfare defense doctrine.

Mr. Sulit has a B.S. in Physics from the University of San Francisco. He also served in the US Naval Reserve, retiring as Captain in 1985.

BIOGRAPHICAL SKETCH

Jack Blasingame is President of Superior Shot Peening, Inc. Before this, he was executive vice president of F.W. Gartner Company, one of the largest thermal spray job shops in the United States. He has been associated with the thermal spray industry since the 1950s. His experience includes wire, powder, arc, and plasma spray processes.

Jack Blasingame is a member of SSPC, International Thermal Spray Association, NACE, IML, and the Coating Society of the Houston Area.

Chapter 5.13

Thermoplastic Sheet Linings

by Donald G. Reinert

OUTLINE

- I. Scope
- II. References
- III. Properties and Typical Uses of Thermoplastic Sheet Linings
- IV. Special Documentation Requirements
- V. Structure and General Site Inspection
- VI. Inspection of Materials and Equipment
 - A. Lining Materials
 - B. Adhesives
 - C. Welding Rod/Strap
 - D. Abrasive Blast Media
 - E. Storage and Handling of Materials
 - F. Equipment
- VII. Surface Preparation
 - A. Removal of Existing Linings and Coatings
 - B. Previously Unlined and Uncoated Surfaces
 - C. Abrasive Grit Blasting
- VIII. Coating Application
 - A. Temperature and Relative Humidity
 - B. Primers and Adhesives, Mixing and Application
 - C. Inspection During Lining Installation
 - D. Inspection During Welding
- IX. Post Application Inspection
 - A. Weld Inspection
 - B. Repairs
- X. Summary

I. SCOPE

This sub-chapter describes inspection procedures specific to thermoplastic sheet liners bonded to steel and concrete substrates. Procedures are outlined for inspection of all phases of the lining operation, from inspection of site conditions to final lining approval.

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 429 Test Methods for Rubber Property - Adhesion to Rigid Substrates

ASTM D 2471 Test Method for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins

ASTM D 2556 Test Method for Apparent Viscosity of Adhesives Having Shear-Rate Dependent Flow Properties

ASTM D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

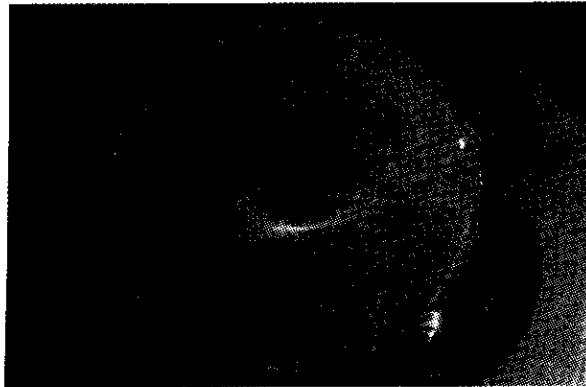
SSPC: The Society for Protective Coatings (SSPC)

SSPC-SP 1 Solvent Cleaning

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-Vis 1 Visual Standard for Abrasive Blast Cleaned Steel

FIGURE 5-53. A thermoplastic lining in use. Courtesy of Atlas Minerals & Chemicals, Inc.



III. PROPERTIES AND TYPICAL USES OF THERMOPLASTIC SHEET LININGS

Thermoplastic sheet liners applied to steel substrates typically have a bondable layer attached to the back of the sheet. This is necessary because the plastics themselves are not readily bondable to steel. The bonding layer may be a synthetic rubber, natural rubber, or fabric. Polyvinyl chloride (PVC) sheet liners are also available with a plasticized PVC backing that allows bonding to steel. Materials currently in use include polyethylene, polypropylene, polyvinyl chloride and fluorocarbon plastics such as polyvinylidene fluoride (PVDF), ethylene tetrafluoroethylene (ETFE), and ethylene chlorotrifluoroethylene (ECTFE).

Thermoplastic sheet linings can be used to protect concrete as well as steel structures (Figure 5-53). They are used in many industries, such as chemical, steel and metalworking, pharmaceutical, and power; pulp and paper; and food and beverage processing. They are typically used to protect substrates from aggressive chemical attack and abrasion.

Most thermoplastic sheet linings have a temperature limitation (e.g., 180°F, 82°C for a typical PVC laminated sheet lining) above which embrittlement and cracking of the lining occurs. In some cases, where further protection is needed, thermoplastic sheet linings are used in conjunction with chemical-resistant masonry sheathings (see Chapter 5.2). The masonry sheathing provides extra ther-

mal insulation, allowing for higher solution temperatures without exceeding the temperature limitation of the lining. The masonry sheathing also provides additional abrasion resistance.

IV. SPECIAL DOCUMENTATION REQUIREMENTS

The results of the inspection should be documented according to the general procedures given in Chapter 3. In addition, it is recommended that:

- Any rejections made by the owner or an authorized inspector be specific in reason for rejection and be accompanied by recommended corrective action or other means of resolution.
- All lining installation inspection items designated in this section are recorded on appropriate forms or in log books and cross-referenced where applicable to locations on the job drawings.

V. STRUCTURE AND GENERAL SITE INSPECTION

Prior to the lining installation, the inspector should review the blueprints and design drawings to assure that all dimensions of the structure are as specified. All inlets, outlets, or pipes that are part of the structure should be inspected for compliance with the job drawings. The specific type, size, and placement of these items usually appear on the drawing.

Steel structures should be inspected for compliance with standard fabrication practices. All welds should be finished as specified, e.g., continuous and smooth with no porosity, holes, high spots, lumps or pockets. Grinding is usually required to remove sharp edges and high spots.

All results of the steel structure inspection should be recorded showing approval signature of the inspector and time and date of the inspection. Reasons for rejections should be specified and recommended corrective action presented. The actual lining process should not be allowed to begin until all necessary corrective actions have been taken.

The inspector should also ascertain that:

- The available utilities are adequate for all phases of the installation, including air for abrasive blasting, safe lighting, heating and cooling equipment as might be necessary
- All safety equipment required by applicable OSHA standards is available and operating properly.
- Appropriate weather protection is in place for structures that are outdoors. Equipment and materials should be shaded from sunlight and protected from weather as required by the specification. Structures and materials should be protected from precipitation during all phases of installation.
- Heating, cooling, and dehumidification are provided as site conditions, job specification and/or manufacturers' instructions dictate.

VI. INSPECTION OF MATERIALS AND EQUIPMENT

All incoming lining materials, adhesives, welding rod, auxiliary materials and abrasive blast media should be examined to verify that materials received are identical to those listed in the job specification. (Note: Welding rod is plastic.)

Each container should be examined to verify the presence of a proper label identifying component type and size, batch number, date of manufacture, and shelf life expiration date as appropriate. The receiving date should be marked on each container.

Torn, broken, or punctured lining material containers should be marked and segregated for use as patch or seam material, if contents are damaged but still usable. If contents are undamaged, no restrictions of usage should be placed on the material. Adhesive material containers that are punctured, leaking or otherwise exposed should be marked and removed to the approved material disposal area.

A. LINING MATERIALS

The lining material should be checked with a micrometer, calipers, or spring-loaded thickness gauge to verify the specified sheet thickness. Tolerances will vary with the thickness, material, and method of manufacture. The lining material should also be examined for defects, such as tears, blisters, and delamination. Any material found to

have surface defects or exhibiting delamination between plies should be rejected.

Materials having fabric backing should be inspected to make certain that the fabric is properly attached to the sheet material and that the sheet material has not extruded through the fabric during manufacturing.

Manufacturers' test reports should be reviewed to ascertain that the lining material received conforms to manufacturing, industry, and/or contract requirements with regard to physical and mechanical properties, e.g., tensile strength, elongation, hardness, impact resistance.

The supplier should be contacted immediately for help in resolution of any problem. Unacceptable materials should be removed from the jobsite.

B. ADHESIVES

Adhesives should be sampled and tested for compliance with the specification. The inspector should verify that sampling and testing is performed according to the job specification. Any material found not to be in compliance with the job specification should be rejected.

Solvent-based elastomeric adhesives should be tested by a laboratory for viscosity and drying time. Reactive adhesives, such as two-part epoxy resins, should be tested for viscosity and gel time. A Brookfield viscometer is usually used to test viscosity of adhesive materials, although other methods do exist and are often used. Testing for gel time of a two-part epoxy is done using a 100 gram sample at a temperature of 77°F (25°C). (Note: Although standards exist for the determination of viscosity of adhesives (e.g., ASTM D 2556) and gel time of reactive thermoset resins (e.g., ASTM D 2471), these standards are not widely used in specifications for thermoplastic sheet linings. Instead, the manufacturer usually defines the testing parameters. For example, for viscosity testing, temperature, viscometer, and viscometer settings will be defined; and, for gel time, mass of adhesive and temperature will be defined.)

Solvent-borne adhesives should also be tested for peel adhesive strength of the materials to be joined, e.g., bonding of lining material to properly prepared steel, according to ASTM D 429, Method E. Typical instruments for measuring peel adhesive strength are described in the test

method. However, in general, a typical laboratory balance is suitable as long as it is accurate to $\pm 0.3\%$.

C. WELDING ROD/STRAP

The diameter of welding rod and dimensions of welding strap should be determined using a micrometer or calipers, and the inspector should verify that these measurements are in conformance with the job specification.

D. ABRASIVE BLAST MEDIA

Abrasive blast media should be examined for evidence of shipping damage, excessive leakage or loss of materials, or evidence of contamination by water or other substances. Random samples should be removed for sieve size and contamination testing (as described in Chapter 8). Sieve size test results should be compared with supplier's reports and recorded.

E. STORAGE AND HANDLING OF MATERIALS

Thermoplastic lining materials should be stored in areas where they are not exposed to direct sunlight and where the temperature does not exceed 86°F (30°C), or in accordance with the manufacturer's recommendations.

The materials should be stored and handled in such a manner that at no time is there any possibility of the material being exposed to freezing conditions, heat, flame or spark, which could damage or ignite the material.

The inspector should check the condition and shelf life expiration of materials prior to use. Labeling of containers should also be checked.

The oldest materials in storage should be issued for use first (up to the limit of shelf life) and preferably from a minimum of batches.

Materials should be transported to and stored at the work area in a manner to prevent their damage, contamination, or access by unauthorized personnel. Unused materials not required for seven days should be returned to controlled storage.

F. EQUIPMENT

Specialized equipment may be required for materials inspection. Such equipment may include but is not limited to the following:

- Micrometer, calipers, spring-loaded thickness gage
- Viscosity measurement devices, e.g., Ford cup, Zahn cup, Brookfield viscometer, as appropriate
- Wet film thickness gages
- Clamping device, weights and weight carrier for ASTM D 429, Method E
- Tensile test machine
- Balance
- Sieves

A list of specialized inspection equipment may or may not be included in the job specification. If not, the inspector should prepare such a list. As described in Chapter 4, the inspector should verify that all necessary inspection equipment is available and is operating properly.

VII. SURFACE PREPARATION

A. REMOVAL OF EXISTING LININGS AND COATINGS

Existing linings or coatings should be mechanically stripped in accordance with standard practices, so as not to damage the underlying substrate. Care must be used at weld seams and welded joints to prevent metal damage.

The inspector should verify that all metal damage incurred by air hammers or other tools from the stripping operation is ground to a suitable finish for relining at the completion of this operation.

All lining or coating material not removed in the initial stripping operation should be removed by buffing. No coating or lining material should remain after completion of this operation. The inspector should verify that all buffing dust and debris are removed from the structure and disposed of by the contractor. Depending on the previous use of the structure, the buffing dust and debris may have to be tested to determine the presence of hazardous materials before removal, handling, and disposal. All materials

should be disposed of in accordance with applicable federal, state and local regulations.

If the metal surface is found to have been contaminated by chemicals, oils, greases or other materials, the inspector should verify that any additional cleaning by solvent according to SSPC-SP 1, soaking with hot water, or steam cleaning with detergents is done as necessary to provide a surface acceptable for grit blasting.

Before grit blasting is allowed to begin, the inspector should examine the structure again. Acceptance and approval for abrasive grit blasting should be documented on appropriate forms or in log books.

B. PREVIOUSLY UNLINED AND UNCOATED SURFACES

All surfaces should be inspected visually for the presence of grease, oil or other contaminants. Chemical tests may be required to detect contaminants such as soluble salts. If solvent cleaning is necessary to provide a surface acceptable for grit blasting, the inspector should verify that it is done according to the specification, e.g., according to SSPC-SP 1. The inspector should inspect the vessel after solvent cleaning.

C. ABRASIVE GRIT BLASTING

The inspector should ensure that no blasting is done unless the surface temperature is at least 5°F (3°C) higher than the dew point. Blasting material should be thoroughly dry and compressor air should be free of moisture and contaminants. Abrasive media should be 20/30 mesh, or of appropriate mesh size to achieve the specified profile and anchor pattern.

The inspector should verify that the specified level of surface cleaning is attained. For the installation of thermoplastic sheet liners, it is usually specified that all carbon steel be dry abrasive blasted in accordance with SSPC-SP 5/NACE No. 1, "White Metal Blast Cleaning."

The inspector should also verify that the specified surface profile is attained. For the installation of thermoplastic sheet liners, surface profile should be 2.0 mils to 3.0 mils (51-76 micrometers) as determined by ASTM D 4417. Results of surface profile tests should be recorded. A dia-

gram noting the areas of each test should be attached for reference.

The surfaces to be primed should be blown down, brushed, and/or vacuumed to remove all visible abrasive and dust. The inspector should inspect the structure after cleaning before adhesive application may begin.

All weld and surface areas should be inspected for porosity, burrs, gouges and pitting. Any defects should be repaired by filling with weld, grinding, and then abrasive blasting again, followed by removal of blasting media as described above. The structure should then be inspected again.

VIII. COATING APPLICATION

A. TEMPERATURE AND RELATIVE HUMIDITY

The inspector should verify that surface temperatures are maintained between 59°F (15°C) and 86°F (30°C) and are at least 5°F (3°C) above the dew point throughout the application of primer and adhesives. No application should be done if the relative humidity is above 70%.

The inspector should also verify that the time between abrasive blasting and primer or adhesive application is as specified. This depends on relative humidity; however, some guidelines are as shown in Table 1.

In any case, there should be no visible rust bloom on the prepared surface when the adhesive is applied. If "flash rusting" (rust bloom) or discoloration occurs, the surface should be abrasive blasted again.

TABLE 1. Guidelines for time interval between abrasive blasting and primer or adhesive application.

Relative Humidity	Maximum Time Interval
61%-70%	8 hours
51%-60%	3 days
50% or below	7 days

B. PRIMERS AND ADHESIVES, MIXING AND APPLICATION

The inspector should verify that mixing and application of primers and adhesives is in accordance with the job specification and the manufacturer's recommended procedures. The primer and/or adhesive system should be applied to all areas that have been prepared and found to be satisfactory. The primer is usually a low viscosity material that is used to protect the substrate from rusting before application of the adhesive. It also helps to wet the surface and maximize adhesion of the adhesive.

The inspector should inspect the vessel after each primer and adhesive application for film thickness and complete coverage. All areas should be completely covered and have proper film thickness before sheet linings are applied.

- For two-part reactive systems, such as epoxies, wet film thickness should be determined.
- For solvent-borne elastomeric adhesives, wet film thickness should be determined on all surfaces to which the primer and adhesive are applied. Also, dry film thickness should be determined on steel surfaces. Solvent-borne elastomeric adhesives may require several coats with specified drying times between coats and before application of the lining. Drying times should be recorded by the inspector.

Any deficiencies in film thickness should be corrected before the lining is applied.

C. INSPECTION DURING LINING INSTALLATION

During lining installation, the inspector should verify that:

- The ambient temperature is maintained between 59°F (15°C) and 86°F (30°C).
- The relative humidity does not exceed 70%.
- The temperature of the surface being cemented is at least 5°F (3°C) above the dew point.
- The temperature of the lining material is at least 59°F (25°C) and not more than 86°F (30°C).

Temperatures should be monitored using a surface temperature thermometer.

Lining pieces should be measured to ascertain conformity to dimensions shown on job drawings. Lining pieces should be numbered and the location of each piece noted on the drawings. As lining pieces are put into place, the inspector should initial and date the drawings at the location of each piece.

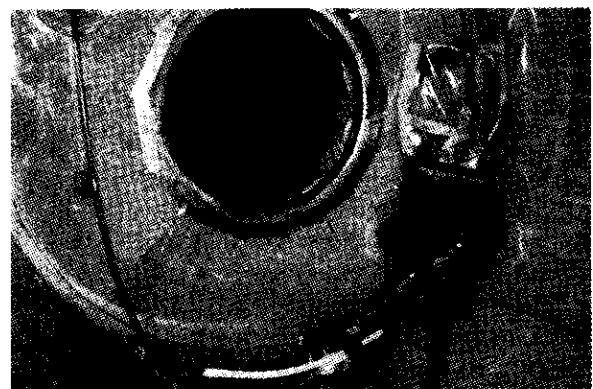
The installation should be inspected progressively to determine that pieces are being installed with edges straight along prescribed lines. Each piece should be carefully handled and thoroughly rolled during installation to avoid trapping air under the sheet. Thorough inspection is required to ensure that all air has been removed.

Depending on the properties of the lining material and the adhesive system, a vacuum may have to be applied to hold the piece in place until the adhesive sets. If a vacuum is used, the inspector should verify that the lining is properly held in place and that there are no hollow pockets under the sheet.

The inspector should verify that all adjoining sheets are beveled against each other as tightly as possible to minimize the width of the seam that must be welded (Figure 5-54). Any deviations should be corrected immediately.

The inspector should monitor the preparation of test panels. Test panels consist of the identical construction materials as used for the application. They are prepared

FIGURE 5-54. Installation of a Halar lining (Atlas).
Courtesy of Atlas Minerals & Chemicals, Inc.



concurrently with all steps of the application. The panels should be marked so as to be traceable to the area of the structure represented by the panel. These panels should be retained for future testing or as directed by the job specification. The number of test panels should be as specified in the job specification.

The inspector should examine the structure after all lining has been applied before welding of seams is started. Any loose areas, bubbles or blisters should be repaired before welding is started.

D. INSPECTION DURING WELDING

After welders have set up equipment and temperatures have been stabilized, the inspector should verify that a weld test is conducted to be certain that air flow, air temperature, material temperature, and welding techniques are proper for the material being welded. This test is performed as follows:

- The surface of the test piece of sheet and rod is scraped. The rod must be 18 to 24 inches (46-61 cm) long. Scraping is the use of a knife or sharp instrument to remove a thin layer of material from the welding rod and sheet before welding.
- The sheet is securely clamped in place.
- A weld bead of 8 to 12 inches (20-30 cm) is placed on the scraped surface of the sheet, leaving a sufficient length of rod unwelded in order to obtain a firm grip with the hand. When extrusion welding is being used, a similar test is conducted except that the rod is being fed from a continuous spool.
- The weld is allowed to cool for 20 to 30 seconds. Then, the unwelded end of rod is sharply pulled perpendicular to the sheet. The warmest end of the weld (no more than one inch) may pull away from the sheet, but the remainder of the weld must remain bonded.

The inspector should inspect the test weld. If it does not pass the test, the test must be repeated, rechecking air flow, temperature, welding speed, and gun position, making changes when necessary, until the test is passed.

Following this test, the inspector should:

- Record test results and initial and date approvals.
Ensure that welding parameters have been established.

- Visually inspect seams for proper bevels and scraping before welding is started. Corrections should be made where appropriate.
- Inspect the welding operation to make certain that sheet and rod scraping is being done and that established welding parameters and techniques are being followed.

IX. POST APPLICATION INSPECTION

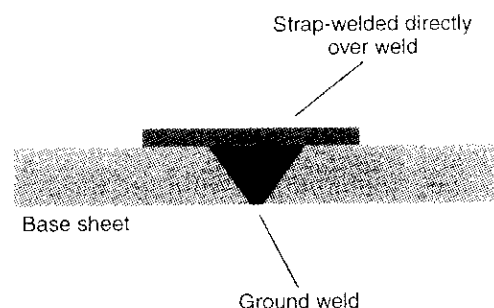
A. WELD INSPECTION

All thermoplastic welds should be spark tested at potentials of 100 volts per mil (4 volts/micrometer) of weld thickness.

- For strap welds, the weld thickness used as the basis for determining spark testing voltage is measured from the edge of the strap to the bottom of the seam, where the conductive backing is (see Figure 5-55).
- The spark tester should not be allowed to rest at one spot and the voltage must be closely controlled to avoid burning holes in the weld or the sheet.

The inspector should mark all visibly defective areas and all areas where pinholes or skips have been detected for repair, and note locations on drawings.

FIGURE 5-55. Cross-section of a strap weld on a thermoplastic sheet lining.



B. REPAIRS

The inspector should verify that repairs are made following the manufacturer's instructions, or as specified in the job contract. Repaired areas should then be re-tested as described above, and the inspector should initial and date inspection forms and drawings to signify approval.

X. SUMMARY

Thermoplastics such as polyethylene, polypropylene, and polyvinyl chloride (PVC), are themselves not readily bondable to steel; however, when a thermoplastic sheet liner has a bondable layer attached to it, it can be successfully applied to steel and concrete substrates. The bondable layer may be a fabric, a natural or synthetic rubber, or, in the case of PVC, a plasticized PVC.

There are many unique inspection requirements for the installation of thermoplastic sheet liners. Storage, handling, and inspection of materials are very important. So is inspecting the prepared surfaces for porosity, burrs, gouging, and pitting.

Primer and/or adhesive systems may be applied before the thermoplastic liner is installed. The inspector should monitor these operations. During liner installation, the inspector should verify that pieces are of the specified dimensions, that they are installed in the proper location, and that they are installed properly--correctly butted against one another, and without trapped air underneath. The inspector should also monitor the preparation of test panels.

A final step in the installation of thermoplastic sheet liners is scraping and extrusion welding of seams. All welds are should be spark tested, and all areas found to be defective should be repaired and re-tested.

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BIOGRAPHICAL SKETCH

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Mr. Reinert has co-authored various articles and has lectured on plastics and their uses at Kutztown University. He also holds patents on products related to Atlas' business interests.

Mr. Reinert graduated from Kutztown University in 1954 with a BS Degree in Chemistry. He continued his education in the 1960's and 1970's at Muhlenberg College.

Chapter 5.14

Inorganic Zinc-Rich Coatings

by Harold G. Clem, Jr.

OUTLINE

- I. Scope
- II. References
- III. Properties of Inorganic Zinc-Rich Coatings
 - A. Curing Mechanisms, Advantages, and Limitations
- IV. Inspection of Materials
- V. Surface Preparation
- VI. Coating Application
 - A. Mixing and Thinning
 - B. Application Method
 - C. Repairs
 - D. Curing Solution
- VII. Post-Application Inspection
 - A. Film Thickness
 - B. Cure of Inorganic Zinc-Rich Coatings
 - C. Topcoat Application
- VIII. Summary

I. SCOPE

This sub-chapter discusses the unique inspection requirements of various generic types of inorganic zinc-rich coatings, which differ primarily in vehicle composition and curing mechanisms. It also discusses important considerations for topcoating of these coatings.

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 4752 Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub

SSPC: The Society for Protective Coatings (SSPC)

SSPC-PA 1 Shop, Field, and Maintenance Painting

SSPC-PA 2 Measurement of Dry Paint Thickness with Magnetic Gages

SSPC-PA Guide 3 A Guide to Safety in Paint Application

SSPC-Paint 20 Zinc-Rich Primers (Type I - Inorganic and Type II - Organic)

SSPC-Paint 29 Zinc Dust Sacrificial Primer, Performance-Based

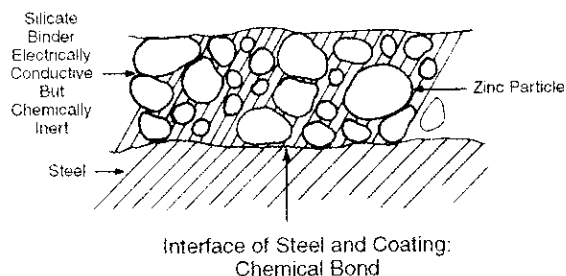
SSPC-PS Guide 8 Guide to Topcoating Zinc-Rich Primers

SSPC-PS Guide 12 Guide to Zinc-Rich Coating Systems

SSPC-SP 1 Solvent Cleaning

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

FIGURE 5-56. Schematic of an inorganic zinc-rich coating on a steel surface.



SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

III. PROPERTIES OF INORGANIC ZINC-RICH COATINGS

The term "zinc-rich" refers to the percent by weight of metallic zinc in the cured coating film, which may range from 50% (e.g., SSPC-Paint 29) to over 90%. Inorganic zinc-rich coatings are available as one, two, or three package products. The desired end product in all cases is a hard, adherent coating composed of metallic zinc powder suspended in a silicate matrix (Figure 5-56). Inorganic zinc rich coatings, in general, have excellent solvent resistance, abrasion resistance and high temperature properties (Figure 5-57).

A. CURING MECHANISMS, ADVANTAGES, AND LIMITATIONS

The complex chemical reactions involved in the film formation of various types of inorganic zinc-rich coatings is beyond the scope of this sub-chapter; however, an understanding of the basic application parameters and curing characteristics is essential for effective inspection of these coatings. For example, high humidity conditions usually accelerate the cure of alkyl silicates (Type 1-C) but may inhibit the cure of some water soluble alkali metal silicate based systems. Following are some highlights of the cur-

ing mechanisms, advantages and limitations of specific types of inorganic zinc - rich coatings, as defined in the SSPC-Paint 20, Zinc-Rich Primers (Type 1, "Inorganic").

Type 1-A: These coatings are water based, post-curing alkali silicates supplied as three-component systems composed of zinc powder, an alkali silicate vehicle, and curing solution. Type 1-A coatings are non-flammable, VOC compliant, and have excellent hardness and abrasion resistance. After the applied coating has dried initially, a curing solution is applied to convert the silica gel into an insoluble silicate matrix. After the coating has cured, the residue of the curing solution must be removed from the surface, which can be accomplished by washing with fresh water. These coatings are sensitive to high humidity or rain until completely cured.

Type 1-B: These coatings are water based self-curing alkali silicates supplied as two component systems. Type 1-B coatings are non-flammable and VOC compliant. After the water evaporates from the applied coating film, the coating self-cures by reaction with humidity and carbon dioxide from the air. As with Type 1-A inorganic zinc-rich coatings, Type 1-B coatings are sensitive to rain and high humidity until the coating has completely cured.

Type 1-C: These coatings are solvent based self-curing alkyl silicates supplied as one or two package systems. Type 1-C inorganic zinc-rich coatings cure by hydroly-

FIGURE 5-57. Highway bridge coated with inorganic zinc-rich coating. Courtesy of Inorganic Coatings, Inc.



sis or reaction with moisture following the evaporation of solvent. These coatings are typically resistant to rain showers in one hour or less. When the relative humidity is less than 40%, either a longer cure time may be required or water may be sprayed on the coating surface to complete the curing process.

IV. INSPECTION OF MATERIALS

Inorganic zinc-rich coating materials should be kept dry and stored indoors in accordance with the ambient temperature range recommended by the manufacturer. In particular, water borne materials should be protected from freezing. The inspector should verify that all coating materials are used before the manufacturer's specified shelf life has expired, and that stored materials are undamaged.

V. SURFACE PREPARATION

The inspection of surface preparation should follow the detailed procedures found in Chapter 4. Inorganic zinc-rich coatings nearly always require a near-white or white metal finish. Some Type I-B coatings require a near-white metal finish for non-immersion service, and often a white metal finish for immersion service. Prior to abrasive blast cleaning, the inspector should verify that the steel substrate is free of grease, oil, dirt, salts and other surface contamination.

The inspector should also verify that the specified surface profile is attained. Surface profile is a critical parameter since excessive profile may cause pinpoint rusting. A profile range of 1 to 3 mils (25 to 76 micrometers) is usually satisfactory.

The inspector should verify that abrasive dust or residue is removed from the steel substrate prior to the application of inorganic zinc.

VI. COATING APPLICATION

A. MIXING AND THINNING

The inspector should verify that the inorganic zinc coating is mixed in clean containers and thinned, if required, in accordance with the specification or the coating manufacturer's instructions. In multi-component coating systems,

FIGURE 5-58. Application of an inorganic zinc-rich coating. Courtesy of Inorganic Coatings, Inc.



the zinc powder is usually added slowly to the silicate vehicle with agitation. After the coating is uniformly blended, the inspector should verify that the mixed material has been strained through a 30-60 mesh screen to remove any undispersed material, and to prevent possible clogging of spraying equipment.

B. APPLICATION METHOD

In general, inorganic zinc-rich coatings are constantly agitated during application to prevent settling and to maintain uniformity. The agitated pressure pot should also be kept at approximately the same level as the spray gun. The inspector should verify that the spray equipment conforms to the manufacturer's recommendations. In most cases, inorganic zinc-rich coatings are applied with a full wet coat overlapping each pass 50% (Figure 5-58). Multiple light spray passes tend to produce excessive dry overspray or non-adherent particulate material.

For inorganic zinc-rich coatings, wet film thickness measurements are not reliable because the zinc pigment is not displaced when the gage is pressed into the wet coating film. In addition, inorganic zinc-rich coatings do not flow well into the marks or impressions left by wet film gages, thus the coating would require repair in each spot measured.

C. REPAIRS

Depending on the type of inorganic zinc-rich coating, corrective measures may involve touchup or the complete removal and reapplication of the coating. Defects in Type 1-A water based post-cured inorganic zinc-rich coatings are usually corrected prior to the application of the curing solution (see below). The inspector should verify that all touchup or repair is done according to the specification.

D. CURING SOLUTION

The inspector should verify that the specified volume of curing solution per unit of coated surface area is applied for Type 1-A coatings; otherwise insufficient curing may occur and the film may become powdery. The inspector should also verify that the surface is protected from moisture for the specified cure time, and that the curing agent residue is washed off in accordance with the specification.

VII. POST-APPLICATION INSPECTION

A. FILM THICKNESS

The inspector should verify that the overall coating thickness conforms to the specification requirements. When the coating is dry throughout the film, the dry film thickness should be checked with a non-destructive gage calibrated to accommodate the surface profile (SSPC-PA 2). The recommended thickness range should be verified. Low film thickness may result in pinhole rusting and inadequate corrosion protection. Excessive film thickness may result in mudcracking (Figure 5-59) or splitting of the inorganic zinc primer, before or after topcoating.

B. CURE OF INORGANIC ZINC-RICH COATINGS

Following the manufacturer's instructions, the inspector should determine the adequacy of cure of the coating.

There are two general methods for determining if curing of solvent reducible inorganic zinc-rich primers (Type 1C) is complete: the solvent rub and the coin rub test methods.

Solvent Rub: This method, which is described in ASTM D 4752, calls for a clean cloth soaked in methyl ethyl ketone (MEK) or other suitable solvent to be rubbed over the coating. The method is primarily appli-

FIGURE 5-59.
Mudcracking.
SSPC file photo.



cable to alkyl silicate zinc-rich primers without organic modifiers. No residue or only traces of residue on the cloth indicates adequate cure.

Coin Rub: This method involves rubbing the inorganic zinc-rich primer with the edge of a coin; if the coating burnishes with little or no powder removal, the coating has cured satisfactorily. This very subjective test becomes more valid as the inspector gains experience.

C. TOPCOAT APPLICATION

Inorganic zinc-rich coatings may be topcoated to provide extended durability, improved appearance, and improved resistance to certain environments. If the specification calls for topcoating, the inspector should verify that the surface of the inorganic zinc-rich coating is clean and otherwise acceptable for topcoating. As described in SSPC-PS Guide 8, this means that the surface must be free of loose zinc salts, dry spray, foreign materials, and unacceptable defects. The inorganic coating should also be free of moisture and adequately cured, as required by the specification and the manufacturer's requirements.

If the specification calls for topcoating, the inspector should verify that the specified topcoat is compatible with the inorganic zinc-rich coating. SSPC-PS Guides 8 and 12 provide more information on this.

VIII. SUMMARY

There are many types of inorganic zinc-rich coatings, which differ primarily in vehicle composition and curing mechanisms. The classification of inorganic zinc-rich coatings is as follows:

Type 1-A: Water based, post-curing alkali silicates supplied as three component systems composed of zinc powder, an alkali silicate vehicle, and curing solution.

Type 1-B: Water based self-curing alkali silicates supplied as two component systems.

Type 1-C: Solvent based self-curing alkyl silicates supplied as one or two package systems.

When inspecting the application of inorganic zinc-rich coatings, the inspector has all of the usual responsibilities for monitoring ambient temperature, surface preparation and coating application. However, there are some special inspection requirements. For example, verifying the specified surface profile is critical since excessive profile may cause pinpoint rusting. The inspector should also verify that proper mixing and straining procedures are followed, and, if specified, that the coating is constantly agitated during application to prevent settling and to maintain uniformity. The inspector should measure the dry film thickness of the coating. The inspector may also be required to test these coatings for cure by a solvent rub or coin rub method.

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Chapter 6.0

Inspection of Facilities:

Introduction

by SSPC Staff

OUTLINE

- I. Scope
- II. Format
- III. Summary

I. SCOPE

This chapter describes the special considerations for coatings inspection on various types of public structures and industrial facilities. It also includes a sub-chapter on underwater inspection (Figure 6-1). It is not intended to stand alone as a set of procedures for inspection of coatings on public structures and industrial facilities. Rather, it is intended to be used in conjunction with Chapters 3 and 4, which describe basic inspection procedures, and Chapter 5, which describes the inspection of various specialty coatings. It therefore contains frequent reference to these other chapters.

This chapter is divided into several sub-chapters. The first three are:

- Storage Tanks, 6.1
- Pipelines, 6.2
- Underwater Inspection, 6.3

The information presented in these first three sub-chapters is general and may be applied to a variety of structures and facilities. The other sub-chapters covering specific types of structures and facilities are:

- Bridges, 6.4
- Ship Hulls, 6.5
- Locks, Dams, Spillways, and Their Appurtenances, 6.6
- Offshore Facilities, 6.7
- Refineries and Petrochemical Plants, 6.8
- Food and Beverage Processing Plants, 6.9
- Waste Water and Water Treatment Plants, 6.10
- Pulp and Paper Mills, 6.11
- Nuclear Power Plants, 6.12
- Fossil Fuel Power Plants, 6.13

The facilities covered in this chapter have a range of features that can necessitate special coating inspection techniques (Figure 6-2). Some of these are:

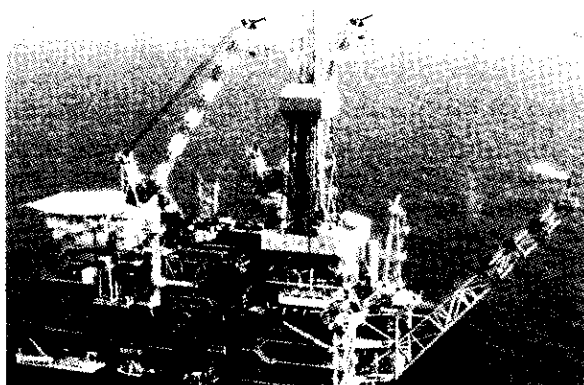
- Aggressive liquid and gaseous chemical environments associated with chemical plants, refineries, waste and water treatment plants, etc.
- Very high and/or low temperatures associated with industrial processes
- Repetitive components such as occurring on bridges
- Aggressive marine environments as on ship hulls and offshore facilities
- Confined spaces, heights, and other hazards that must be addressed

As demonstrated in this chapter, each type of facility has special requirements. In each case, the inspector must become familiar with the policies, restrictions, and unique configuration of the facility before submitting a bid or

FIGURE 6-1. Underwater inspection at an industrial facility. Courtesy of Underwater Engineering Services, Inc.



FIGURE 6-2. An offshore platform, a facility with many special inspection requirements. Courtesy of S.G. Pinney & Associates, Inc.



committing to perform the work. This may entail acquiring information about specific processes and work schedules, as well as plant layout, access, and individual unit configuration.

II. FORMAT

As far as possible, a standard format was used in each sub-chapter to provide uniformity and permit quick reference:

- Scope
- References
- Structural and Environmental Considerations
- Coatings Used
- Health and Safety
- Surface Preparation and Coating Application
- Post-Application Inspection

(Many times, however, there are additional or slightly different headings.)

Scope outlines and defines what items are covered in the sub-chapter.

References lists standards and guides for operations related to the use of coatings in the specific type of facility. The latest issue, revision, or amendment of the reference standards should be used unless otherwise specified.

Structural and Environmental Considerations include unique features of structure, design, site, or environment that affect the inspection of coating operations (Figures 6-3 and 6-4). Some examples of the type of information that can be found here are:

- A special identification system may be needed to keep track of areas to be inspected on repetitive units such as bridge spans.

FIGURE 6-3. Unique structural features must be considered. Shown here is a floating roof with legs jacked up to apply FRP lining beneath. Courtesy of Amoco Chemicals.



FIGURE 6-4. The environment surrounding the structure must be considered. Courtesy of KTA-Tator Inc.

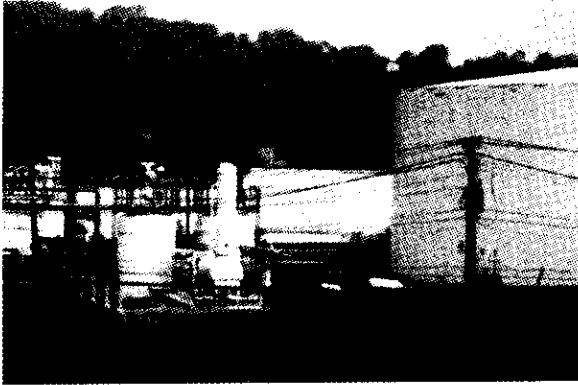


FIGURE 6-5. An example of a safety concern: working at heights. SSPC file photo.



- Access to work may require special actions such as dry-docking of ships, draining of tanks, and floating platforms for docks, gates, and locks.
- Humidity may pose a special problem such as ballast sweating of ship hulls and water tanks.
- It may be necessary to accommodate very short down times (or outages). This may limit the selection of surface preparation techniques and coating materials.

- There may be restrictions on abrasive blasting due to disruption of ongoing processes or other intrusion on the plant personnel.

Coatings Used discusses typical coating materials used in the facility. This also includes information on special considerations that are made in choosing materials for the type of facility. For example, some coating systems require government approval for special use, such as in food and beverage processing plants and potable water storage tanks.

Health and Safety discusses health, safety, and/or environmental hazards in the facility (Figure 6-5). These include confined spaces, heights, chemical fumes, radiation (from nuclear power plants), and lead-based paint (such as present on older bridges). The inspector must be fully knowledgeable and trained to protect himself from these hazards and, in some cases, monitor containment, storage, and disposal of hazardous debris.

Surface Preparation and Coating Application discusses special surface preparation and coating application requirements (Figure 6-6). For example:

- Exterior abrasive blasting may require containment of particulates, particularly when the existing coating contains heavy metals.
- Closed-cycle blasting machines may be used for ship hulls and decks or storage tanks.
- Marine fouling may have to be removed by water-blasting before cleaning steel for coating.
- Containments used for blasting may also be suitable for protection from the wind during coating application.
- Special rollers or mitts may be required for coating piping or tall, hard-to-reach structures.
- In confined spaces, heating and forced ventilation may be required between coats to remove all the residual solvent.

Post-application Inspection includes important items regarding post-application inspection that the inspector must be aware of. For example:

- Intersections of structural members, areas coated by mitt, and inside corners will have a much greater variation in film thickness



FIGURE 6-6.
Ultra high
pressure (40,000
psi) water
cleaning of 3/8
inch natural
rubber from a
steel tanker.
Courtesy of Valley
Systems Inc.

- In nuclear power plants, inspection tools must be protected from radioactive contamination.
- Underwater inspection tools such as cameras and lights must be water-tight.

III. SUMMARY

The coating inspector for industrial facilities must be thoroughly familiar with both standard inspection techniques and those that are unique for the structures being coated. This will permit him to complete his work successfully and protect himself, others about him, and the environment.

Chapter 6.1

Storage Tanks

by E. Crone Knoy

OUTLINE

- I. Scope
- II. References
- III. About Tanks
- IV. Unique Features of Tanks
 - A. Unique Design Features
 - B. Access
- V. Coatings Used on Tanks
 - A. Interior Surfaces
 - B. Exterior Surfaces
- VI. Health and Safety
 - A. Heights and Depths - Fall Protection
 - B. Confined Spaces
 - C. Toxicity Problems
 - D. Fire and Explosion Problems
 - E. Visibility
 - F. Lead in Coatings
- VII. Surface Preparation and Coating Application - Tank Interiors
 - A. Surface Cleaning
 - B. Surface Preparation Requirements
 - C. Coating Application
 - D. Ventilation
 - E. Applying Intermediate and Finish Coats
- VIII. Surface Preparation and Coating Application - Tank Exteriors
 - A. Surface Cleaning
 - B. Surface Preparation Requirements

- C. Coating Application
- IX. Summary

I. SCOPE

The purpose of this sub-chapter is to provide technical information relevant to the inspection of coatings on the interior and exterior of storage tanks. It focuses on those features unique to large field-erected steel tanks, but some of the information may be useful for other types of tanks. Besides describing the inspection of generic tank exteriors and interiors, it also describes some of the features that are unique to water, fuel, and chemical storage tanks. Other sub-chapters of this chapter (e.g., 6.8, Refineries and Petrochemical Plants and 6.10, Water and Wastewater Treatment Plants) provide more information on these specific types of tanks. (Note: Further information relevant to coatings inspection on tanks can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American National Standards Institute (ANSI)

ANSI Z117.1 Safety Requirements for Working in Tanks and Other Confined Spaces

American Petroleum Institute (API)

API RP 652 Lining of Aboveground Petroleum Storage Tank Bottoms

Code of Federal Regulations (CFR)

29 CFR 1910.146 Permit Required Confined Spaces

29 CFR 1926.62 Lead

29 CFR 1926.500 Guardrails, Handrails, and Covers

Federal Aviation Administration (FAA)

US Dept. of Transportation, Federal Aviation Administration, Advisory Circular AC 70/7460-1H, "Obstruction Marking and Lighting," 1991.

NSF International (NSF)

NSF/ANSI 61, Drinking Water System Components - Health Effects

SSPC: The Society for Protective Coatings (SSPC)

SSPC-Guide 6 Guide for Containing Debris Generated During Paint Removal Operations.

SSPC-Guide 7 Guide for the Disposal of Lead-Contaminated Surface Preparation Debris

SSPC-SP 1 Solvent Cleaning

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

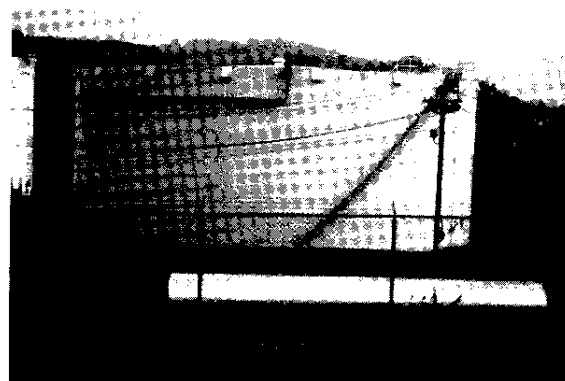
SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

Underwriters Laboratories Inc. (UL)

UL 298 Standard for Safety, Portable Electric Hand Lamps

UL 781 Standard for Safety, Portable Electric Lighting Units for Use in Hazardous (Classified) Locations

FIGURE 6-7. Fuel storage tank. Courtesy of KTA-Tator Inc.



III. ABOUT TANKS

For the past 100 years or more, water storage tanks have been constructed throughout the United States to help maintain proper water pressure and supply for domestic use and fire protection. Tanks also play an integral role in the chemical and petrochemical industries, where they are used to store chemicals and fuel (Figure 6-7).

Although tanks come in many shapes and sizes, tanks typically consist of a container which holds the liquid, a foundation which supports the structure, and appurtenances for various aspects of tank operation, such as filling and delivering, level indication, access, and lighting.

Tanks designed to contain liquid materials may be elevated on a single pedestal or multiple legs, located at ground level, or buried underground (Figure 6-8). Most elevated tanks contain water. Ground level water tanks with diameters equal to or larger than their heights are called reservoirs; those with heights greater than their diameters are called standpipes.

A large percentage of the tanks in service today are constructed of steel. When exposed to the exterior environment and the liquid in the tank, steel can rust. Coatings on the interior of the tank form a protective barrier between the steel and the tank contents; coatings on the exterior, a protective barrier between the steel and the atmosphere. Tanks containing liquids other than water usually have

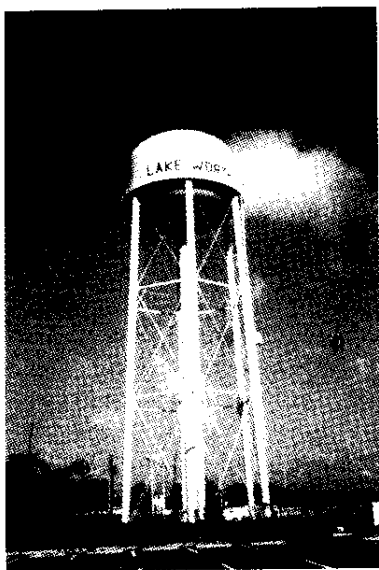


FIGURE 6-8.
Elevated water
tank. Courtesy of
S.G. Pinney &
Associates, Inc.

- Tank roofs are often supported on beams that have sharp edges, crevices, and other features that are difficult to coat and more prone to corrosion.
- The floors of most tanks are sloped to an outlet to permit complete drainage. However, in some tanks, drainage pipes may extend 1-2 feet (0.3 - 0.6 meters) above the floor of the tank.
- In fuel tanks, areas immersed in fuel are in general less corrosion-prone than those exposed to the interior atmosphere. (This, however, is not true on the tank bottom, where water from contaminated fuel always collects despite regular removal from sumps.)
- Some water tanks are cathodically protected with an impressed current system, which, if properly designed and maintained, can control corrosion in the submerged areas on the interior of the tank. (The upper atmospheric portion of the tank interior does not receive cathodic protection.)

containment systems or double protection systems to prevent serious contamination of the earth or surface water in the event of a tank failure.

Tank rehabilitation projects cost tens--even hundreds--of thousands of dollars. Because of this, prudent tank owners rely on the expertise of trained inspectors to monitor the initial coatings application, to evaluate the condition of tanks that are in service, to make recommendations for repainting and repair, and to oversee the required maintenance. Without expert observation of the initial coatings work, the tank owner's expectations may not be met and coating work of inferior quality may result.

IV. UNIQUE FEATURES OF TANKS

A. UNIQUE DESIGN FEATURES

Storage tanks may have unique design features that can affect coating application and inspection. For example:

- Elevated tanks may be required to have a checkered finish of squares colored aviation orange and white or a special lighting system to warn aircraft in the area (described in Federal Aviation Administration Circular AC 70/7460-1H) (Figure 6-9).
- Fuel tanks may have floating or fixed roofs.

B. ACCESS

One of the biggest problems in inspecting exterior tank coating work is obtaining access to it. Because of poor access, coating workmanship may also suffer. Special rigging is usually necessary. The outside bottom of a column-supported elevated tank is especially difficult to access,

FIGURE 6-9.
Special finish on
tops of tanks to
warn aircraft in
the area.
Courtesy of S.G.
Pinney &
Associates, Inc.



and its intersections with the supporting column are especially difficult to clean and coat satisfactorily.

V. COATINGS USED ON TANKS

A. INTERIOR SURFACES

The choice of coating materials (and associated surface preparation, application, and inspection procedures) for interior surfaces of a tank depends on what is to be stored in the tank. API 652 provides much useful technical information on materials, surface preparation, and application for the lining of tanks used for storage of liquids.

Linings for potable water storage tanks require approval when tested according to ANSI/NSF Standard Method 61. Approved products are most frequently epoxies. Epoxy and coal tar epoxy systems are most commonly used to line waste water tanks. (Further information on coating and lining materials for water and waste water treatment plants is given in Chapter 6.10.)

Coatings for lining tanks that contain chemicals or fuels are selected for their resistance to the particular chemical stored. Epoxy coating systems are most commonly used on fuel storage tank interiors. API Standard 652 is applicable for coating tank bottom interiors.

B. EXTERIOR SURFACES

The choice of a coating system for steel storage tank exteriors normally depends upon the severity of the environment and owner requirements for service life and esthetics. For example, a three-coat alkyd system (e.g., two coats of alkyd primer and one coat of silicone alkyd finish) may be used in a mild environment, whereas a higher performance system (e.g., an organic or inorganic zinc-rich primer, an epoxy intermediate coat, and an aliphatic polyurethane finish coat) may be used for a more severe environment. (Note: Alkyd coatings are not recommended for water tanks which form condensation on their exterior.)

VI. HEALTH AND SAFETY

The coatings inspector should be aware of the hazards of coating operations associated with storage tanks and have the necessary personal protective and support equipment

to conduct his work safely. General safety for inspectors is described in Chapter 7 of this book.

A. HEIGHTS AND DEPTHS - FALL PROTECTION

Most large storage tanks have heights between 30 and 200 feet (9 - 60 meters). Falls from even the shorter tanks can be fatal. Frequently, shorter tanks have relatively flat roofs that may provide workers with a false sense of security. Elevated water tanks frequently have riser pipes three or more feet in diameter and 100 or more feet (30 meters) high, and these must be properly rigged and the worker protected to prevent falls. Safety grates should be in place over the top of the large riser pipes if workers are not otherwise protected from falling into the riser. Tank ladders and rails must conform to safety requirements.

The inspector should use the required safety equipment for climbing and should not climb or inspect high or interior areas unless other workers are available who are trained to provide emergency support.

Accessing exterior and interior walls and roofs usually requires specialized rigging for fall protection. According to the OSHA requirements for fall protection in construction (Subpart M 1926.500), each employee on a walking/working interface with an unprotected side or edge which is 6 feet or more above a lower level must be protected from falling by the use of guard rail systems, safety net systems, or personal arrest systems. Approved systems may consist of safety harnesses, lanyards, etc. Such safety devices should be secured to an independent attachment point.

The OSHA requirements also specify that each employee who might be exposed to fall hazards must receive fall protection training. Training enables employees to recognize the hazards of falling and the procedures to follow in order to minimize the hazards.

B. CONFINED SPACES

The interiors of most storage tanks, including those without roofs, are considered to be confined spaces, because access is limited, and the space is not normally occupied by people (Figure 6-11). Confined space entry rules are defined in Occupational Safety and Health Agency (OSHA) 29 CFR 1910.146, "Permit Required Confined

Spaces." These regulations require employers to establish a program for confined space entry that includes identification, testing, permitting, training, emergency response, rescue, and lockout procedures. These requirements apply to all the usual coating procedures: Cleaning, surface preparation, coating application and curing, and inspection of these procedures. Further information on entry permitting into confined spaces is given in Chapter 7.

C. TOXICITY PROBLEMS

During solvent cleaning and application of coatings to interior surfaces, toxic vapors may accumulate. These vapors may have short-term, long-term, or cumulative health effects on workers. Thus, exposure to these toxic vapors should be limited as much as possible by ventilation and/or use of respirators, as required by the rules and regulations. Proper ventilation requires sufficient air to be circulated so as to reach all tank areas. Since many solvent vapors are heavier than air and accumulate at the bottom of the tank, ducting and/or manholes should be designed to address this condition in low areas. Before an employee enters a confined space, the internal atmosphere must be tested with a direct-reading instrument for the following: oxygen, flammable gases and vapors, and potential toxic air contaminants. Monitoring with instruments should

ensure that Threshold Limit Values (TLVs) are not exceeded.

Dusts formed during abrasive blasting also have adverse health effects that require the use of personal protective equipment. They can also reduce worker visibility and thus increase the likelihood of accidents. Dusts also may be explosive.

D. FIRE AND EXPLOSION PROBLEMS

When working with solvents and other flammable coating materials inside tanks, all necessary precautions (as described in Chapter 7), should be taken to prevent fires and explosions.

E. VISIBILITY

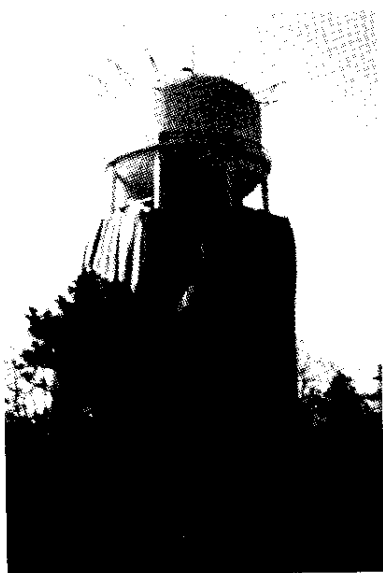
Visibility in tank interiors is very limited, even when dust isn't present. Interior lighting during coating operations should not be limited to where work is being done. Limited visibility not only increases the likelihood of accidents but also decreases the ability to produce quality workmanship, including inspection. Lighting of at least 10 foot candles is adequate for general work, but 20 foot candles is preferred. Lighting of at least 20 foot candles is adequate for surface preparation, coating application, and inspection, but 50 foot candles is preferred. The only standard that addresses temporary lighting conditions for industrial projects such as painting in confined spaces is ANSI Z117.1, "Safety Requirements for Working in Tanks and Other Confined Spaces."

Lighting systems must be explosion proof and meet the requirements of Underwriters Laboratory Standards 298 and 781. The lights should be enclosed in a shatterproof case and should be white in color. Coating systems are easiest to visually inspect if they are light in color.

F. LEAD IN COATINGS

For many years, lead-containing coatings were applied to the surfaces of storage tanks. Lead pigments were often used in inhibitive primers and special colors such as aviation orange. Removing lead-containing coatings during blasting or mechanical cleaning disperses lead-containing particles into the atmosphere in fine dusts (Figure 6-10). The requirements of 29 CFR 1926.62 must be met to protect workers. SSPC-Guide 6 (CON) and 7I (DIS) provide

FIGURE 6-10. Outrigging for a containment. Courtesy of Tank Industry Consultants, Inc.



guidance for containment and disposal, respectively, for lead-containing paint.

VII. SURFACE PREPARATION AND COATING APPLICATION - TANK INTERIORS

A. SURFACE CLEANING

Prior to surface preparation of the tank interior, the inspector should verify that the surfaces are cleaned free of contaminants such as deteriorated paint, sludge, and residual stored liquids. This may be accomplished, depending upon the types of contaminants, by:

1. Pressure washing using appropriate detergent or alkali solutions
2. High-pressure water jetting
3. Steam cleaning with or without detergent
4. Solvent cleaning (SSPC-SP 1)

Before acceptance for surface preparation, the inspector should check for conditions of surface irregularities, welds, and edges, if this is required in the specification.

B. SURFACE PREPARATION REQUIREMENTS

The inspector should verify that the specified level of surface cleanliness and profile are attained. Interior tank linings usually require a white (SSPC-SP 5) or a near-white (SSPC-SP 10) level of abrasive blast cleaning and a profile height of 1 to 3 mils (25 to 75 micrometers). The desired profile height is achieved by proper selection of the abrasive. Methods of measuring surface cleanliness and profile height are described in Chapters 4 and 8. The inspector should monitor cleaning quality by observing the blast operator's techniques. To clean seams and structural members completely may require directing the nozzle from several angles. The cleaned surfaces should be inspected at random locations for contaminants such as soluble salts. Chapter 8 describes methods for testing for soluble salts.

The inspector must be concerned about dust remaining on steel surfaces after blasting because it will reduce the coating adhesion. Dusts frequently have an electrostatic charge and thus a tendency to cling to surfaces, even vertical and overhead ones. Brushing down followed by vacuuming is

usually the preferred method for dust removal. Health regulations may preclude blowing down the surfaces with compressed air. Also, this method just blows the dust to another location in the tank. Seams, structural stiffeners, and other discontinuities present special dust removal problems. The inspector should spend extra time checking these surfaces for dust, especially top surfaces normally difficult to see.

C. COATING APPLICATION

There are several special application concerns associated with tank interiors:

1. Surface Temperature

There can be a wide variation in the temperatures on the interior surfaces of steel tanks, especially on sunny days. The inspector should monitor the temperatures of areas being coated to ensure that they are within the specified range and well above the dew point.

2. Mixing and Thinning

Most interior tank lining materials are multiple-component systems. The inspector should monitor pre-mixing of components, their blending, final mixing, proportioning, thinning, induction time, and pot life. For successful application and curing, it is critical that these be in conformance with the job specification and manufacturer's published instructions.

3. Striping

The inspector should monitor striping, if it is required by the specification. Brush striping of all seams, edges, rivets, bolts, and other irregular surfaces is often specified to precede application of the primer coat. This provides a base for these irregular surfaces to receive the spray-applied primer and to allow the primer to flow across the surface without forming holidays.

In older bolted or riveted tanks, it is a common practice to seal the seams with a 100% solids material such as an epoxy-based material.

4. Priming

If possible, the inspector should monitor the application of the primer to ensure proper application, minimum overspray, a smooth, uniformly thick film, and a film thickness that meets the requirements of the specification. However, the type of rigging and scaffolding and the presence of toxic vapors may preclude direct observation of the application process.

D. VENTILATION

For coating of tank interiors, the specification may require specially designed ventilation that prevents overspray from being pulled onto the wet coating. Overspray on wet coatings creates a rough surface that may create voids in the film. These rough areas should be sanded smooth before applying the next coat.

Proper ventilation is also necessary for complete solvent release before the next coat is applied. Most solvents are heavier than air, so the lowest portion of the tank must be exhausted. The next coat should be applied during the window of time specified by the supplier to obtain good inter-coat adhesion. If this time is exceeded, lightly abrading the first coat or use of a tie coat may correct this problem.

E. APPLYING INTERMEDIATE AND FINISH COATS

The general precautions described for applying the primer should also be followed for the intermediate and finish coats. Differently tinted successive coats will make visual detection of thin or skipped areas easier.

After application of the total lining system, the interior surfaces should be holiday tested in accordance with the job specification. Curing should occur as described by the supplier or the specification before the tank is placed in service. Potable water tanks will require washing with potable water and disinfecting.

VIII. SURFACE PREPARATION AND COATING APPLICATION - TANK EXTERIORS

A. SURFACE CLEANING

The inspector should verify that surface cleaning is conducted, as required by the specification, to remove all detrimental contaminants before initiation of blast cleaning.

B. SURFACE PREPARATION REQUIREMENTS

The inspector should verify that the specified level of surface cleanliness and surface profile are attained. Surface cleaning of the exterior steel should be followed by blast cleaning. For example, for an alkyd system, a commercial blast (e.g., SSPC-SP 6) is normally adequate, whereas for a higher performance system, a near-white blast (e.g., SSPC-SP 10) is usually recommended.

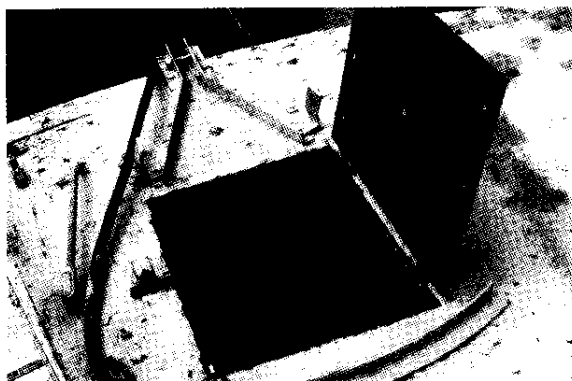
In order to protect surrounding areas from toxic or otherwise undesired products of abrasive blasting, the specification may call for the erection of a containment structure. This may be done in sections or the entire structure may be enclosed. The inspector should ensure that each section that is blast cleaned and coated joins well into adjacent sections.

C. COATING APPLICATION

The enclosure used for blast cleaning may also be used for exterior coating application to avoid overspray drifting onto undesired surfaces, adjacent property, cars, etc. In removing the containment and rigging, care should be taken not to damage the coating systems. Inspectors must make records of damaged areas and be sure that they are corrected satisfactorily.

In most locations, the temperature of the tank contents is usually lower than the exterior atmospheric temperature.

FIGURE 6-11. Entry hatch on a tank. Courtesy of Tank Industry Consultants, Inc.



This lowers the dew point on the exterior surface and the resulting condensation may affect the adhesion of the coating being applied. Also, riveted and bolted tank seams may have some seepage. Thus, tanks should be drained while their exteriors are being coated and until the coatings cure.

Some coatings, when exposed to moisture during curing, develop unsightly blushing. When these types of coatings are applied, the inspector should check the humidity and dew point periodically. In some climatic conditions, it may be necessary to stop application several hours before the end of the day.

Most tanks have exterior appurtenances such as ladders, rails, and systems for filling and delivery of stored products. The inspector should ensure that they are coated as indicated in the specification without painting them shut or otherwise affecting them adversely. Safe-climbing cables or rails should never be painted.

Upon the completion of work, the inspector should verify that waste materials are disposed of in accordance with the specification and any referenced safety and environmental regulations.

IX. SUMMARY

Steel tanks are of many possible designs. They can be elevated, at ground level, or underground, and they can hold water or other liquids. Consequently, there are various

important safety precautions for work in and on tanks. For tank interiors, some of the risks are oxygen deficiency, toxic vapors, fire, and explosion. For tank exteriors and interiors as well, safe access to heights and depths, and fall protection must be addressed.

There are also many important coating and inspection requirements for steel tanks. These requirements encompass surface cleaning, surface preparation, and coating application. Monitoring surface cleaning and surface preparation is often critical on tank interiors, where contamination, sludge, residual liquid, dust, and seams may be a problem. Monitoring coating application is also critical--both on tank interiors and tank exteriors. For tank interiors, some of the inspector's special concerns may be monitoring the mixing and thinning of multiple-component materials, striping, surface temperature, and ventilation.

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Mr. Knoy is a member of many professional organizations, including the American Water Works Association, SSPC, NACE International, the Steel Plate Fabricators Association, the National Association of Professional Engineers, and the American Society of Mechanical Engineers. He is a member of the Board of Governors of the SSPC. He is the Chairman of the American Water Works Association Steel Tank Manual Task Force, and a member of D102

AWWA Standard for Painting Water Storage Tanks Revision Task Force, D100 AWWA Steel Tank Standard Revision Task Force, and AWWA Standards Committee for Steel Elevated Tanks, Standpipes, and Reservoirs. He is also a member of the National Sanitation Foundation Protective Materials (Barriers) Task Group for USEPA Standards.

Mr. Knoy has written and presented many papers at conferences. He also developed and coordinated the Steel Plate Fabricators Association Steel Tank Seminars.

Mr. Knoy has a BS in Mechanical Engineering from Rose-Hulman Institute of Technology and a MBA from Indiana University. He is a registered professional engineer in 34 states, Washington, DC and one Canadian Province, an SSPC Protective Coatings Specialist, and a certified American Petroleum Institute Above Ground Storage Tank Inspector.

Chapter 6.2

Pipelines

by Robert H. Rogers

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I. SCOPE

This sub-chapter begins with a general discussion of the pipeline construction environment, general criteria for pipeline coating, various generic coating types commonly used on pipelines, and the compatibility considerations for different coating combinations.

This remainder of the sub-chapter deals with the inspection of coatings applied in the field to essentially completed pipelines for below ground or sub-sea services. It covers the application of various types of coatings in the field to girth weld joints and tie-in weld joints, as well as over-the-ditch application to entire lines. Basic procedures for inspection of pipeline coatings are presented first. This is followed by special inspection requirements for the following coating types:

- Fusion-bonded epoxy (FBE) and powder joint coatings
- Coal tar enamel systems
- Thermoplastic ("cold applied") tapes
- Heat shrink sleeves
- Solvent-borne thermoset coatings
- Solvent-free (hot spray) thermoset coatings

It should be noted that this sub-chapter does not address the inspection of coating application for aboveground service, coating application to the body of the pipe in the factory, or coating application at pump stations and similar facilities.

(Note: Further information relevant to coatings inspection on pipelines can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 4285 Method for Indicating Oil or Water in Compressed Air

ASTM D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

ASTM D 4940 Test for Conductimetric Analysis of Water Soluble Ionic Contaminants of Blasting Abrasive

ASTM E 337 Test Method for Measuring Humidity with a Psychrometer (The Measurement of Wet- and Dry-Bulb Temperature)

ASTM G 8 Test Methods for Cathodic Disbonding of Pipeline Coatings

ASTM G 42 Test Method for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures

American Water Works Association (AWWA)

AWWA/ANSI C 203 Coal-Tar Protective Coatings and Linings for Steel Water Pipelines - Enamel and Tape - Hot Applied

AWWA/ANSI C 210 Liquid Epoxy Coating Systems for Interior and Exterior of Steel Water Pipelines

AWWA/ANSI C 213 Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines

AWWA/ANSI C 216 Heat-Shrinkable Cross-Linked Olefinic Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines

Deutsches Institut für Normung e. V. (German Standards Institution; DIN)

DIN 30672 Corrosion Protection Tapes and Shrink Sleeves. Pipe Wrappings of Corrosion Protection Tape and Shrink Sleeves for Underground Pipelines Destined for Gas and Water Supply

NACE International (NACE)

NACE RP0169-92 Control of External Corrosion on Underground or Submerged Metallic Piping Systems

NACE RP0274-93 High Voltage Electrical Inspection of Pipeline Coatings Prior to Installation

NACE RP0375-94 Application and Handling of Wax-Type Protective Coatings and Wrapper Systems for Underground Pipelines

NACE RP0490-95 Holiday Detection of Fusion Bond Epoxy External Pipeline Coatings of 10 to 30 mils (0.25 to 0.76 mm)

Control of Pipeline Corrosion, A.W. Peabody, NACE International, Houston TX, 1967.

Pipe Protection: A Review of Current Practice, U. Hassan, C.E. Jewsbury, A.P.J. Yates, Paint Research Association.

SSPC: The Society for Protective Coatings (SSPC)

SSPC-AB 1 Mineral and Slag Abrasives

SSPC-SP 1 Solvent Cleaning

SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

SSPC-PA 2 Measurement of Dry Coating Thickness with Magnetic Gages

SSPC-Paint 16 Coal Tar Epoxy-Polyamide Black (or Dark Red) Paint

SSPC-Vis 1 Visual Standard for Abrasive Blast Cleaned Steel

SSPC-Vis 3 Visual Standard for Power- and Hand-Tool Cleaned Steel

US Army Corps of Engineers

C200 Coal Tar Epoxy

III. ABOUT PIPELINES

Pipelines constitute a significant portion of many industries, particularly the oil, gas, water, sewage, and mining industries. In these industries, steel pipelines may serve a variety of purposes. For example:

- In the oil industry, there are crude oil product pipes and service pipes on the oil production platform; pipelines from the platform to storage and loading areas, or directly to shore; pipelines from the shore to the refinery; and pipe-work within the refinery itself
- In the gas industry, steel pipelines are used for gas transmission.
- In the mining industry, pipelines are used for hydraulic transport of solids, e.g., long distance transport of iron ore slurries.

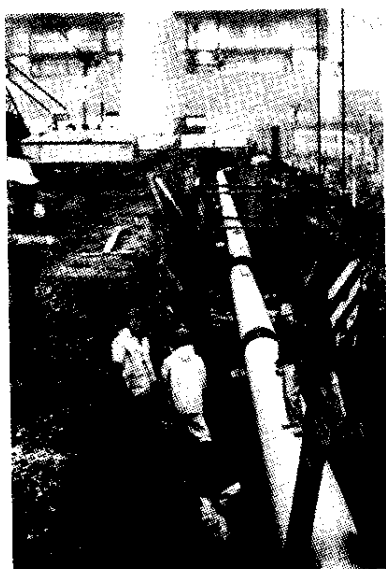


FIGURE 6-12. Pipeline in trench. Courtesy of S.G. Pinney & Associates, Inc.

Within these industries, steel pipelines may be exposed to a variety of environments: they may be underground (Figure 6-12), overland, or submerged. This sub-chapter focuses on pipelines for below ground or sub-sea services.

The assurance that a pipeline has been properly coated before burial or laying at sea is valued greatly by the owner. Getting it right the first time is of prime importance because maintenance or refurbishment of the pipeline coating over a typical 25 year life span is impossible or, at best, a very expensive proposition. Inspection is a key part of the effort to prevent corrosion and produce the documentation required to assure the owner that quality workmanship, conformity to the specification, and long life potential will be achieved.

IV. INSPECTOR BACKGROUND AND EXPERIENCE

For buried pipelines, preventing corrosion is especially challenging because the jobsite is always moving and the mechanisms of soil corrosion and corrosion protection are multifaceted. The coatings inspector for pipelines should, therefore, have knowledge and experience in the following areas:

- Constraints of the construction environment
- Basic soil mechanics
- Basic corrosion mechanisms
- Cathodic protection, and other means to supplement the corrosion protection provided by coatings
- Methods of destructively testing a pipeline coatings' mechanical properties (such as peel strength, lap shear strength, pull off adhesion, etc.)

The inspector should also be aware of the modes of failure experienced by actual pipeline coatings in service. A.W. Peabody's book on cathodic protection (see references) published by NACE is recommended reading.

V. APPLICATOR QUALIFICATION

Before pipeline coating operations begin, it is incumbent on the engineer or owner to qualify the coating procedure and the applicator's skill through testing his application skills. The inspector may have a significant role in the qualification testing or only be involved by monitoring the applicator's procedures during the execution of the job.

The applicator should furnish an application procedure for the product to be applied. The product selected should be applied in accordance with the written application procedure on test pipe identical to pipeline pipe. In order to qualify, the applied coating must pass the inspection criteria and destructive evaluations as required by the job specification.

For manual application processes, each individual applicator should be trained to apply the coating in accordance with the written application procedure. The applicator candidate should demonstrate proficiency by applying coating to actual pipeline pipe and passing the visual and destructive evaluations. Disqualified applicators should be required to retrain and successfully pass re-testing.

VI. THE PIPELINE CONSTRUCTION ENVIRONMENT

A. CONSTRUCTION OVER LAND

The prevalent industry practice for providing corrosion protection to pipelines is to furnish factory coated pipe to the field in 20, 40, or 80 foot (6, 12, or 24 meter) lengths, weld the joints together, and apply a joint coating to the weld area. The field weld area consists of the girth or circumferential weld and the bare steel pipe surface on each side of the weld where the pipe's factory coating was "cut back" away from the pipe ends. This cut-back distance is determined by the welding process and the factory coating's resistance to the heat of welding. Typical cut-backs range from six inches for a polyethylene pipe coating to one inch for fusion-bonded epoxy.

Another construction option, common inside petrochemical plants, but less prevalent in cross-country pipelines, is to weld the bare pipes together into a completed line before any coatings are applied (Figure 6-13). The protective coating is then applied "over the ditch" to the cleaned body of the pipe and to the joining welds in one continuous, seamless application. The application process moves down the pipe behind the joint welding crew. This second option could potentially provide a high quality continuous coating without transportation damage.

However, over-the-ditch coating is not prevalent because the field conditions are seldom ideal for coating application. The necessary conditions can be maintained in the controlled environment of a shop or pipe mill. While some

FIGURE 6-13. Sequence for pipeline construction over land. Top - Pipes are "strung" along right-of-way. Center - Strung and bent pipes are welded and joints are coated. Bottom - Welded and coated pipes are "lowered in." All three photos courtesy of Bechtel Corporation.





FIGURE 6-14. Application of continuous reinforced concrete pipe coating. Courtesy of Bredero Price Co.

coatings are amenable to the field application method, many sophisticated coating operations are practically impossible to sustain out of a factory setting. Many would be impossible to properly control on a moving stage traveling down the pipeline.

B. LAY BARGE OPERATIONS

Pipelines laid in the sea, rivers, or lakes, with a few notable exceptions, are laid from barges (called "lay barges"). These are specially designed for the purpose of welding coated pipe lengths and patching the shop applied coating at the weld joints. One exception where marine pipelines are not laid from a barge is where they are completed and coated on shore and towed into position. For these lines, most of the comments above for over land pipeline construction are applicable.

Pipelines with diameters above 8 to 12 inches (20 - 30 cm; depending on the pipe wall thickness) usually require a concrete weight coating applied over the corrosion protection coating to prevent floating (Figure 6-14). In some cases precast concrete weights may be used instead of a continuous weight coating. Precast weights may produce stresses detrimental to the pipe coating, whereas a continuous concrete application spreads the weight uniformly over the coating. When a weight coating is used, the weight coating, like the corrosion coating, must be cut

back from the pipe end for welding. For many owners it is desirable that the concrete weight coating is made continuous across the joint in order to prevent snags as the pipe is fed over the rollers of the lay barge or later when laid and exposed to anchors, shrimp nets, or the like.

The operations of welding, joint coating, inspection, and application of the weight coating to the joint area (infill) must be accomplished at tandem work stations. Usually operations require that the work at a station be completed in 10 to 15 minutes before the completed joint is released off the end of the barge and all joints move up one station. Tough joint coatings that can be immersed quickly are best suited for lay barge operations. The application environment on the barge is less favorable to coating than shop environments and most environments encountered over the ditch on land. Chloride contamination of the substrate by sea water or salt air will lead to early failure of most joint coatings.

VII. CRITERIA FOR PIPELINE COATINGS

A. JOINT COATINGS

The mission of the joint coating is to protect the field weld area of the pipe from soil or water corrosion. The success of the joint coating in providing protection for the weld joint must be judged in relation to the expected performance of the adjacent pipe coating. Ideally, the two systems should provide equivalent corrosion protection. In actual practice the field-applied coating rarely achieves the quality of protection afforded by the factory-applied coating.

In order to provide effective corrosion prevention, the joint coating must exhibit five primary characteristics.

1. Compatibility with the pipe coating, both in pipeline operation and during application.
 - The application temperature for the joint coating must be less than the temperature limit for the pipe coating.
 - The joint coating must adhere to the pipe coating as well as to the exposed portion of steel pipe.
 - There must be no adverse reaction of the pipe coating to the joint coating material or application procedure.
2. Withstand soil and pipe laying stresses and maintain position and integrity.

- The coating should not slide down the pipe, roll up, crack or wrinkle as the soil and pipe move in relation to each other.

- The joint coating must resist being damaged by lay barge rollers or lowering-in equipment.

3. Function well with the cathodic protection (CP) system resulting in minimum cathodic disbondment and producing minimum areas of cathodic protection shielding.

- Cathodic disbondment at or above the operating temperature should be 25 mm (1 inch) maximum disbondment radius at 28 days per ASTM G42; or should be less than the value obtained for the adjacent pipe coating at the operating temperature.

- The coating should have no visual or electronically detectable holidays.

- The application method must prevent voids between the pipe and coating which could shield the cathodic protection current.

4. Resist breakdown from exposure to soil or water chemistry.

5. Minimize the diffusion of oxygen and water to the steel surface.

B. OVER-THE DITCH COATINGS

The criteria outlined above for joint coatings are also true for over-the ditch pipe coatings. One exception is that compatibility with a mill coating is no longer of concern since the pipe is bare. Of course this concern is replaced by a new one--the coating must be compatible with line travel application machine and the field environment.

VIII. COATINGS USED ON PIPELINES

A. FUSION-BONDED EPOXY

Fusion-bonded epoxy (FBE) is a coating system applied to the body of a pipe in the pipe mill or to the field weld joints along the right-of-way at the side of the ditch.

Fusion bonded epoxy is one of the most commonly used factory coatings. The field welds are cleaned, the joint area is heated, and the epoxy powder is sprayed by a set of mechanized powder flocking heads rotating around the pipe. The powder contacts the pipe, melts, flows out, and finally solidifies with cooling to obtain the epoxy coating.

FBEs are discussed further in Chapter 5.8. Also, more information is available in AWWA C213.

B. POWDER THERMOPLASTICS

Powder thermoplastic coatings are applied much like the FBE and are used primarily for factory coating. They may be used in this regard with FBE primers to produce multi-layer systems. For example, one proprietary 3-layer pipe coating system uses thermoplastic second and third layers sprayed as a powder. Powder thermoplastics have been used experimentally on joints. The use of powder thermoplastics in the field is not widespread, but may become practical in the future as a joint coating used in conjunction with the other thermoplastic factory coating including extruded thermoplastic. Powder thermoplastic coatings are discussed further in Chapter 5.8.

C. EXTRUDED THERMOPLASTICS

The slide and ring extrusion processes for covering a pipe with polyethylene, polypropylene or other thermoplastic are strictly factory processes. Field joint coating using extrusion methods are not common because of the heavy extrusion die required. Developing field processes do offer promising methods of producing a homogeneous joint coating for lines factory coated with polyethylene.

D. COAL TAR ENAMEL

Coal tar enamel is used frequently in over-the-ditch applications. It is also used as a shop applied pipe coating, as well as a joint coating in the field. When coal tar is applied in the factory, the field joints may be coated later with the same or another compatible system. Coal tar enamel has enjoyed a relatively long and generally revered history as both a factory applied coating and a coating for over-the-ditch application. However, it is now not permitted for field or over-the-ditch applications in several states, due to clean air and safety restrictions.

Often referred to as hot tar, coat and wrap, the coal tar enamel coating system consists of a primer, coal tar, glass fabric, and felt. The glass fabric and felt are spiral wrapped into the melted tar by the line travel machine. The number of tar and fabric layers can be increased to enhance coating thickness, toughness, and impermeability. When coal tar coatings are used as a field joint coating, the application is by hand and the fabric and felt layers may be cigarette

wrapped rather than spiral wrapped. Usually when the coal tar enamel is used as a joint coating, it is used in conjunction with coal tar enamel mill coated pipe.

E. THERMOPLASTIC TAPES

Thermoplastic tapes consist mostly of a polyethylene or polyvinylchloride backing with a thermoplastic adhesive on the pipe contact side. Because the adhesive or mastic is attached to the thermoplastic sheet backing in the factory, they are often called prefabricated tapes. More information on them can be found in AWWA C203 and AWWA C209.

Thermoplastic tapes are used frequently in field over-the-ditch-applications. They are also used as shop applied pipe coating as well as joint coatings in the field. As joint coatings, they can be used with a variety of mill coatings.

The tapes are normally applied by hand or by hand operated (line travel) machines as field weld joint coatings. Like the glass fabric and felt of the coal tar enamel coatings, the tape can be spiral or cigarette wrapped. Tension in the tape during application is needed to promote intimate contact with the pipe surface. This intimate contact is required to obtain good adhesion.

It should be noted that petrolatum and petroleum wax-based tapes are also sometimes used on pipelines. They are suitable for above ground service. They perform especially well on valves, fittings, connections, road crossings, and other short runs of pipe. Chapter 5.11 provides further information on the application and inspection of petrolatum and petroleum wax-based tapes.

F. HEAT SHRINK SLEEVES

Heat shrink sleeves used to protect field weld areas on pipelines are furnished in two forms: Tubular sleeve and wrap-around sleeve. The tubular sleeve has no longitudinal seam and must be slid over the end of the pipe before the joint is made. The wrap-around sleeve, on the other hand can be wrapped around the weld area after welding and closed to form the "sleeve" using a heat activated closure strip or mechanical zipper. For large diameter pipe, the tubular sleeve is not practical. More information on heat-shrink sleeves is available in AWWA C216.

The shrink sleeve consists of irradiated polyethylene sheet or backing covered with a heat activated mastic or adhesive.

The backing can be reinforced with glass or other fabrics to increase toughness for road crossings, river crossings, and other similar applications. The adhesive is a thermoset or thermoplastic, exhibiting various melting points, lap shear strengths and operating temperature limits depending on formulation. When the sleeve is placed on the pipe, an inner protective release paper is removed, allowing intimate contact of the adhesive to the prepared steel surface and overlapped pipe coating surface as the sleeve is heated and shrunk.

In rare situations, heat shrink sleeves can be used over the ditch to protect short pipeline runs, but primarily they protect field welds. Shrink sleeves are also used for repairs to various shop applied pipe coatings.

G. SOLVENT-BORNE THERMOSET COATINGS

Solvent borne thermoset coatings such as traditional epoxy, coal tar epoxy, polyurethane, and polyester have been used to coat pipe in the shop. They have also been used to coat completed pipelines over the ditch, but very rarely. The coating is applied through conventional or airless spray equipment that may be modified for line travel. In order to adhere to the steel, the thermoset coatings require a much cleaner substrate than the thermoplastic pipe coatings. Coal tar epoxies are described in SSPC-Paint 16 and Corps of Engineers Specification C200.

The epoxy coatings usually average 16 to 20 mils (410 - 510 micrometers) in thickness without any fabric reinforcement in the film. Some thermoset pipe coatings utilize a glass or other fabric reinforcement wrapped into the coating to increase thickness and enhance mechanical strength. Epoxy coatings can demonstrate some of the most favorable, smallest cathodic disbondment values of any pipe coating. Glass reinforced polyester coatings are also used for joint coatings. They are less extensively used for line travel applications. The unreinforced thermoset coatings typically do not fail by disbondment of the coating in sheets, but rather fail from discrete holidays which slowly expand in size under the influence of the cathodic protection system.

H. SOLVENT FREE (HOT SPRAY) THERMOSET COATINGS

Solvent free coatings must usually be applied by heating the resin and pumping it through a high pressure airless spray unit. The catalyst is mixed with the hot resin just before the spray gun, or in the spray gun. This application scheme allows for the formulation of coatings that cure quickly and can be applied in a single coat to thicknesses of one millimeter (40 mils) or more without reinforcement. Epoxy, coal tar epoxy, polyurethane, and coal tar polyurethane are the most prevalent types. The coatings are applied in the field on new lines as well as old lines using line travel techniques.

Joint coatings suitable for use on a wide range of factory coatings are possible because of the short cure time. Like the solvent borne thermoset coatings, these coatings generally do not disbond in sheets and thereby shield the cathodic protection system.

IX. COATING COMPATIBILITY

Table 1 summarizes the coatings used in pipeline protection, notes where the coating is normally applied (factory or line travel), and shows which coatings are suitable for field joints with a particular mill or factory coating.

X. SURFACE PREPARATION AND COATING APPLICATION

A. GENERAL INSPECTION PROCEDURES

The inspector must be present at critical points in the construction process (hold points) to find and, when given the authority, reject defects and other specification deviations.

The following material and surface preparation inspections should be performed for all pipe coating jobs:

1. Upon receipt of the coating materials, tapes, sleeves, or other products in the field, the inspector should make sure they are stored in conformance with the manufacturer's storage recommendations, and in an area where they will not get too hot.
2. Materials should be inventoried, recording product and batch or lot numbers. The unopened containers

should exhibit the manufacturer's original markings. Manufacturers should be contacted to confirm shelf life expiration date, if not evident on the product markings. Batches should be used consecutively, oldest first.

3. Mineral abrasive used for blast cleaning should be checked to assure that it is free of foreign matter, clay, and soluble salts, and is capable of producing the minimum profile. The procedures outlined in SSPC-AB 1 and ASTM D 4940 (for conductimetric analysis) should be followed (Figure 6-15).

4. If required by the specification, the surface of the pipe should be tested for the presence of any chloride, sulfate or other contaminants that would cause cathodic disbondment, blisters, or loss of adhesion. Soluble salts can be removed by water washing, and

TABLE 1. Pipeline coatings.

Coating Description	Factory Applied	Line Travel	Field Weld Joint Options
Fusion-bonded epoxy	yes	no	Fusion-bonded epoxy Powder thermoplastics Thermoplastic tapes Heat shrink sleeves Solvent-based thermosets Hot spray thermosets
Powder thermoplastics	yes	no	Fusion-bonded epoxy Powder thermoplastics Thermoplastic tapes Heat shrink sleeves Hot spray thermosets
Extruded thermoplastics	yes	no	Thermoplastic tapes Heat shrink sleeves Hot spray thermosets
Coal tar enamel	yes	no	Coal tar enamel Thermoplastic tapes Heat shrink sleeves
Thermoplastic tapes	yes	yes	Thermoplastic tapes Heat shrink sleeves
Heat shrink sleeves	yes	no	Heat shrink sleeves
Solvent-borne thermosets	yes	yes	Fusion bonded epoxy Powder thermoplastics Thermoplastic tapes Heat shrink sleeves Solvent-based thermosets Hot spray thermosets
Hot spray thermosets	yes	yes	Fusion bonded epoxy Powder thermoplastics Thermoplastic tapes Heat shrink sleeves Solvent-based thermosets Hot spray thermosets

FIGURE 6-15. Surface preparation of a field joint.
Courtesy of Bechtel Corporation.



phosphoric acid washing (followed by water washing), but not by abrasive blast cleaning alone.

5. The compressed air supply should be checked to determine if water or oil are present. (Details of how to perform this test are given in ASTM D 4285 and in Chapter 8.)

6. Factory-applied coatings should be inspected. Factory-applied coating on the pipe may be damaged in transit to the right-of-way and require repair using the same materials used on the field weld joints or some other specified material. Damage should be identified and marked for repair. (Note: Cathodic protection lead connections to the pipe will cause the pipe coating to require repair.) After completing the repairs, the pipe coating should be subjected to a holiday test appropriate for the pipe coating and the repair coating. The guidance of NACE RP0274-93, NACE RP0490-95, or AWWA C203 should be followed for test voltage determination and methodology. The latter two are specifically for fusion-bonded epoxy and coal tar enamel, respectively.

7. Steel surfaces should be inspected for weld spatter, slivers, gouges, scabs, or laminations that protrude from the surface and can cause a holiday in the coating. The correction of metal defects should be monitored to confirm that hand tools are used that do not contaminate the surface, burnish the surface, or remove excessive metal reducing the pipe wall thickness below that allowed by the pipe material specification. Pneumatic tools which do not have traps on the exhaust air are

likely to contaminate the surface. The owner should be consulted if power tool grinding or rewelding is potentially required to correct metal defects. Because many of the metal defects such as laminations are only obvious after abrasive blasting, the inspection should be repeated after blast cleaning.

8. Before any surface preparation or coating application begins, the inspector should verify that the pipe surfaces are at least 5°F (3°C) above the ambient dew point. Unless it is raining, heating the pipe surface will usually raise the steel temperature above the ambient dewpoint; and many pipeline surface preparation and coating processes incorporate heating. The ambient dew point should be determined by using a sling psychrometer or other appropriate instrument, following ASTM E 337. The pipe temperature should be measured with a magnetic contact thermometer or a digital contact pyrometer.

B. INSPECTION PROCEDURES FOR FBE AND POWDER JOINT COATINGS

For FBE and powder joint coatings, the inspector should verify that:

1. The specified level of surface preparation is attained. The field welds are cleaned with portable abrasive blasting equipment to achieve a Near White Blast Cleaned surface, SSPC SP-10. In the process of cleaning the steel, the adjacent mill coating, usually FBE, is roughened slightly to facilitate adhesion of the joint coating to the pipe coating.
2. The joint area is at the proper temperature. Before coating, the joint area should be heated (usually with an induction heater) so that its temperature is within the specified application temperature range as recommended by the coating manufacturer. The temperature of the pipe during coating application should allow for complete fusion, flow-out, and wetting (i.e., no premature gelation), and should not be lower than that at which optimum polymerization occurs. The post-application cure temperature and time should not be less than that required for full cure of the applied coating. For accurate control of temperature, the joint area should be checked with a heat indicating crayon or other suitable device, making sure that the amount of materials deposited and the length of the marks will be limited and be wire brushed from the surface before coating application.

3. The manufacturer's recommendations for full curing are followed. The curing reaction of the coating must be completed prior to any forced cooling, inspection, and repair. Accurate magnetic film thickness readings may not be possible when the steel is above 150°F (66°C). The thickness gage should have a zero to 40 mil (1 mm) working range and should be calibrated frequently. Thickness for powder joint coatings normally range from about 12 to 16 mils (300 to 410 micrometers).

After application, the inspector should:

1. Visually inspect the finished coating using bright light and confirm the surfaces are free of voids, loss of adhesion, blistering, excess powder mounds, peeling, bluing (a blue color resulting from oxidation--a sign that the pipe has been heated to hot, and may have changed heat treatment properties), lifted pipe scabs, and discoloration from burning or substrate rusting.
2. Inspect all surfaces of the coated joint using a high voltage holiday tester (NACE RP0490-95) (Figure 6-16). The voltage should be set in accordance with specification requirements or the coating manufacturer's recommendations. Joints with more than two or three holidays should be re-blasted and recoated after correcting any faults in the surface preparation or coating process.
3. Check the coating hardness and solvent resistance in accordance with the job specification or manufacturer's instruction.

C. INSPECTION PROCEDURES FOR COAL TAR ENAMEL SYSTEMS

For coal tar enamel systems, the inspector should:

1. Verify that the specified level of surface preparation is attained. For coal tar enamel AWWA C203 now requires cleaning to SSPC-SP 6 or SP 10 (although much coal tar enamel has been successfully applied using a power wire brush surface preparation). If SSPC-SP 6 or SSPC-SP 10 are required, SSPC-Vis 1 should be used to evaluate the degree of cleaning. If the coatings are used as a joint coating, the inspector should ensure that the pipe coating is prepared at the overlap to ensure proper tie-in of the joint coating.
2. Monitor pipe preheating. Pipe preheating may be required. Preheat temperatures should be checked with

FIGURE 6-16. Holiday testing of a coated pipeline. Courtesy of KTA-Tator Inc.



thermometers, pyrometers, or temperature indicating crayons.

3. Observe the application of the primer. After surface preparation, usually a solvent based tar primer is applied. The inspector should monitor the primer application for uniform coverage. Primer usage rate should be monitored to calculate the primer thickness. Direct measurement is usually not possible because the enamel must go on while the primer is tacky. The inspector should verify that specification requirements or the manufacturer's guidelines are followed for the time between primer and the next application.
4. Observe the application of the enamel. For enamel systems, the inspector should ensure that:
 - The enamel pot, or tape is at the correct temperature during application. Not only temperature, but agitation of the coal tar enamel is critical to prevent "hot spots."
 - The glass fabric is completely embedded in the tar enamel.
5. Check the finished coating thickness to confirm all layers are present and tape tension was correct during application.
6. Holiday test in accordance with NACE RP0274-93 and repair the holidays before the lowering of the pipe into the ditch.

D. INSPECTION PROCEDURES FOR THERMOPLASTIC TAPES

1. Verify that the specified level of surface preparation is attained. For thermoplastic tapes, surface preparation ranges from Near White Blast Cleaning (SSPC-SP 10) to Power Tool Cleaning (SSPC-SP 3). For petrolatum and petroleum wax-based tapes, typically, wire brushing is specified to remove accumulated grime, loose rust or scale, and frost.

If SSPC-SP 3 is the required surface preparation, SSPC-Vis 3 should be used to evaluate the degree of cleaning. Wire brushes and scrapers should be checked to see that they are replaced when they wear out. Oil and grease can quickly be spread by the brushes in an automated process. All surfaces ahead of the surface preparation process should be inspected to ensure that solvent cleaning removes completely any oil or grease deposits.

2. Monitor pipe preheating. Depending on the formulation of the thermoplastic adhesive, the tapes may be applied cold or with heat. When applied with heat, the tape systems develop a more continuous barrier across the spiral overlaps. Pipe preheating may be required. Preheat temperatures should be checked with thermometers, pyrometers, or temperature indicating crayons.

3. Observe the application of the primer. After surface preparation, usually a solvent based tar primer is applied. The inspector should monitor the primer application for uniform coverage. Primer usage rate should be monitored to calculate the primer thickness. Direct measurement is usually not possible because tape must go on while the primer is tacky. The inspector should verify that specification requirements or the manufacturer's guidelines are followed for the time between primer and the next application. (Note: In the case of petroleum wax or petrolatum primers, drying or curing of the primer does not occur.)

4. Observe the application of the tape (Figure 6-17). For thermoplastic tapes, the inspector should ensure that:

- The tension of tapes during the spiral wrapping process is correct.
- The tapes are correctly overlapped.
- There are no air bubbles, voids or wrinkles in the tape.

- The adhesive is continuously extruded along the edges of the thermoplastic backing.

5. Visually inspect the finished coating to confirm all layers are present and tape tension was correct during application. This inspection should also include checking for proper seal and width of the overlap, nicks or cuts on the outer film of the tape, excessive or severe wrinkling, or any other obvious mis-application. The completed system should be impervious to the entrance of moisture.

6. Holiday test in accordance with NACE RP0274-93 and repair the holidays before the lowering of the pipe into the ditch.

E. INSPECTION PROCEDURES FOR HEAT SHRINK SLEEVES

For heat shrink sleeves, the inspector should:

1. Confirm that all mill scale, weld slag, and rust are removed by blast cleaning (or power tool cleaning if specified) from the girth weld area. When shrink sleeves are used as a joint coating or for repairs to various shop applied pipe coatings, the area of the pipe coating to be overlapped by the sleeve may require abrasive blast cleaning or other specified treatment to promote adhesion of the sleeve to the pipe coating. Preparation of the surface normally includes: solvent cleaning to remove contamination, Near-White Blast Cleaning (SSPC-SP 10), preheating the pipe surface,

FIGURE 6-17. Manual application of a tape to a pipeline. SSPC file photo.



and, in many cases, application of a primer. The inspector should verify that the specification requirements for degree of cleaning and surface profile are attained. These are typically SSPC-SP 10 and 2.5 mils (64 micrometers) profile depth.

2. Observe the preheating of the pipe. Heat causes the adhesive to melt and the polyethylene to shrink. Because the shrink sleeve is a poor thermal conductor, it is advisable to preheat the pipe, as much as the pipe coating will allow, before the sleeve is placed over the weld area. Preheating of the pipe before the sleeve is in place can be accomplished using a propane torch, infrared heater, or an induction heater. This step is required to store heat energy in the pipe and promote adhesive flow-out. Once the sleeve is in place the rate of heat input to the steel is limited by the insulating qualities of the polyethylene.

The preheating of the pipe should be observed to determine where cold and hot spots will be. The steel temperature should be measured with a contact pyrometer or thermometer to determine when preheat temperatures are reached and the sleeve or primer application should begin.

3. Verify complete coverage by primer (if primer is used) and estimate film thickness compliance from coverage. In order to prevent "tenting," specifications may call for the use of filler putty to be applied adjacent to welds, at the edges of overlapped coating, or underlapped sleeve edges.

4. Observe the placement of the sleeve.

5. Verify that the sleeve zip leads or closure strip are properly installed.

6. Observe the shrinking of the sleeve. Once in place, the pipe sleeve is shrunk using a controlled and limited application of heat from a propane torch or an infrared heater. The inspector should observe the heating of the shrink sleeve to ascertain if the heating is even and results in the sleeve shrinking uniformly.

The gas fired infrared heater offers the best method for shrinking the sleeve. The heater distributes radiant heat in a narrow band continuously around the pipe circumference. The machine moves down the pipe at a fixed rate, shrinking the sleeve uniformly, thus allowing air to move out from under the sleeve ahead of the moving pipe/adhesive contact ring.

Heating by torch requires the applicator to skillfully heat the center of the sleeve, all around the circumfer-

ence, and work the shrinking sleeve with the torch and roller to move the air bubbles out under the edge of the sleeve. Much effort and skill are required to obtain installation without numerous air bubbles. Overheating can result in charring and splitting of the sleeves.

Times for application of the sleeves ranges from about five minutes for a three inch diameter pipe to 30 minutes for a 48 inch (120 cm) diameter line. These times are dependent on the manufacturer's required preheat temperature, ambient temperature, pipe wall thickness, and applicator's proficiency. Usually only one man is required for pipe diameter up to 14 inches (36 cm). A 48 inch (120 cm) line requires a three-man crew, if an epoxy primer is used.

7. Visually inspect the finished sleeve. The finished sleeve should meet the following requirements:

- When tapped lightly with a blunt object and when observed visually, especially over weld profiles where "tenting" can occur, no detachments from the substrate or air bubbles should be detected in excess of those specified. A good guideline for air bubbles is: No void larger than 3 in.² (19 cm²); no void larger than 0.5 inch (13 mm) in diameter within two inches of the sleeve edge; and not more than 16 voids larger than 0.5 inch (13 mm) in diameter per 10 ft² (0.9 m²) of sleeve area.

- The sleeve surface should be free of burns, punctures, and scrapes reducing the polyethylene thickness by more than 25%, or other surface defects defined in the manufacturer's literature.

- Primer (if required) and hot melt adhesive should be visible on the pipe coating continuously around the circumference of the sleeve edge. The primer should be applied sufficiently past the overlap area so that it always shows. The hot melt adhesive should flow out from under the sleeve edge but not completely obscure the primer at any point. The polyethylene should overlap the pipe coating at least two inches.

8. Verify the adhesion of the sleeve to the pipe coating. The adhesion of the sleeve to the pipe coating should withstand attempts to lift both edges of the sleeve with the fingernail.

9. Spark test the sleeve, if required. Shrink sleeves can be spark tested, but two points must be kept in mind: the mastic or copolymer adhesives alone can prevent detection of holidays in the polyethylene backing, and holidays due to wrinkles at the overlaps may not be

detected because the path to the steel under the polyethylene is too long.

F. INSPECTION OF THERMOSET COATINGS

For thermoset coatings, the inspector should:

1. Determine that the mineral abrasive is free of contaminants and meets the requirements of SSPC-AB 1. The specification may require acid cleaning or water washing followed by a test of the surface to confirm the absence of soluble salts before abrasive blast cleaning begins.
2. Verify that the degree of cleaning and anchor profile specified are achieved. For solvent-borne thermosets, surface preparation usually is SP 10, Near-White Blast Cleaning. Blasting is often accomplished with centrifugal steel grit blasting machines, but automated mineral abrasive machines have also been used over the ditch. Commonly used epoxy and coal tar epoxy systems are described in AWWA C210 and in SSPC-Paint 16 and Corps of Engineers, C200, respectively.

For solvent-free thermosets, the surface preparation is much like the surface preparation for other thermoset coatings. However, because of the greater film thickness, a deeper anchor profile is required. Typically cleaning to SSPC-SP 10 or SSPC-SP 5 with a 2.5 to 4.0 mil (64 to 100 micrometers) anchor profile are required for the steel substrate.
3. Inspect the existing pipe coating (if the thermoset is to be applied as a joint coating) to confirm that it has also been roughened by the abrasive blast cleaning process or other specified means. The roughening of the pipe coating should extend at least one inch past the area of expected overlap. After the joint coating is applied the edge of this abraded area of the pipe coating should still be visible and confirm the roughening was accomplished.
4. Measure the coating thickness using a magnetic film thickness gauge. (This should be done after the applied coating hardens so that it can not be cut with a fingernail.) The inspector should confirm the coating thickness is within the specified minimum and maximum for the area over the steel. Many solvent borne epoxy coatings are applied at 16 to 20 mils (410 to 510 micrometers) while the hot spray coatings like tar-polyurethane may be applied as thick as 60 mils (1500

micrometers) or more. Ideally the working range of the gauge should be about 2.1 times the nominal coating thickness and, for joint coating applications, capable of measuring both the pipe coating thickness plus 2.1 times the joint coating thickness.

For joint coatings, the inspector should also confirm the minimum and maximum thickness requirements are met in the area overlapping the pipe coating. The overlapping coating thickness can be determined as follows:

- Measure the thickness of the pipe coating at five places on both sides of the joint, away from the joint coating.
- Take an average of those five measurements.
- Subtract this value from the magnetic gauge readings taken in the overlap areas.

For thermoset joint coatings, maximum thickness, especially in the overlap area, is an important limit because coatings that are too thick will tend to lose adhesion from the substrate, despite a good anchor profile.

Areas deficient in thickness may require additional coating to be applied; however, if the time between coats exceeds the manufacturer's recommended recoat time (window), the deficient coating should be abraded by sanding or abrasive blasting to roughen the surface and provide a mechanical coupling for the subsequent coating. Coal tar epoxy coatings and many of the hot spray coatings with short cure times have particularly narrow recoat windows. Attempts to recoat after several days, or hours in some cases, without roughening the surface can result in delamination of the added layer.

5. Carefully monitor curing in relation to the manufacturer's data for coating hardness, at a given temperature and time. Coatings that will not ever cure completely, because of improper mixing or for other reason, must be identified quickly before the pipeline is buried. See Chapter 8 for methods of determining complete curing.
6. Test for holidays using a high voltage spark tester.

XI. HEALTH AND SAFETY

For pipeline construction over land, ditching procedures should be according to owner specifications and OSHA requirements. This also will include the proper support of

pipe on skids. All other measures and procedures that maximize safety considerations should be utilized.

XII. SUMMARY

Many types of coatings can be applied to pipelines in the field. The coatings inspector working on pipelines should be familiar with the properties, compatibilities, application procedures, and inspection procedures for the particular coatings being used. If required by the specification, the inspector may also have to verify that applicators are qualified to apply that particular coating. The inspector should also be familiar with the construction environment, be it construction over land or a lay-barge operation. It is also very important that the inspector understands the basics of soil and corrosion science and cathodic protection.

When joint coatings are applied in the field, the inspector is responsible for the usual coatings inspection activities, such as inspection of coating materials, monitoring of ambient conditions, and monitoring of surface preparation and coating application.

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Chapter 6.3

Underwater Inspection

by Randall M. Baker

OUTLINE

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I. SCOPE

This sub-chapter presents an overview of how coatings inspection operations are performed in an underwater environment. It includes discussions of:

- Reasons for performing underwater inspection
- Benefits of underwater inspection
- Unique challenges of underwater inspection, such as life support and access
- Technology used to assist in underwater inspection

It also describes the procedures, methods and unique considerations that may be applied by divers performing underwater coating inspections. (Note: Further information relevant to underwater inspection can be found in other sub-chapters of this chapter and in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Society for Testing and Materials (ASTM)

ASTM D 610 Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces

ASTM D 660 Test Method for Evaluating Degree of Checking of Exterior Paints

ASTM D 714 Test Method for Evaluating Degree of Blistering of Paints

ASTM D 4541 Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

Code of Federal Regulations (CFR)

29 CFR 1910.29 Subpart T, Commercial Diving Operations

SSPC: The Society for Protective Coatings (SSPC)

Steel Structures Painting Manual, Volume 1, Chapter 23, "Causes and Prevention of Paint Failure"

SSPC-PA 2 Measurement of Dry Coating Thickness with Magnetic Gages

SSPC-Vis 2 Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces

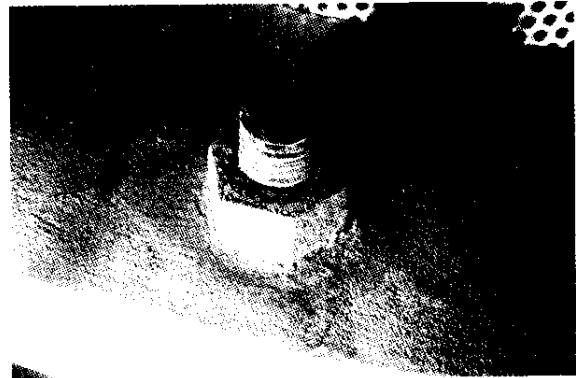
III. ABOUT UNDERWATER INSPECTION

A. WHY PERFORM UNDERWATER COATINGS INSPECTIONS?

Steel structures in water immersion service are subject to severe corrosion processes and often have complex designs and corrosion protection measures. However, since these structures are not visible nor readily accessible for normal maintenance procedures, coating failure and resultant corrosion are not generally discovered until after serious damage, such as structural or operational failure, has occurred. Thus, one important reason for underwater inspection is to avoid such serious damage. In natural bodies of water such as oceans, lakes, rivers etc., underwater inspection is normally the only practicable method of performing a meaningful coating condition assessment.

Underwater inspection using qualified diver/inspectors may also be required on man-made water retaining structures such as potable water, fire water, and utility water storage tanks; nuclear power plant suppression pools (Figure 6-18) and other structures. Although it may be possible to drain such structures for inspection (Figure 6-19), underwater inspection may offer the following advantages:

FIGURE 6-18. Corrosion on an underwater structure. Courtesy of Underwater Engineering Services, Inc.



- The structure remains operational.
- Vertical surfaces are easily accessible to the diver for hands-on inspection and testing, without the need for scaffolding or other staging apparatus. Many times, erection and dismantling of scaffolding and rigging causes significantly more damage to the coating than was present before the inspection!
- Existing coatings are not subject to wet/dry cycles. Epoxy coatings typically used as linings for immersion service can become embrittled by repeated wet/dry cycles.
- Intact blisters in the coating, particularly common in the lower regions of epoxy lined water storage tanks, are not exposed to embrittlement and subsequent fracturing and disbondment by foot traffic.

B. INSPECTION PLAN

It is essential that a detailed inspection plan be established prior to commencement of underwater inspections. The degree of planning and forethought has a direct bearing on the success of any project and is particularly important in the underwater environment. In order to ascertain the scope and level of detail of the inspection, it first should be established what type and extent of data is desired, and what decisions are to be made on the basis of available results. Obviously, these decisions must be heavily weighted upon available budget, schedule, and the potential negative effect of coating failure and subsequent corro-

sion and operability of steel structures and components. As a minimum, the inspection plan should include:

- Scope and extent of the inspection
- Type and extent of photographic and video documentation required
- Size, frequency, and distribution of inspection sample areas
- Methods and criteria for cleaning surfaces for inspection
- Important features requiring special attention, e.g., bolted connections
- Type, frequency, and location of nondestructive and destructive test methods
- Documentation methods

For periodic long term monitoring of a coated structure, the first inspection is considered the baseline assessment. Baseline data are necessary to establish trends and relate these trends to the capability of a coating to meet design requirements over time. The primary purpose of the baseline survey is to document the current condition of coatings and corrosion present on a structure. This allows comparison with future inspections. Accordingly, baseline inspections should be as detailed as possible, employing applicable visual, photographic, nondestructive and destructive inspections and tests. Subsequent inspections build on the baseline and generally require less effort.

IV. COATINGS USED ON STRUCTURES IN IMMERSION SERVICE

Steel structures in water immersion service include water tanks, ship hulls, piers, and hydraulic structures. Approved products for lining potable water tanks are most frequently epoxies. As discussed in Chapter 6.1, epoxy and coal tar epoxy systems are most commonly used to line waste water tanks. Typical materials on ship hulls are epoxies, polyurethanes, polyesters, vinyl copolymers, and resins that are mixtures of these and other basic materials. (Coatings for underwater use may also contain special components to resist marine growth and fouling.) Further information on these coating and lining materials is given in Chapter 5 and in Chapters 6.1, 6.5, 6.6, and 6.10.

FIGURE 6-19. Use of a cofferdam to apply materials for immersion service. SSPC file photo.



V. HEALTH AND SAFETY

A. DIVING AND DIVING SAFETY

It is not the intent of this sub-chapter to provide comprehensive instruction or commentary on conducting commercial diving operations. Let it suffice to say that the underwater realm is not our natural habitat, and as such underwater work is inherently dangerous and should be left to qualified professionals working in accordance with applicable codes and regulations. As a minimum, all commercial diving operations must be conducted in strict compliance with 29 CFR 1910.29. In addition, all diving operations should be conducted in accordance with a written Diving Operations Plan, that addresses key safety and operational issues such as:

- Dive Team Requirements
- Logistics
- Diving Mode
- General Work Scope Encompassed Under the Dive Plan
- Conditions
- Activity Hazard Analysis
- Diving Parameters
- Emergency Management Plan
- Tag Out Procedures
- Dive Procedures

- Alterations to the Plan

B. UNDERWATER WORK SYSTEMS

A myriad of other underwater work systems are available for underwater inspections, including manned and unmanned approaches. The selection of the appropriate system must be based on factors such as water depth, temperature, currents, chemical, biological or radiological hazards, and the nature and extent of inspection and tests to be conducted.

1. Unmanned approaches, such as the use of a remote operated vehicle (ROV) can often provide a safe and effective method of performing video inspections; and in some cases still photography, sonar imaging and certain nondestructive test methods. Unmanned inspection techniques should be considered when extreme depth or personnel hazards exist, as an ROV is not limited by decompression restrictions, as is a human. It is the intent of this sub-chapter, however, to address the hands-on approach, whereby the coatings specialist/diver performs inspections and tests on the actual coated surface, using the appropriate qualitative and quantitative techniques at his disposal.

2. Hard hat diving operations. Underwater inspections are often conducted in a polluted, congested, or otherwise hazardous environment. Much of this dive work is conducted utilizing surface supplied "hard hat" diving operations. This mode of diving employs a breathing air compressor at the surface, which continuously supplies the diver with breathing air, communications, video and lighting cables via a tethered "umbilical" to a diving helmet. Hard hat diving provides maximum head protection as well as isolation of the divers mouth, ears, eyes and nose from contact with hazardous chemical and biological contaminants which may be present in the water. Many types of surface supplied dive hats are available, including those with demand and free-flow air regulators, and a wide variety of communications and lighting options. Although the diver has limited mobility because of the tether, there is a great advantage in having direct verbal communication between the diver/inspector and the engineer or inspection team leader on the surface. In addition, this results in the ability to perform real time narration during video inspections. These make surface supplied diving with a fully enclosed helmet the optimum configuration for inspection work.

FIGURE 6-20.
Diver using
SCUBA. Courtesy
of Underwater
Engineering
Services, Inc.



3. SCUBA. It is not the intent of this section to preclude SCUBA (Self Contained Breathing Apparatus) as a viable diving mode for underwater inspections (Figure 6-20). This is particularly true in shallow (less than 30 meters; 100 feet), unpolluted water without overhead obstructions or other hazardous conditions. A close look at the advantages and disadvantages of SCUBA will best emphasize the basic factors by which it may be compared with surface supplied gear. The main advantages are mobility, portability and reduced requirement for surface support. The main disadvantages are limited depth, limited duration, increased breathing resistance, lack of voice communications (although developments in technology are addressing this problem), limited environmental protection and remoteness from surface assistance.

VI. CLEANING SURFACES FOR INSPECTION

Often, the surfaces to be inspected are obscured by silt and/or biological growth such as aquatic flora and fauna (e.g., grass, algae, barnacles, clams, mussels, and sponges). Water storage tanks bottoms are often covered with a layer of "sludge" or sediment that has settled from suspended particulate in the water. Detailed inspection and testing of the coating in these areas may require removal of these deposits from the surface, at least in representative

sample areas (Figure 6-21). There are a number of methods that are commonly employed to remove fixed biofouling, including hand tools, pneumatic and hydraulic power tools, water jets and hydrolasing.

Hand-tools may include scrapers, wire brushes, scaling hammers, abrasive pads, sandpaper, and a host of other manually operated tools. Although hand-tool cleaning is generally a suitable and inexpensive method of removing loosely adherent deposits, this method is generally slow and relies very much upon the vigor of the operator. Firmly fixed fouling such as mussel holdfasts and barnacles cannot be removed without great effort, which quickly results in diver fatigue. These tools may also cause coating damage.

Pneumatic and hydraulic power-tools such as power wire wheels, abrasive wheels, impact or rotary scaling devices, rotary brushes and scrubbers are extremely effective in removing even the most tightly adherent fouling. However, extreme care should be taken to avoid damaging sound coating. Pneumatic power tools are generally reasonably priced, and compressed air systems easily obtainable. However, they become extremely inefficient at depths below approximately 66 feet (20 meters). Hydraulically driven power tools are equally effective cleaning devices, with the added advantage of not being affected by water depth.

Hydrolasing is also a very fast and effective method for removing biofouling-fouling and debris; however, water pressure and the selection of cleaning tips should be carefully controlled to avoid damaging sound coating.

VII. INSPECTION METHODS

A. VISUAL INSPECTION

According to the specification and the prescribed inspection plan, a visual inspection of the structure(s) should be performed to qualitatively assess the coating and corrosion conditions (Figure 6-22). The location, scope, frequency, and distribution of coating deficiencies such as erosion, checking, cracking, blistering, peeling, softening, pinpoint rusting, and rust-through should be identified by the diver/inspector. Visual observations may be communicated by voice activated radio microphone in the dive hat to the inspection team leader at the dive station. The dive team

FIGURE 6-21. Cleaning surfaces for inspection. Courtesy of Underwater Engineering Services, Inc.



leader should document these findings on applicable inspection reports. In the event that verbal communication with topside personnel is not available, data may be documented on underwater slates, video and/or still photography.

1. Blistering - Blistering, if present, should be evaluated as to relative size and distribution in accordance with ASTM D 714. Determination of the minimum, maximum and average blister diameters, as well as the average number of blisters per square foot may also be determined. Macro photographs of blistered areas should be taken with a reference scale in the field of view to assist in this determination.

2. Rusting - Areas of pinpoint rusting and/or localized corrosion should be evaluated and documented as to density and percentage of area affected in accordance with SSPC-Vis 2.

3. Checking - Areas of checking, if present, should be evaluated as to type and distribution in accordance with ASTM D 660.

There are a multitude of other coating defects and failure characteristics that may be encountered. Volume 1, Chapter 23 of the SSPC Steel Structures Painting Manual, entitled "Causes and Prevention of Paint Failure" provides excellent commentary on the description of, and possible causes, of most coating deficiencies that may be encountered.

FIGURE 6-22. Top - Visual inspection underwater. Courtesy of Underwater Engineering Services, Inc. Bottom - A blister found in an underwater coating. Courtesy of Underwater Engineering Services, Inc.



B. SAMPLE COLLECTION

In the event of coating disbondment, the inspector may be required to collect samples of the coating for laboratory testing. Samples should be collected directly from the coated surface and placed in a sealable plastic sample bag using tweezers or other equipment that assures that the sample is not contaminated by the diver's gloves.

Often, corrosion nodules or tubercles are encountered in areas such as water storage tanks or cooling water systems. This may be evidence of microbiologically induced corrosion (MIC). The inspector may be required to collect samples of these corrosion products for analysis of type and concentration of organisms which may affect corrosion. Kits are commercially available for sample collection and culturing for identification and analysis of biological and chemical constituents.

C. STILL PHOTOGRAPHY

Photography is an essential part of any underwater inspection, as it provides a permanent visual record of as-found conditions. Underwater photography poses some interesting problems not encountered in air:

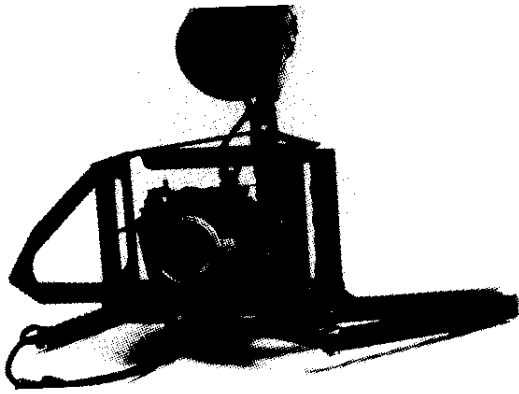
- Reflection and refraction of light
- Loss of light intensity due to absorption and the effects of light scatter from suspended particulate and increasing depth
- Loss of color, due to water absorption of colors from the light spectrum with increasing depth
- Loss of contrast due to loss of light intensity

These must be recognized and compensated for to assure quality photographs. Most of these effects can be compensated for by using specially adapted underwater flash units, lenses and specialty apparatuses. Many types and brands of underwater cameras and accessories are commercially available, at a wide range of costs. However, most commonly used underwater cameras fall under one of two categories, submersible cameras and housed cameras.

1. Submersible Cameras

The submersible camera is an amphibious device that is totally waterproof by design, with no need for specially designed housings (Figure 6-23). Nikonos supplies a compact submersible camera that provides high degree of quality and versatility. It is a unique kind of camera, being a simple viewfinder type but having interchangeable lenses. A submersible 35mm single lens reflex (SLR) cam-

FIGURE 6-23. Submersible camera with fixed focal probe.
Courtesy of Underwater Engineering Services, Inc.



era with through-the-lens viewing is now available from Nikonos as well, but this unit may be cost prohibitive for small budget operations. There are a variety of accessories available for the Nikonos camera, including macro and wide angle lenses, framing brackets, and a wide variety of compatible flash units.

2. Housed Cameras

A housed camera is simply a standard 35mm SLR camera that is encased in a waterproof housing specifically designed for the camera body. Advantages of housed cameras include through-the-lens viewing and bulk-loaded film (over 250 frames) in some models. Disadvantages of the housed camera in comparison with a submersible camera include loss of compactness and simplicity in operation.

D. VIDEO PHOTOGRAPHY

As with still photography, detailed video documentation of underwater visual inspections provides a permanent record of as-found conditions; however, video can have either a continuous or segmented format, and this can provide a more accurate representation of the overall condition of the structure. Two other advantages of video documentation are:

- Videotaped images can be superimposed with pertinent inspection data such as location, date, time, depth, etc.

- Video images can offer engineers or other responsible personnel who are not divers the opportunity to observe coatings and corrosion conditions in real time at the dive station.

Videotape records of inspections are a must for inspections performed in SCUBA, where written documentation may be limited due to a lack of communication with the surface.

Underwater video camera systems, used in conjunction with 35mm still photography provide an excellent visual basis for comparison with future inspection results to monitor rates of degradation over time. As with still photography, a number of hardware options are available, based on the project specific needs. Factors such as water turbidity, ambient light available, depth, and of course budget must be considered in the selection of an appropriate system. Many types and brands of underwater cameras and accessories are commercially available. However, most commonly used video systems used for underwater inspections fall under one of two categories, closed circuit television (CCTV) cameras and standard videotape recording cameras enclosed in a waterproof housing.

1. Closed Circuit Television (CCTV) Cameras

A multitude of brands, styles and custom options are commercially available for CCTV cameras, to suit most any situation. Most units employ standard color charged coupled device (CCD) TV camera, the camera circuitry enclosed in a waterproof anodized aluminum housing. These cameras may be hand-held or mounted to the diver's helmet for simplicity and ease of operation. The video signal is transmitted via an umbilical to a video cassette recorder and video monitor on the surface. Electrical power cable for underwater lighting is also incorporated into the umbilical.

Video inspections are often required in extremely murky or turbid conditions where underwater lighting systems create severe backscatter from suspended particulate. In these cases, a Silicon Intensified Target (SIT) camera, or an Intensified Charged Coupled Device (ICCD) camera may be employed. These cameras are designed to provide extreme low light sensitivity with high resolution in all water conditions.

2. Housed Video Cameras

As with still cameras, waterproof housings are commercially available for standard video recording cameras. An advantage of this type of camera assembly is through-the-lens viewing, with no power or video cable to the surface. Disadvantages include excessive bulk, and the need to return the unit to the surface to change video cassettes and battery packs.

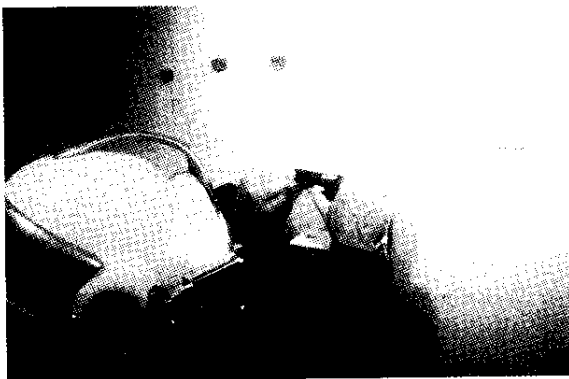
E. NONDESTRUCTIVE TEST METHODS

Many of the nondestructive test methods and equipment commonly used to test and evaluate coatings and corrosion in atmospheric conditions have been adapted for use by a diver/inspector underwater. A thorough coating and corrosion condition assessment includes test methods such as:

1. Coating Dry Film Thickness Measurements

A coating dry film thickness (DFT) survey may be required to determine the thickness of coating remaining on the structure (Figure 6-24). Determination of remaining coating thickness may be of particular importance when sacrificial coatings such as untopcoated inorganic zinc

FIGURE 6-24. Dry film thickness measurement with a Type 1 magnetic pull-off gage. Courtesy of Underwater Engineering Services, Inc.



coatings are present. Magnetic pull-off type gauges have been extensively used in underwater inspections with excellent results. However, even with regular cleaning and lubrication, gage service life is limited due to the harsh environment. Fixed probe gages with remote probes attached to waterproof cable up to 300 feet (90 meters) in length are now commercially available. SSPC-PA 2 provides procedures for measurement of a nonmagnetic coating applied to a ferromagnetic substrate.

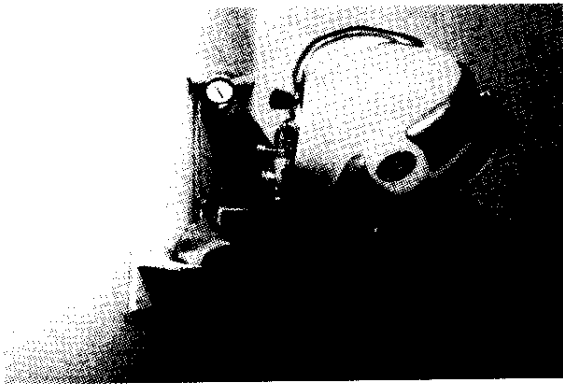
2. Pit Depth Measurements

The depth and diameter of pitting corrosion should be measured, at least in worst case locations (Figure 6-25). All corrosion products should be removed from the pit with a knife blade or probe and stiff wire brush prior to taking measurements. Pit depth measurements may be made using a calibrated depth micrometer. The baseline pit depth value is then measured at the deepest location. Care must be taken to align the instrument base longitudinally to any curvature in the structure, such as on a tank wall, to assure that the instrument rests flush on the surface. If surface curvature, roughness or irregularity is such that the gauge foot does not rest flush on the surface, the zero setting adjustment value for the depth gage should be determined directly adjacent to the measured pit. The coating thickness (if present) should be measured around the perimeter of the pit with a coating dry film thickness inspection gage. The coating thickness and zero adjustment (as applicable) should be subtracted from the base pit depth to ascertain the actual substrate pit depth. The location of measured pits should be documented with respect to linear distance from, and position relative to identifiable welds, structures or components in the immersion area.

3. Ultrasonic Wall Thickness Measurements

Ultrasonic thickness measurements may be required where carbon steel wall thickness is suspect due to corrosion. Digital thickness measurements can be taken with meters adapted for use underwater. Alternatively, the diver can place a remote probe on the surface to be measured, and readings can be recorded from the base unit at the dive station. Ultrasonic thickness measurements may be taken at locations where pit depth measurements were made to determine remaining wall thickness under pits.

FIGURE 6-25. Diver using a dial depth gage to measure pit depths. Courtesy of Underwater Engineering Services, Inc.



4. Other Test Methods

Although it is not the intent of this sub-chapter to provide a detailed commentary on nondestructive testing, the engineer and inspector should be aware that these test methods may be successfully employed underwater. They may be extremely beneficial in providing a more complete picture of the effects of coating degradation and subsequent corrosion on submerged steel structures. In addition to the non-destructive test methods described above, the following test methods have been readily adapted for underwater use:

- Ultrasonic Flaw Detection
- Magnetic Particle Inspection
- Electric Potential Measurements
- Eddy Current Inspection and Electromagnetic Flaw Detection
- Radiographic Inspection

VIII. SUMMARY

Despite the problems that accessibility and life support can pose, there may be several important reasons for performing an underwater inspection. Besides allowing the structure to remain operational, underwater inspection may make it easier to access vertical surfaces, and may prevent the embrittlement of coatings that can occur as a result of repeated wet/dry cycles. Whatever the reason for

performing an underwater inspection, the coatings inspector must have a detailed inspection plan, including details of the diving operation, which may be a "hard hat" or SCUBA diving operation or an un-manned approach.

Besides being qualified for the diving operation, the underwater coatings inspector must be trained in special procedures for cleaning surfaces prior to inspection, visual inspection, sample collection, photography, and, if required, video photography. Special submersible cameras are available for this purpose.

Non-destructive test methods used by the underwater inspector include DFT and pit-depth measurements and ultrasonic wall thickness measurements. Additional tests may be required.

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George V. Spires - Advanced Corrosion Engineering, Inc.

BIOGRAPHICAL SKETCH

Randall M. Baker is the Vice President of the international division of Underwater Engineering Services, Inc., a wholly owned subsidiary of S.G. Pinney & Associates, Inc. Having worked in the protective coatings field since the 1970s, his experience includes field inspection, quality assurance, engineering, consulting, and failure analysis. Since 1990, these efforts have been exclusively dedicated to the development and implementation of underwater inspection and maintenance programs.

Mr. Baker is an active member of NACE International, the American Nuclear Society (ANS), and the National Board of Registration for Nuclear Safety Related Coating Engineers and Specialists (NBR).

Mr. Baker currently holds an ANSI N45.2.6 Level III certification in protective coatings inspection, and is a NBR certified Protective Coatings Specialist.

Chapter 6.4

Bridges

by Kenneth B. Tator

OUTLINE

- I. Scope
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- III. About Bridges
 - A. Locating Specific Areas on Bridges
- IV. Unique Features of Bridges
 - A. Environmental Concerns
 - B. Design Concerns
 - C. Component Nomenclature
 - D. Difficult-to-Reach Areas
 - E. Corrosion-Prone Areas
- V. Coatings Used on Bridges
- VI. Health and Safety
 - A. Heights
 - B. Lead and Other Toxic Materials in Existing Coatings
 - C. Bird Droppings
 - D. Traffic
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I. SCOPE

This sub-chapter describes the unique features of bridges and how these features affect bridge coating and inspection operations. The objectives of this sub-chapter are:

- To define different types of bridges and their constituent parts.
- To identify difficult-to-access and high corrosion areas on bridges that require special attention
- To identify inherent hazards in bridge coating operations and methods to safely conduct a coating inspection while ensuring a quality coating application.

(Note: Further information relevant to coatings inspection on bridges can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

Code of Federal Regulations (CFR)

29 CFR 1926.62, Lead

Federal Highway Administration (FHWA)

Bridge Inspector's Training Manual 70, US Department of Transportation/Federal Highway Administration, 1979

Bridge Inspector's Training Manual/90, US Department of Transportation/Federal Highway Administration, 1979

SSPC: The Society for Protective Coatings (SSPC)

SSPC-PA 1 Shop, Field, and Maintenance Painting

III. ABOUT BRIDGES

Bridges are important structures that can be constructed of steel, concrete, or timber. Steel bridges are the ones most commonly painted. The strength, ductility, toughness, and rigidity of steel makes it the preferred material of construction for all bridge structures with span lengths exceeding 125 feet (38 meters) (Figure 6-26). In addition, steel is used for many of the short girder span overpass bridges.

Bridges span waterways, highways, and railroads to permit the smooth flow of private and industrial traffic. Thus, they must be kept in safe, operational condition with minimum closures for maintenance. Coatings not only provide control of bridge deterioration but also a pleasing appearance to these highly visible structures.

A. LOCATING SPECIFIC AREAS ON BRIDGES

Because of the size and repetitive nature of bridge components, a system is required for the inspector to precisely

locate areas where (1) work is to be done, (2) work and inspection has occurred for that day, and/or (3) deficiencies requiring correction have been noted. Temporary location markings can often be noted on the bridge structure itself for the convenience of the contractor, but they should always be placed on plans or schematics for documentation.

If plans or schematics are not available, geographical orientation of the bridge (north, south, east, or west) can be made using the upstream or downstream sides or the nearest cities or towns to either side. Houses, apartments, and playgrounds can also serve as references. A precise location on a bridge can be established by counting the number of spans or segments from either abutment or by counting the number of piers or supports (there is usually an expansion joint over each pier). Specific structural members can be identified as horizontal, vertical, or diagonal, extending from upper or lower panel points or connections. Sometimes a large truss can be divided into sections or "bays".

IV. UNIQUE FEATURES OF BRIDGES

The unique features of bridges that most affect both their deterioration and the inspection of their coatings are:

- Their environments, which may accelerate coating deterioration and/or corrosion
- Their structural design, which may restrict access or otherwise accelerate corrosion and/or create coating difficulties

(Note that in describing each of these features in the individual sections below, there is some overlap of concerns.)

A. ENVIRONMENTAL CONCERNS

There may be a variety of environmental factors that affect bridge coating and inspection operations.

1. Salt

Bridges located near sea water are likely to have salt contamination. This contamination also occurs where de-icing salts are used on decks to melt ice. Because salt contamination of steel surfaces is likely to significantly affect coat-

FIGURE 6-26. A bridge with a long span. Courtesy of S.G. Pinney & Associates, Inc.

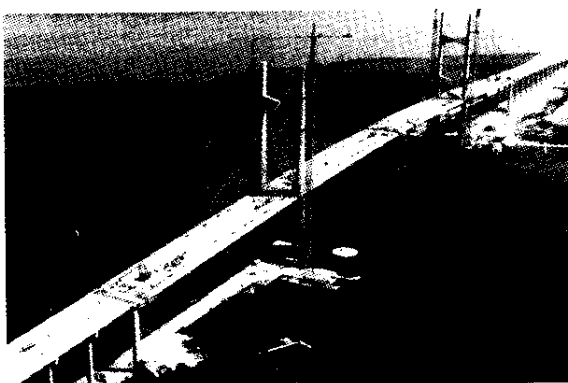
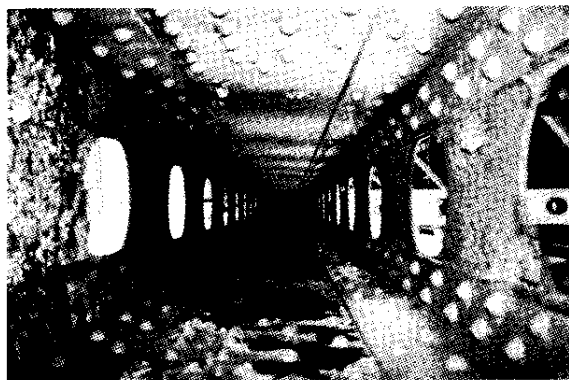


FIGURE 6-27. Corrosion on a bridge. Courtesy of KTA-Tator, Inc.



ing deterioration and corrosion of steel (Figure 6-27), testing for chloride ion is sometimes required on bridge surfaces to be coated. This procedure, described elsewhere in this book (Chapter 8), is becoming recognized as an important item to be included in coating specifications.

2. Moisture and Spray

Many bridges are located near rivers or lakes, which may wet their surfaces by condensation. Sheltered areas below bridge decks are subject to moisture condensation overnight, especially, if they are close to underlying water or have confined spaces, such as near the abutments. Since these areas do not receive significant sun or wind to dry the steel, the inspector should ensure that they are sufficiently dry for coating.

3. Dirt, Dust, Graffiti, and Pollution

Dirt, dust, and exhaust from vehicles may contaminate cleaned surfaces. They may also contaminate the surfaces of undercoats before overcoating, or finish coats before curing.

Bridges with pedestrian traffic are also subject to graffiti. Thus, special graffiti and corrosion-resistant coatings may be required.

Many bridges are located in areas with significant industrial pollution. These pollutants may adversely affect the

performance of coatings, the corrosion of steel, and/or the health of workers.

B. DESIGN CONCERNS

The basic bridge designs that a bridge inspector should be familiar with are girder bridges and truss bridges. Girder bridges are by far the most common. Most grade separations and shorter-span crossings over water or valleys are girder bridges. Longer expanses require truss, suspension, and, more recently, cable-stayed bridges.

1. Girder Bridges

Bridges of this type are made up of multiple rolled structural steel beams or fabricated plate girders (welded or riveted) supported by piers and abutments through bearing assemblies (Figure 6-28). Cross bracing or diaphragms are connected between the beams for rigidity.

Girder bridges consist essentially of a floor system supporting a deck. The most common girder bridge designs involve: (1) stringer beams, (2) girders and stringer beams; or (3) floorbeams, girders, and stringer beams (see Glossary).

2. Truss Bridges

Bridges of this type have a floor system of transverse floorbeams and longitudinal stringers, but the flooring is supported by trusses (Figure 6-29). Trusses are lattices formed of straight members and triangular patterns. The truss and chord members can be composed of girder-type beams or box beams. Box beams can be constructed with portals or with lacings on one or two sides.

3. Other Bridges

There are other bridge designs such as suspension, cable-stayed, bascule, vertical lift, arch, swing, etc. These bridges represent a small percentage of the total number of bridges, although some of them, such as suspension bridges, are among the largest. They all have floor systems that are similar to truss bridges.

FIGURE 6-28. Girder bridge. Courtesy of KTA-Tator, Inc.

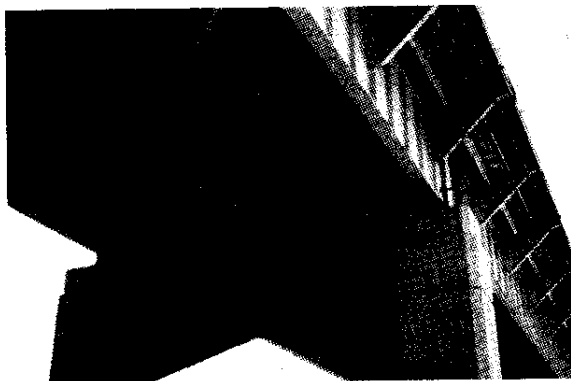
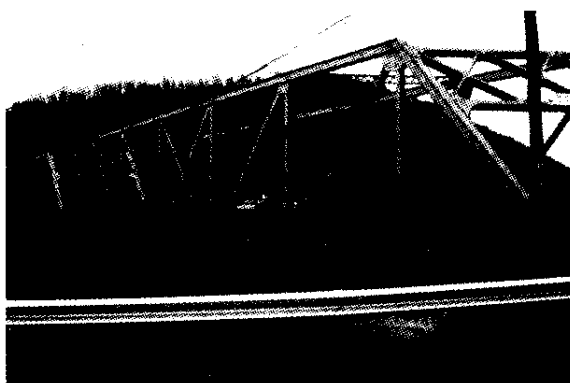


FIGURE 6-29. Truss bridge. Courtesy of KTA-Tator, Inc.



C. COMPONENT NOMENCLATURE

Bridge structural components have names that are specific to bridge construction. Some of these are noted in the Glossary.

Several commonly used bridge designs give rise to difficult-to-reach and corrosion prone areas. The impact of

these designs on coating operations and coatings inspection is described below.

D. DIFFICULT-TO-REACH AREAS

1. Lattice Work

Prior to 1950, many bridges, such as trusses, were designed with a lattice work of channels, angles, and/or bars secured to each other with bolts, rivets, or welds (Figure 6-30). Drawbridges often have open grid decks and machinery areas. Limited lattice openings restrict proper surface preparation, coating application, and inspection, thus these areas are likely to have specification deviations. Inspectors may have to devise special techniques to obtain access to these areas for inspection of surface preparation, film thickness, and holidays.

2. Other Difficult-to-Reach Areas

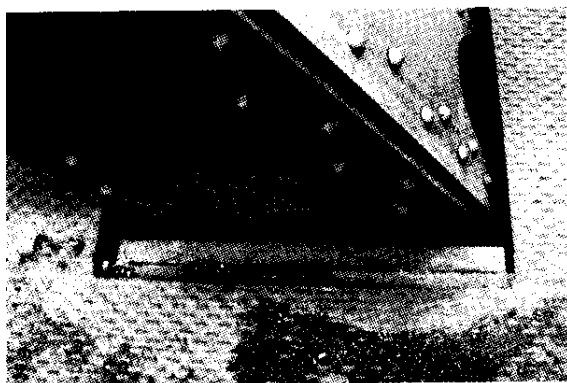
Some of the most difficult-to-reach areas on bridges are:

- Top surfaces of diaphragms and cross-bracing members
- Back surfaces of end floorbeams, diaphragms, and cross-bracing members at abutments

FIGURE 6-30. Lattice work on a bridge. Courtesy of KTA-Tator, Inc.



FIGURE 6-31. Corners and angles on a bridge. Courtesy of KTA-Tator, Inc.



- Facing surface areas on large bridges with two floor beams on a pier
- Back-to-back angles on cross frames

There is usually very little clearance between the deck and the diaphragms and between the end members and the abutments. This makes coating and inspection operations difficult. In many cases, only best-efforts can be expected.

Besides these structural features that limit access, applicators may move scaffolding or rigging before coatings cure sufficiently for testing the dry film, thus further limiting the inspector's access to these areas.

E. CORROSION-PRONE AREAS

1. Connections, Corners, and Angles

Many older bridges have bolted or riveted splice plates and other connections that are difficult to clean and coat. Top flange edges, tops of bottom edges, and bearings are perhaps the most critical areas to inspect. The inspector should pay special attention to all of these items.

The inspector should also pay special attention to sharp edges, where coatings can contract, and thus have reduced thicknesses. Edges are often rounded by grinding or striped with coating (as described in SSPC-PA 1 and Chapter 4) before applying a full prime coat. This ensures

that the minimum thickness requirements are met in these areas.

The inspector should check all corners and angles to determine that excessive coating thicknesses do not develop in these areas (Figure 6-31). This may adversely affect the curing.

2. Water Traps and Crevices

Areas with water traps and crevices can create very serious problems. They are very common, prone to greatly accelerated corrosion, and difficult to coat. Thus, the inspector should carefully check them for film defects. This is particularly true for the lower surfaces of bottom flanges that stay wet well into the morning.

3. Areas Near and Below Bridge Decks

The inspector should pay special attention to areas near the bridge deck that are subject to the spray of water (often containing de-icing salts), small stones, and other debris picked up and thrown by tire treads. These areas may be prone to coating degradation and accelerated corrosion.

Expansion joints in bridge decks allow water, dirt, de-icing salts, and other road debris to fall through onto structural members below. These materials may accumulate to form a mass that greatly accelerates corrosion. Thus, a higher level of cleaning and/or a higher performance coating may be required in these areas. The inspector should also pay special attention to these areas.

V. COATINGS USED ON BRIDGES

In the past, most steel bridges were painted with alkyd or other drying oil coating systems, frequently over mill scale, and frequently contained lead pigments. Today, higher performance, lead-free, low-VOC coating systems are more commonly used on abrasive blasted steel surfaces. Such coating systems include two coats of epoxy with a finish coat of aliphatic polyurethane and one coat each of inorganic zinc, epoxy, and aliphatic polyurethane.

VI. HEALTH AND SAFETY

There are many inherent hazards in bridge coating operations that may adversely affect the inspector, other workers, or the environment. It is important that there be a

safety plan specific for the operation and that it be fully implemented. Management has the responsibility to communicate all hazards to workers and provide for their protection.

A. HEIGHTS

Bridge components are often located at significant heights above the ground or water, thus the coatings inspector may be required to have special certifications and equipment (e.g., harnesses, lifelines, and nets), and follow special procedures (e.g., climbing in pairs and climbing only in suitable weather) (Figure 6-32). Further information on safety when working at heights can be found in Chapter 7.

B. LEAD AND OTHER TOXIC MATERIALS IN EXISTING COATINGS

The coatings on many older bridges contain lead or other toxic materials that can present a serious hazard to the inspector and other workers. The owner must therefore test existing coatings for such toxic materials before preparing a contract for work that will disturb them.

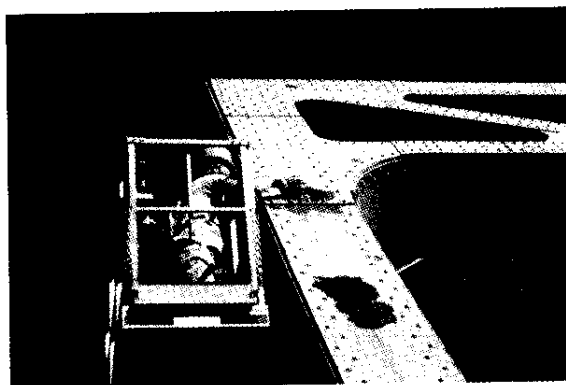
If lead or other toxic materials are present, the inspector must be trained and equipped with personal protective equipment, so that he has the ability to conduct his work safely. All requirements of 29 CFR 1926.62 apply to inspectors as well as construction workers disturbing existing lead-containing paint.

Dry or wet abrasive blasting in a contained environment is usually the most productive method for removing hazardous coatings. It effectively removes the existing mill scale often found on older bridges. Alternate surface preparation methods include water blasting and power tool cleaning with vacuum shrouded tools. These require less sophisticated containment systems. The inspector may be assigned responsibilities for monitoring the containment, collection, storage, and/or disposal of toxic debris. These responsibilities should be spelled out in the job specification. In general, however, nothing should be allowed to fall from the bridge to the environment below.

C. BIRD DROPPINGS

Pigeons or other birds frequently nest within the bridge structure or perch on various members both above and below bridge decks. Consequently, these areas accumulate

FIGURE 6-32. Access systems for work on bridges. Top - SSPC file photo. Bottom - Courtesy of KTA-Tator, Inc.



quantities of bird droppings, which deteriorate coatings and accelerate steel corrosion. They also are a source of disease to workers who inhale the dried particulate dust or place contaminated fingers, cigarettes, or food into their mouths. Thus, all droppings should be removed by power washing by properly protected personnel prior to any surface preparation or coating operations. In addition, respirators should be used whenever particulate dust contaminated with droppings is produced.

D. TRAFFIC

Arrangements should be made to control traffic during coating operations. Partial closure of bridges require that workers be kept safety separated from the traffic.

VII. SURFACE PREPARATION AND COATING APPLICATION

In order to ensure long-term corrosion protection of bridges and limit the number of closures necessary for maintenance, the following procedures (discussed in detail in Chapters 4 and 8) are considered appropriate for inspection of bridge coating operations (Figure 6-33):

- Monitoring ambient conditions
- Verification of surface cleanliness and profile
- Detection of salt and other potential surface contaminants
- Monitoring mixing, thinning, and application procedures
- Dry film thickness measurement
- Holiday detection
- Measurement of coating adhesion

VIII. SUMMARY

Because bridges are such large structures with many repetitive components, one of the initial concerns of the bridge coatings inspector is to develop or obtain a system to document the location of the different areas in which surface preparation or coating operations are taking place. The inspector should also be familiar with the type of bridge, the nomenclature of its components, and the design features that are difficult-to-access or corrosion prone.

Bridges can be exposed to many environments, such as salt, moisture, spray, dirt, and industrial pollution. The inspector should understand how these impact surface preparation, coating application and inspection. He should also be aware of the hazards involved in the job, which may include working at heights (sometimes over water) and exposure to lead or other toxic materials, and take all necessary precautions to protect himself from such hazards.

FIGURE 6-33. Inspection of a coated surface of a bridge.
Courtesy of KTA-Tator, Inc.



As for inspection of the bridge coating, the inspector has all of the usual responsibilities for monitoring ambient conditions, surface preparation, mixing and thinning, coating application, and testing; however detection of salt and other surface contaminants may be critical.

ACKNOWLEDGEMENTS

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Lloyd Smith - Corrosion Control Consultants & Labs, Inc.

BIOGRAPHICAL SKETCH

A biographical sketch of Kenneth B. Tator appears at the end of Chapter 2.

Chapter 6.5

Ship Hulls

by Walter H. Radut

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- III. About Ships
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- X. Inspection of Painting After Undocking
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I. SCOPE

The sub-chapter describes coatings inspection on ship hull exteriors. It covers the various coatings operations that take place during new construction, as well as repairs made during dry-dock. Inspection features that are unique to these operations are presented. (Note: Further information relevant to coatings inspection on ship hull exteriors can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

SSPC: The Society for Protective Coatings (SSPC)

SSPC-AB 2 Specification for Cleanliness of Recycled Ferrous Metallic Abrasives

SSPC-SP 3 Power Tool Cleaning

SSPC-SP 10 Near White Blast Cleaning (NACE No. 2)

SSPC-SP 12 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating (NACE No. 5)

FIGURE 6-34. Vessel being built in a graving dock.
Courtesy of W.H. Radut Associates.



III. ABOUT SHIPS

Ship hulls are made of steel, and their exteriors are exposed to very harsh sea water environments. Modern marine coatings can provide excellent corrosion protection, when properly applied and used in conjunction with cathodic protection of immersed areas. Good coating systems and coatings inspections are required to protect ships from corrosion and extend the times between necessary dry-docking for maintenance. It should be noted, however, that the times between dry dockings is usually dictated by the need to re-apply anti-fouling coatings.

IV. SHIP HULL PAINTING AND INSPECTION

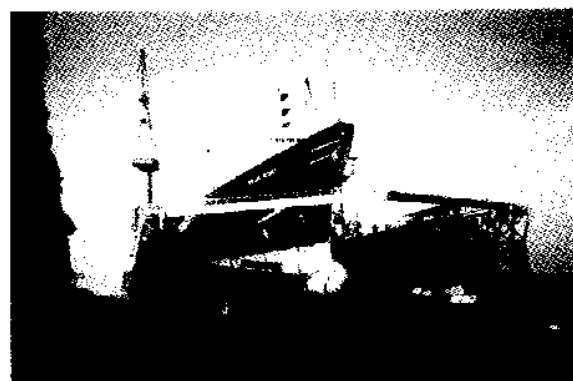
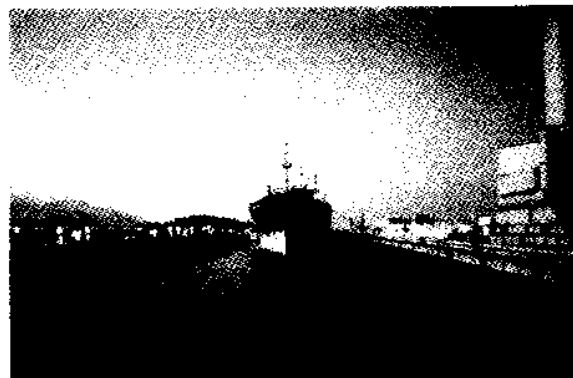
For new construction, modern shipyards have automatic plate cleaning and paint spraying machines and under-cover sheds for use during the assembly process. However, most of the hull painting is done outside in the open atmosphere, subject to changing weather conditions. Painting starts in the plate-by-plate stage, continues through the sub-assembly stage. After the sub-assemblies are completed, they are lifted down onto the building way where they are joined together to form the vessel's hull. The building way may be on a slip-way or a graving dock (Figure 6-34). On a slip-way, the vessel is launched by sliding down the structure into the water. A graving dock is a basin in which the vessel is floated out when ready for

launching (Figure 6-35). Whichever method is used, the facility is referred to as a "building way."

For repairs, a common method of dry-docking is a "floating dry-dock" where the vessel is floated into a submerged, floating dock and lifted by pumping out ballast thus raising the dock. The vessel sets down onto blocks which have been pre-set to fit the vessel's structure. Then the dock is raised completely out of the water and pumped dry. The hull is then ready for repair work including painting.

Coating of the underwater, exterior bottom and side shells must be completed before launching. For new construc-

FIGURE 6-35. Top - Vessel being pulled into a floating dry dock; Bottom - Vessel inside of floating dry dock, with water pumped out. Both photos courtesy of W.H. Radut Associates.



tion, painting of above-water hull areas may continue until the day of delivery. The entire construction process, which may take from 18 to 24 months, generally allows ample time for decision-making.

Maintenance is a continuous process on ships. The crew is constantly painting on deck and in other areas whenever time and weather permits. However, there are specific repair periods (occurring every 2 to 5 years) when the vessel is out of service for a matter of days, up to 2-3 weeks.

During dry-docking for repairs, decisions must be made quickly to complete the work properly without costly delays.

The painting of ship hull exteriors, both in original construction and in repair periods, poses specific problems. In both cases, the coatings inspector should have a working knowledge of ship construction, marine technology, and the various environments to which the coating systems are exposed. The coating inspector's specific responsibilities during ship hull painting will depend on the way the owner operates. Some owners leave the paint process under the supervision of the paint manufacturer's inspector. Such an inspector would only be responsible for monitoring mixing, paint application, and paint inventory. More prudent owners, however, may have their own in-house or hired inspectors who take on the total responsibility of the painting, including contractual matters and the cost of the final billing to the shipyard.

V. COATINGS USED ON SHIP HULLS

A large portion of the exterior hull is continuously immersed and thus requires a high-performance anti-corrosive system. Epoxies are used most frequently because they are water impermeable and abrasion resistant. Coal tar epoxies are also used for their superior water impermeability but their use is becoming more and more restricted because of toxicity concerns. For above the waterline, acrylics, polyurethanes and mixtures of generic types such as acrylic/polyurethane, acrylic/alkyd, silicone/alkyd, and vinyl/alkyd are most common types. Chlorinated rubber and vinyl systems, which have been used extensively over the years, have been restricted recently because of environmental (VOC) concerns.

The immersed portion of the hull also requires an anti-fouling system to control the attachment and growth of

FIGURE 6-36.
Marine fouling.
SSPC file photo.



marine fouling organisms (Figure 6-36). Since fouling can reduce ship speeds, increase fuel consumption, and reduce maneuverability, the use of anti-fouling coatings can mean big fuel savings. Some anti-fouling coatings function through the action of toxic agents, such as copper oxides or organotin compounds. Others are "low surface energy" coatings, to which fouling organisms can attach only very loosely. Most sought after are those which are "self-polishing." This feature enhances smoothness which in turn is a big factor in fuel savings.

As with other coatings, the development of new coatings for ship hulls is somewhat hampered by environmental restrictions. The use of lead, chromium, and other heavy metals, as well as the VOC content of coatings, are now restricted. Larger shipyards have specific VOC limits for various categories (e.g., zinc rich coatings) and may need to restrict the use of certain coatings based on the VOC content of the coating and the total VOC's emitted from the yard. In addition there are concerns about the toxicity of anti-fouling agents. It is sometimes difficult to formulate newer, safer products that perform as well as those that have been restricted.

VI. HEALTH AND SAFETY

The inspector should be aware of the adverse health effects of the marine coatings that are applied to hulls. Not only

are the hazards present during the application of the coating, but also during removal, e.g., by abrasive blasting. The organotin compounds used in some anti-fouling coatings are especially toxic, and have special safety requirements, including the use of respirators. All EPA, OSHA, and state regulations must be complied with. No coatings should be used that are not permitted in ports that are to be visited.

VII. INSPECTION DURING NEW CONSTRUCTION

A. PRE-JOB RESPONSIBILITIES

For new construction, the coatings inspector has a number of pre-job responsibilities, such as becoming aware of the detailed job specification and work procedure agreed upon by the representatives of the owner and the applicator. As described in Chapter 3, the inspector should also obtain or prepare any forms necessary for recording the results of the inspection.

B. PRECONSTRUCTION PRIMING

Soon after automatic blasting machines were developed to remove mill scale from plates and shapes, it was recognized that the surface they produced was very appropriate for painting. This led to the development of the automatic process known as preconstruction priming (Figure 6-37).

The process of automatic surface preparation and priming includes the following:

- A conveyor system to move the plates along the process. The conveyor is designed to have minimum contact with the underside of the plate so as to not disturb the wet paint applied to the underside.
- A drier to dry the incoming plates in inclement weather and to heat the plate to promote quick drying. A centrifugal wheel machine that propels abrasive onto the steel surface to produce the desired whiteness and profile.
- A drying cabinet to allow the freshly applied coating to dry before being moved out into the weather.
- A magnetic crane to remove the coated steel from the conveyor.

FIGURE 6-37. Automated blasting and painting facilities at a shipyard. SSPC file photo.



If the preconstruction primer is to be retained, it becomes a part of the coating system and is included in the coating inspection procedure. The inspector should verify the following on a daily basis, as required by the specification and the paint manufacturer (i.e., the one supplying the subsequent coats):

- Plate speed for blasting is as specified
- Blasting abrasive is the specified size, shape, and hardness and mix
- All centrifugal wheels are working, and there are no blasting holidays
- Blasted or power tool cleaned surfaces receive the correct degree of surface cleanliness and profile. Epoxies, used frequently on ship hulls, usually require surface preparation to SSPC-SP 10 (or, for touch-up, SSPC-SP 3).
- Painting process provides good, wet, continuous film
- Paint is dry before exposure to the weather
- Dry film thickness is as specified
- Film is free of holidays
- Plates stored after priming have proper spacers between them to allow adequate ventilation during curing time.

If a shipyard is building more than one vessel at a time, it may have a primer developed for its total operation, which may not be compatible with all the subsequent paint systems included in the paint specification. In such a case, the

primer may have to be removed by manual blasting. This has to be addressed and the matter resolved before coating starts--and whatever the solution is, it must be confirmed in writing.

C. SUB-ASSEMBLY COATING AREA

In the sub-assembly coating area, the primed plates are edged, cut into shapes, bent, rolled, welded, and otherwise formed into sub-assemblies (Figure 6-38). The disturbed areas, e.g., weldments, mechanical damages, masked areas, and the surface of the primer itself, are prepared before the next coat of paint is applied. Some shipyards may do this in a coating shed where the work is in a controlled environment. Or, depending upon geographic location, they may perform the additional surface preparation and painting outside, exposed to the weather.

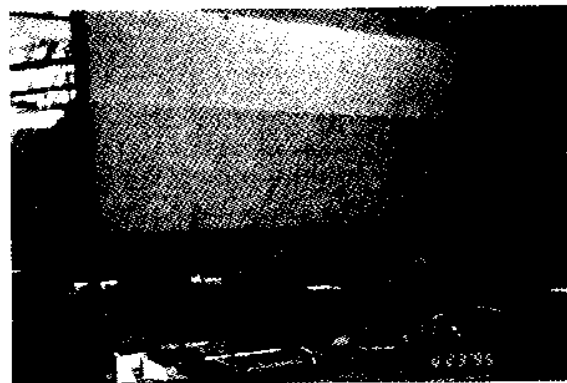
After the damaged surfaces are prepared and all bare steel is primed, full coats of paint are applied except on the edges of the welding seams and butts. Each of these full coats should be monitored, as required by the specification.

Although specific inspection requirements depend on the shipyard's mode of operation, the coatings inspector typically is required to verify on a daily basis that:

- Blasting abrasive used for spot repair is the correct size, shape, and hardness. If reclaimed, it should be inspected for cleanliness (see SSPC-AB 2).
- Mechanical tools (if used) are maintained in proper working condition, i.e., are not dull, rounded, or worn out.
- Blasted or tooled surfaces are clean and receive the correct degree of surface preparation and profile. Epoxies, used frequently on ship hulls, usually require surface preparation to SSPC-SP 10.
- Painted surfaces are dust free and visually clean.
- The specified minimum and maximum drying times between coats are maintained.
- Dry film thicknesses are as specified.
- Steel temperature, humidity, and dew point, are within the range permitted by the job specification.

Note: The inside of the sub-assemblies are also coated depending on their location in the hull. These become

FIGURE 6-38. Sub-assembly area. SSPC file photo.



bulkheads for machinery spaces, void spaces, tanks, cargo holds, etc.

D. PAINTING ON THE BUILDING WAY

After the sub-assemblies are joined together in the erection process to form the hull, the welds and damaged areas are prepared for subsequent coats. This may be done by blasting or power tool cleaning, depending on the specification. Such areas usually require a number of touch-up coats to build up the coating thickness. After all surface preparation and touch-ups are complete, the entire coating should be washed down with fresh water to remove all abrasive dusts, salt, and other debris. After this, full coat painting can proceed.

Since this work is performed out in the weather, it is necessary to monitor ambient conditions. The temperature, humidity, and dew point should be checked before any work is allowed to start. No surface preparation that exposes bare metal, or paint application, should be allowed when outside of the specified weather limits. Ambient conditions should be measured and recorded on a regular basis throughout the entire period of surface preparation and coating. A rule of thumb is that no painting is allowed at freezing temperatures, relative humidity above 85%, or if the steel temperature is less than 5°F (3°C) above the dew point. However, some products have more specific weather limitations. Further information of this kind can be found in the job specification or the manufacturer's technical data sheet.

VIII. INSPECTION DURING REPAIRS

A. PRE-JOB RESPONSIBILITIES

For an existing vessel in a dry-dock for repair, the work is done out in the weather, and is subject to adverse weather that can drastically influence the coating performance. Also there are time constraints since the cost of taking a commercial vessel out of service can be in the tens of thousands of dollars per day. Because of time constraints during dry-dock repair, decisions must often be made on the spot and corrective measures must be taken immediately. Close coordination and inspection must be maintained between the various phases of surface preparation and paint application, as well as between the various trades making repairs.

For repairs, the coatings inspector has a number of pre-job responsibilities, described in general in Chapter 3. However, because delays cannot be tolerated, the importance of these pre-job responsibilities is magnified. Before the vessel arrives, a meeting between the inspector and the shipyard, applicator, and paint supplier's representatives should be arranged to be sure that all items in the specification and procurement document are properly prepared. Too often such a meeting is not arranged and difficulties arise that can shut down the job completely or cause serious delays and extra costs.

At the meeting, the inspection procedure, surface preparation, and coating systems, should be reviewed and a work schedule should be prepared. The following typical items should be addressed:

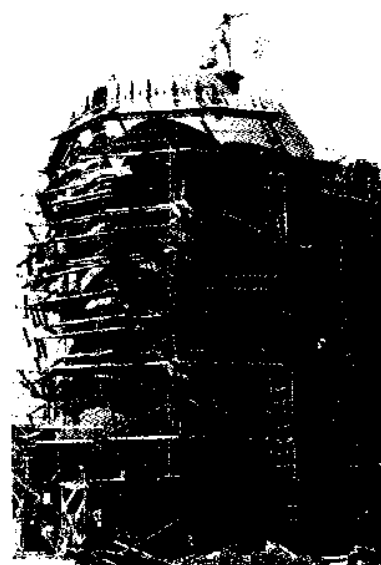
1. **High pressure wash equipment.** size, type, and procedure (Figure 6-39).
2. **Paint schedule** showing product, number of coats, wet and dry film thickness of each coat, and drying times between coats and before immersion. The anti-fouling coating system is usually renewed at the time of dry-docking.
3. **Application instructions**, including recommended type of spray equipment (including tip sizes for each generic type, hose size and length), thinning and mixing details, etc.
4. **Paint Supply.** The inspector should inspect the paint supply and ensure that the correct products and sufficient volumes are on hand for the work planned. It should be verified that the amount of paint ordered was

delivered. Each batch number for the various generic types should be recorded. If two component materials are involved, the correct components, i.e., base and hardener, should be stored together. The inspectors should check at each mixing that the correct components are mixed together. Thinners also should be segregated according to product to avoid using the wrong thinner.

5. Special requirements for anti-fouling paints. Most modern day anti fouling paint formulations are required to be the last coats applied. The inspector should determine what painting must be completed before the anti-fouling paint is applied, and ensure that such requirements are taken into account in the schedule.

The inspector should also be aware that some paint manufacturers recommend volume control for anti-fouling paints, since film thickness is critical for service life. In accordance with this method, the total area to be coated is sub-divided into smaller areas. The area for each sub-area is calculated and the appropriate volume of paint is assigned to that area. This amount must be applied. (Note: In order to determine the volume of paint per unit area, a wastage factor is included in the calculation. If that volume is overestimated, the paint will be applied too thickly. This will lengthen the dry-

FIGURE 6-39.
Equipment for
accessing a ship
hull. SSPC file
photo.



ing time before immersion. If underestimated, the lower thickness will reduce the intended service life.)

6. Blasting equipment. The inspector should inspect the blasting equipment, checking for size and quality of abrasive, blasting pots, nozzles, and source and quality of compressed air. The volume and pressure of air should be sufficient to accommodate the number of nozzles designed to accomplish the specified work, on schedule. The air compressors should have air receivers, filters, and coolers to ensure that water and oil are removed from all air used in the blasting and coating process. The inspector should verify that the contractor has sufficient spares, spare parts, and maintenance plans for the equipment on site to avoid interruptions to the schedule.

7. Access procedures. The inspector should review the procedure for access to the structure by scaffolding, staging arms, "man-lifts," or "cradles" suspended by overhead crane (Figure 6-39). It should be verified that the blasters and painters have proper access to the steel structure for uniform blasting and spraying of paint. The structure should be made accessible to the inspector whenever required.

8. Procedure for dry-docking. The keel blocks under the vessel should be staggered from the previous dry-docking in order to be able to coat the previously uncoated areas under the blocks. (Note: Fleeting requires the vessel to be floated, moved fore or aft, and then redocked to a new blocking arrangement to allow coating of the previously uncoated areas.)

9. Procedure for treating the line of demarcation (Figure 6-40). Where the topside, boottop (if any), and underwater systems meet, a procedure should be agreed upon as to how the different generic types should come together, e.g., in a straight line. One system should overlap the other. The compatibilities will determine which product is applied first.

B. WASH DOWN OF THE HULL

Once the vessel arrives and is ready for wash down, the condition of the hull should be determined. The inspector should report to the owner the condition of the hull prior to wash down. The extent of fouling, detachments, grounding damage, and other observations should be noted so that the performance of the existing coating between dry-dockings can be evaluated.

The inspector should be present during the wash down of the hull—even if this is done, as is often the case, during the night shift. All oil, mud, salt deposits, fouling (flora and fauna), other contaminants, and loose paint should be removed. This cleaning is necessary even though the surface may have to be prepared by blasting. A condition report should also be provided to the owner after wash down, as some peeling and other damage may have been covered by fouling.

C. DISCHARGE BLANKING

The inspector should verify that all drains, scuppers, and other overboard discharges are blanked off to keep effluent from running down the sides of the hull during the painting process. If the discharge is to remain in service, then chute drains or deflectors must be installed. Care should be taken that these drains are not plugged by grit (from blasting).

D. ASSESSING AREAS FOR REPAIR

Depending on the level of responsibility assigned to him by the job specification, the inspector may be required to work with the shipyard representative to assess various areas for repair. This may include structural repairs necessitated by grounding damage or other factors, as well as

FIGURE 6-40. Line of demarcation visible on a ship hull. Courtesy of S.G. Pinney & Associates, Inc.



present, the painting in these areas should be stopped. Work should be postponed until more favorable atmospheric conditions exist or, in situations of persistent inclement conditions, the ballast should be transferred or drained.

G. MATERIAL CONTROL

For repairs, the paint is usually supplied by the owner. For new construction, the paint is usually supplied by the builder. If supplied by the owner, the paint materials remaining are to be counted after the job is finished. This is required in order to record the exact quantities of each product used. In some instances the leftover materials (in usable condition) are returned to the vendor for credit. An exact count is necessary to be witnessed and signed by the inspector and the paint supplier's representative. This information should be handed to the owner's representative before he/she leaves the shipyard.

H. REPORT

For inspection of ship hulls, the information that should be recorded includes:

- Persons involved in the work
- Vessel's characteristics, including builder and date of delivery
- Description of shipyard facilities, including a description of equipment and mode of operation
- Scope of work and paint specification
- Coating applied at previous dry-docking or repair period
- Condition of hull on the dry-dock, before and after washing
- Chronology of events (a daily log of everything that happened, including time of start and finish, weather data, and quantities of paint used for each coat)
- General remarks, notes about significant events, and recommendations for future maintenance and repairs

The report is very important. It records all the information needed should there be a failure or problem with the paint after the vessel is in service. Most owners want a basic report before the owner's representative leaves the shipyard. Some owners have a particular format or specific forms to fill out. A more detailed report with photographs can follow later. Such a report is necessary for the next

dry docking in order to be able to continue the paint program and follow any recommendations given in the report. (Note: Further information on inspection documentation can be found in Chapter 3 of this book.)

IX. INSPECTION OF PAINTING BEFORE UNDOCKING

1. Hull Markings - The inspector should verify that all draft marks, plimsol marks, hailing port, and other markings are applied as specified.

2. Removal of Masking - The inspector should check that all masking of underwater equipment, such as anodes, reference cells, fathometer, speed log, etc., and items above deck are removed.

3. Touch-up - The entire coated underwater surface should be touched-up as required and approved before the vessel is floated out. Any areas not completed to the inspector's satisfaction should be so documented in an exception report.

X. INSPECTION OF PAINTING AFTER UNDOCKING

For both new construction and repairs, painting may continue after the vessel is launched. The inspector may continue to monitor these operations. When the vessel departs the shipyard, the impressed current cathodic protection, if any, should be kept off for a period of 2 weeks to 1 month so that the paint can "cure" before having a current impressed upon it. The length of time may vary depending upon the type of paint and the design of the cathodic protection system.

XI. SUMMARY

The inspector has many concerns when inspecting the coating of a newly-constructed ship hull. The inspector is responsible for monitoring preconstruction processes, such as machine blasting and coating and offsite painting. As the operation moves from the sub-assembly coating area to the building way, the inspector should ensure that repairs and touch-ups are done properly and coordinated with other activities.

When a vessel is in dry-dock for repairs, a key responsibility of the coating inspector is to closely coordinate activi-

ties so as to get the vessel back in service as quickly as possible. Consequently, the inspector has much to do before the vessel arrives. This includes verifying that all necessary equipment and materials are available and in good condition, that all means for access to the vessel are in place, and that there is a detailed plan and schedule for all operations. The inspector should also verify that any sensitive pieces of equipment are masked and unmasked as required by the specification.

For repair vessels, the inspector should also monitor and document the consumption of paint for each generic type, existing conditions, washdown of the hull, ambient conditions, surface preparation, and coating application. The hatch numbers of the various paints used should be made part of the permanent record.

For both new construction and repairs, the inspector should oversee the restoration of markings and any touch-up that is needed before the vessel is put back into service. Once the vessel is undocked, the inspector continues to monitor coating operations until all coating work is complete.

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BIOGRAPHICAL SKETCH

Walter H. Radut is the owner of W.H. Radut Associates, a corrosion and coatings consulting firm that he started in 1983. In this position, he has served as a consultant for various ship owners and shipbuilders, and has attended many dry-dockings of ships in Japan, Korea, Singapore, Taiwan, Europe, Caribbean, and the USA.

Mr. Radut retired from EXXON International, Inc., Tanker Dept., after more than 30 years service. At EXXON he was responsible for the design of coating systems, including those for ship hulls, cathodic protection, and troubleshooting of corrosion related field problems. He held various technical positions in the RUST-BAN Coatings Division. Throughout his career he participated in the painting of ships, both new construction and repairs. He also attended the painting of repair vessels in dry-docks for EXXON's world wide fleet of ships.

Mr. Radut has been an active member of NACE International, SNAME, the National Shipbuilding Research Program, ASTM, and SSPC. He is also the Past Chairman of SNAME Panel O-23, Ship's Paints; a member of the ASTM Committee F-25 on Shipbuilding (Coatings Committee); and a member of the Panel SP-3, Surf. Prep. & Coatings of the National Shipbuilding Research Program.

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Chapter 6.6

Lock, Dams, Spillways, and Their Appurtenances

by John Baker

OUTLINE

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- II. References
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 - C. Advance Planning
- IV. Structural and Environmental Considerations for LDSTA
 - A. Terminology
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 - A. Lead-Based Paints
 - B. Coal Tar Coatings
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 - D. Epoxies
 - E. Polyurethanes
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 - A. Masking and Protecting Adjacent Equipment
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- C. Application of Coatings at Low Temperatures
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I. SCOPE

This sub-chapter discusses inspection principles and procedures for locks, dams, spillways, and their appurtenances. It also discusses the significance of the different exposure zones on the choice of coatings, many of which are required to withstand more than one such zone. For brevity, "locks, dams, spillways, and their appurtenances" will be referred to simply as "LDSTA." (Note: Further information relevant to coatings inspection on LDSTA can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

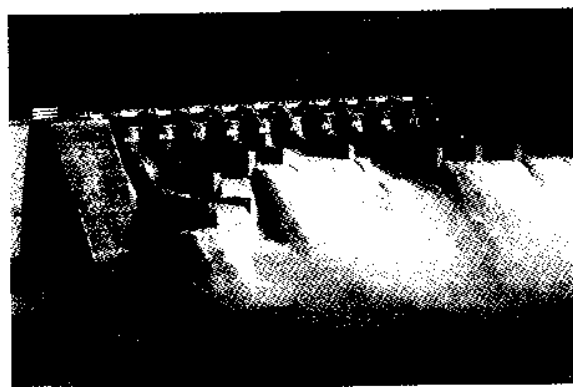
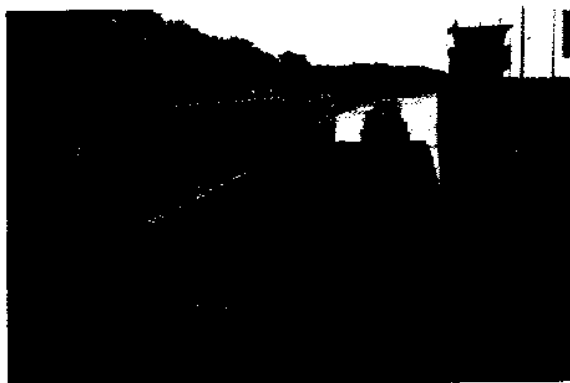
II. REFERENCES

SSPC: The Society for Protective Coatings (SSPC)

SSPC-Vis 1 Visual Standard for Abrasive Blast Cleaned Steel

K.A. Trimber, Industrial Lead Paint Removal Handbook, Second Edition, KTA-Tator, Inc., Pittsburgh, PA, 1993 (SSPC 93-02)

FIGURE 6-41. Top - A lock. Bottom - A dam. Both photos courtesy of S.G. Pinney & Associates, Inc.



III. ABOUT LDSTA

A. DESCRIPTION OF LDSTA

A lock is basically a "water elevator," i.e., it is used to raise or lower vessels so that they can pass from one water level to another (Figure 6-41, Top). A lock consists of a flooded enclosure with gates at each end to control the flow of water. The gates are swinging or sliding devices and may include valves.

A dam is a bank or wall across a waterway to control the flow and level of water on either of its sides (Figure 6-41, Bottom). Dams may be used in connection with locks on navigable waterways, or individually on non-navigable waterways where flood control, irrigation, power genera-

tion, or all three, are the primary purpose for the dam's existence.

A spillway is a paved apron over which water can be released from a dam.

"Appurtenances" to locks, dams, and spillways include control houses, galleries, interior and deck equipment, etc.

B. IMPORTANCE OF TIME FRAME

When working on LDSTA, the inspector should consider the importance of time frame to coating operations. For navigation structures and structures that deliver water to agricultural customers, there is often a narrow window of opportunity for coating operations--and this becomes even narrower in northern areas where the coating season is appreciably shorter. Also, since there is a natural tendency toward "getting the job done and the water running again," the inspector often faces the additional stress of reduced times available for coating work. Because of these time considerations, the prebid and/or prejob conferences are very important for LDSTA coating operations, and it is imperative that the coatings inspector(s) be present at them. With adequate advance planning and without an unforeseen "act of God," there can be adequate time for a satisfactory coating operation on LDSTA.

C. ADVANCE PLANNING

For coating operations on LDSTA, the inspector should do the following advance planning:

1. Be familiar with the job specification, including referenced regulations, e.g., the Clean Air Act, 29 CFR 1926, etc.
2. Be familiar with SSPC surface preparation specifications, SSPC, and other organizations' specifications and guides pertinent to the job. For example, knowledge of how to use SSPC-Vis 1, a visual standard, and/or a test panel can avoid time-consuming disputes on the job about what constitutes satisfactory abrasive blasting. If surface preparation involves removing existing lead-containing paint, the latest version of the "Industrial Lead Paint Removal Handbook," by K.A. Trimber, should be consulted, as well as the requirements cited in the specification.
3. See to it that inspection instruments are calibrated. Instruments, such as dry film thickness gauges, are best

jointly calibrated by the contractor and the inspector(s). This way, any discrepancies in calibration can be checked and adjusted in advance. The inspector should also find out ahead of time exactly when post-application testing is to be conducted and what methods and instruments are to be used.

4. Meet with key people. This may be redundant, but it is important enough to be mentioned again. The inspector(s) should have an opportunity to meet or contact all the key people in the coating operation. This includes the specifiers, the owner, the applicator (especially the coating foreman), and the coatings manufacturer's technical representative. To prevent unnecessary delays and conflicts during the coating process, all of those connected with the process must iron out disputes and misunderstandings in specification requirements in advance. The necessary teamwork approach should also be established in advance, and it should be carried through from start to finish of the work.

IV. STRUCTURAL AND ENVIRONMENTAL CONSIDERATIONS FOR LDSTA

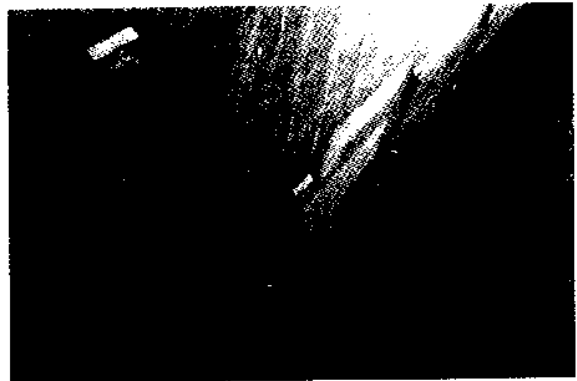
A. TERMINOLOGY

The terms "waterline," "immersion zone," "atmospheric exposure zone," and "swing area," are used in this subchapter. The waterline is the interface between the body of water and the atmosphere, and is usually not constant. The immersion zone is the area of the coated surface that is in contact with a body of water. An atmospheric exposure zone is one in which the coated surface is exposed to the surrounding atmosphere and may be exposed to sunlight, rain, snow, or other atmospheric phenomena. A swing area is an area that is alternately in the immersed zone and in the atmospheric zone. This may be due to the raising and lowering of the water level (e.g., in a lock) or the ebb and flow of the tides (e.g., at a bulkhead). The swing areas are the ones where coatings are usually most stressed.

B. CHARACTERISTICS OF LDSTA

Although LDSTA are not totally different from other structures, neither are they exactly the same. What makes many LDSTA different from other hydraulic structures (e.g., the interiors of tanks and pipelines), is that they often

FIGURE 6-42. Areas requiring special consideration. Top - Swing area on a lock. Courtesy of KTA-Tator Inc. Bottom - High abrasion area, downstream, below tainter gates on the Mississippi. Courtesy of US Army Construction Engineering Research Laboratories.



have to perform in more than one exposure zone and under changing exposure conditions. For example, a coating on the control gates of a lock or dam often has to perform in both immersed and atmospheric exposure zones, as well as a "swing area" (Figure 6-42). This means that resistance to wetting and drying is required, as well as resistance to immersion and atmospheric exposure. (Note: Unless otherwise noted, immersion refers to immersion in water.)

The coatings systems on LDSTA are also subject to varying degrees of wear. For example, the coating system on a spillway that is subjected to water containing suspended

abrasive solids and/or moving large particles, such as rocks or gravel, experiences more severe wear than one conveying relatively "clean" water. Similarly, a structure such as a gate, lock, or bulkhead that is subjected to fast-moving debris (logs, drums, etc.) experiences more wear at the waterline than one that is subjected to water only (Figure 6-42).

Although coatings for LDSTA are seldom subjected to the types of chemical exposure that coatings in pulp and paper mills or wastewater treatment plants are subjected to, the exposures are not always benign. Salt or brackish water exposure may exist at or near seacoast areas and affect the choice of a specific coatings system. The cleanliness of the water in the immersed areas is also of concern and affects the performance of the chosen coating system. Even inland rivers and other waterways may contain salts and other chemicals from pollution of various kinds.

V. COATINGS USED ON LDSTA

The types of coatings the inspector is likely to encounter are becoming more varied. Because of the narrow window of opportunity for coating work on LDSTA, there is an interest in coatings that cure at low temperatures and require short cure times before immersion. In addition, regulations and technological change are causing departures from the "standard" coatings systems that were used in former times. Some of the coating systems that have been or are currently used on LDSTA are described below.

A. LEAD-BASED PAINTS

At one time, lead (principally red lead)-containing primers with aluminum pigmented or other topcoats were used on LDSTA, but these systems were replaced by other more environmentally safe ones a relatively long time ago. However, they are still encountered in some recoating operations. Removal of these old lead-containing coatings in conformance with health and environmental regulations is a major part of the recoating process.

B. COAL TAR COATINGS

Coal tar containing coatings (see Chapter 5.3) were once used in great quantities for totally immersed structures or those out of direct sunlight. They are still used in these situations. Coal tar epoxies have been the most frequently used coatings systems of this group in recent years. Field

applications of coal tar enamel have sharply declined in recent years because of restrictive regulations and the decreasing availability of skilled applicators. Coal tar epoxies are used in direct sunlight, although some organizations require aluminum pigmented epoxy protective topcoats.

C. VINYL COATINGS

Vinyl coatings systems have been widely used for LDSTA. They are versatile and perform well in both immersion and atmospheric exposure service. They also are more resistant than epoxies to damage from floating debris at the waterline. (Epoxies have a tendency to chip under such conditions.) Vinyls are applied in multiple coats to total dry-film thicknesses (DFTs) of 6 to 10 mils (150 to 250 micrometers). Edge and striping coats are used to increase the total DFT in areas where additional film build is required. Vinyls require 10 days curing at 70°F (21°C) before immersion.

Vinyls are still used today, but with constantly decreasing frequency. Because of their high volatile organic compound (VOC) content, application of vinyls has been effectively banned in an increasing number of air pollution control jurisdictions. Coatings manufacturers have worked toward producing low-VOC vinyl coatings, but at the time of this writing (early 1994), no low-VOC vinyl is available that meets the composition and performance requirements of conventional high-VOC vinyls. The low-VOC vinyls are modified with other polymers, such as polyurethanes, to raise the solids and hence to lower the VOC content. This modification changes application characteristics and properties such as corrosion resistance, weathering, and recoatability.

D. EPOXIES

Two-package epoxy systems are being used more widely because, unlike the vinyls, they can be made in high solids and 100 percent solids (low and negligible VOC) versions. They have good corrosion resistance, but they chalk in exterior exposure. In addition, these are vulnerable to chipping from floating debris. They require a minimum temperature of 50 to 55°F (10 to 13°C) to cure and 7 days at 70°F (21°C) before immersion. Coal tar epoxies, which are types of two-package epoxies, have already been discussed. Some two-package epoxies have greater resistance to cathodic disbondment than vinyls, but as already men-

FIGURE 6-43. Tainter gate coated with elastomeric polyurethane over an epoxy primer. Courtesy of US Army Construction Engineering Research Laboratories.



tioned, they are more brittle. DFTs for two-package epoxies usually are in the range of 10 to 16 mils (250 to 410 micrometers), although some are applied in DFTs of up to 25 mils (640 micrometers).

E. POLYURETHANES

Two-package polyurethanes are among the newer coatings systems that are being tried on LDSTA (on a smaller scale than two-package epoxies). Many of these polyurethanes are of the elastomeric ("rubbery") variety. Elastomeric polyurethane coatings have been used as wear resistant "pads" over vinyls to prevent chafing by steel cables (Figure 6-43). Studies are being conducted on the use of elastomeric polyurethanes as impact and abrasion resistant "overlay" coatings for epoxies. They are also used by themselves as immersion coatings. Although short curing times before immersion are claimed for some types of two-package polyurethanes, most require 5 days curing at 70°F (21°C) after the final coat has been applied.

A recent development has been the use of moisture-cured polyurethanes for LDSTA. Some of these one-package polyurethanes cure at low temperatures, as low as 20°F (-7°C) or lower. Others require higher temperatures to cure. Also, certain moisture-cured polyurethanes can be immersed 8 hours after the final coat has been applied.

F. ZINC-RICH COATINGS

Zinc-rich coatings are finding increasing use on LDSTA. The use of zinc-rich primers in immersion service has been somewhat controversial; however, there have been successful tests and applications in this type of service. Inorganic zinc-rich primers require special care in surface preparation, application and topcoating. Organic zinc rich coatings are more tolerant of application irregularities. They will not galvanically protect scratches as well as inorganic zinc-rich coatings, but they have good resistance to undercutting of the coating film by corrosion. Topcoating is less of a problem than for inorganic zinc-rich coatings. Organic zinc-rich coatings can also be immersed in water. They are also suitable for patching galvanized surfaces.

G. OTHER COATINGS USED ON LDSTA

Hot dip galvanizing is a shop-applied coating generally used on small structures. (Larger structures tend to warp.)

Metallizing (thermal spray metallic coating) with zinc, aluminum, or zinc-aluminum alloy is a shop- or field-applied coating system which has been widely used on LDSTA in Europe and is becoming more common in the United States. (See Chapter 5.12.) Application is by flame spray or electric arc gun. In immersion applications, organic seal coats, such as two-package epoxies are required. The time before immersion at 70°F (21°C) is the time required for the seal coats to dry or cure.

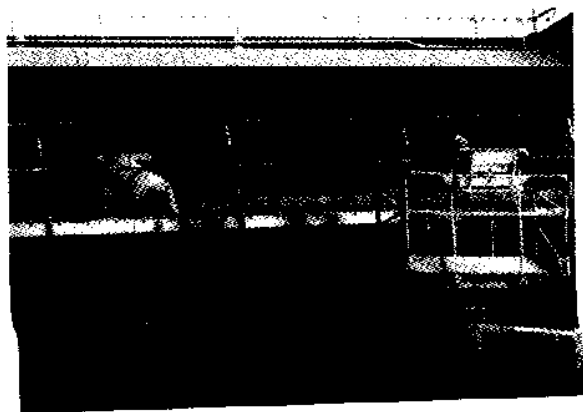
There are other types of coatings, such as polyesters, which have been used on a limited scale. The coatings on appurtenances are similar to those used on the interiors and exteriors of general industrial structures. For deck machinery and other nonimmersion applications, alkyds or emulsion coatings are usually chosen. Appurtenances that experience frequent, heavy condensation are treated as immersion type surfaces.

VI. HEALTH AND SAFETY

A. RIGGING AND ACCESSIBILITY

It is crucial that areas where surface preparation and coating operations are taking place, or have taken place, are

FIGURE 6-44. Equipment for accessing tainter gate. Courtesy of US Army Construction Engineering Research Laboratories.



safety and functionally accessible to both the crews and inspectors. The more minimal the personal hazards that crews and inspectors have to face, the more they can concentrate on performing the tasks involved in surface preparation, coating, and inspection.

Rigging for LDSTA is not unlike that for other structures (Figure 6-44). If a dry or solid base (e.g. ground or solidly frozen ice) is available, modern scaffolding is used. Other options include:

- Suspended platforms
- Mobile mechanically and hydraulically operated lift platforms
- Floating platforms

In all rigging and accessibility operations, safety is a prime consideration. Safe access for inspectors is increasingly being included in modern coating specifications. Proper harnesses and safety lines and/or safety nets are used in elevated working and access areas. Organizations must provide rigging and access training to their inspectors in the form of rappelling, bosun's chair, and other forms of access training classes. (See Chapter 7 for further information on rigging.)

B. LOCK-OUT

A particular danger when working on LDSTAs is that coating work is conducted on or downstream from structures that control the flow of water. Gate and valve operating machinery must be locked out in the closed position. In addition, structures that are to be coated in an elevated position, (e.g. gates) must be securely blocked before work begins.

C. VENTILATION

In coating operations on LDSTA, ventilation is used to maintain the airflow and temperature required for curing. It is also an important worker safety factor. Proper ventilation is required in spillway tunnels, gate chambers, galleries, and the inside areas of large gates. It is also required in temporary enclosures.

Ventilation is maintained by fans that supply outside air to the work area by taking in or exhausting air. In some instances, both intake and exhaust fans are used. Explosion-proof fans should be used where solvents are present, especially on the exhaust end of the ventilated area. It should be emphasized that personal protective equipment, such as appropriate respirators and clothing, may still be required for those working in a ventilated area, i.e., with ventilation in place, a chemical may indeed be below its lower explosive limit (LEL), but still above its permissible exposure limit (PEL). Air sampling is a means of determining whether or not limits are being exceeded.

D. REQUIREMENTS FOR CONTAINMENT OF DEBRIS

Containment of debris, although critically important when removing hazardous materials such as red lead paint, is also important when removing "non-hazardous" coatings. For coating operations on LDSTA, water pollution as well as air pollution regulations must be considered. In built-up areas, failure to contain dust and spent blasting media can lead to citations. Some states do not permit even "non-hazardous" materials to be discharged into waterways.

FIGURE 6-44. Equipment for accessing tainter gate. Courtesy of US Army Construction Engineering Research Laboratories.



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For organizations in the public eye, the appearance of non-compliance with environmental regulations can be damaging, even when the coating operation is in complete compliance. Blasting media can cause public relations problems if it is flushed down a spillway, even though it is non-toxic and no regulation is broken and no harm is done. The inspector's authority in enforcing the degree of containment required, as well as other health and safety regulations, is defined by the job specification. However, even where the inspector's authority is limited (for example, he or she lacks authority to shut the job down), violations or apparent violations should be reported to the responsible person.

VII. SURFACE PREPARATION AND COATING APPLICATION

A. MASKING AND PROTECTING ADJACENT EQUIPMENT

Protecting adjacent equipment (e.g., buildings, parking lots, deck equipment, etc.) is an important consideration during coating operations on LDSTA. Often the degree of special protection required by "adjacent equipment" depends on the coating application method to be used. Spraying has been the quickest, least expensive, and most aesthetically pleasing application method for areas of any appreciable size, but may result in unacceptable overspray. Therefore, in particularly sensitive situations, brush and/or roller application may present the fewest problems and the lowest overall cost.

It is usually advisable and sufficient to protect deck machinery and immediately adjacent areas by covering with suitable tarpaulin or tarpaulin-like materials. However, when deck machinery is blast cleaned prior to recoating or refinishing, experience has shown that despite the most thorough and careful masking operations, dust will somehow find its way into the deck machinery's bearings. A satisfactory alternative (particularly when the machinery is to be coated with an alkyd system) is power tool cleaning with normal masking.

Buildings can be protected by properly placed screens or other barriers or enclosures at the jobsite. The best way to protect vehicles in a nearby parking lot is to empty the lot. It may not cause any problems if nearby maintenance or storage buildings receive some very minor overspray; however, any noticeable overspray on a vehicle, boat, pri-

vate dwelling, or commercial building serving the public is sure not to be overlooked.

The inspector's responsibilities in masking and protecting adjacent equipment should be covered in the prebid and/or preconstruction conferences. Prevention of overblast/overspray problems, if at all possible, should be the object and should be considered up front. Although there are organizations that specialize in removing overspray, it adds to the expense of the coating operation and may not be included in the contract price.

B. TREATMENTS OF CONNECTIONS AND INACCESSIBLE AREAS

Depending on how they are constructed and what they are made from, the connections on LDSTA may require special coating treatment and inspection. Permanent solid connections should be properly prepared and coated. Attached connections, such as the seals (usually preformed elastomeric materials) between gates and their seats are usually removed before the coating operation begins and are reattached, or often replaced with new seals afterwards. Other types of connections, such as expansion joints in spillways, canals, etc., may require sealants. As an alternative to special coating treatment, resistant construction materials may be used in connections to prevent problems. Cathodic protection is another option for buried or immersed areas.

Areas that are difficult to access may be reached by special rigging or access equipment and the use of special tools. Wand type blasting and spraying equipment is available. Electrostatic spraying equipment and long-handled brushes or rollers are also options. Areas that are accessible only with varying degrees of difficulty are not only difficult to coat, they are also difficult to inspect. In areas that present severe problems of accessibility, mutually agreed upon (by all parties) compromises within the written specifications may be necessary to obtain the best coating operation quality under the circumstances.

C. APPLICATION OF COATINGS AT LOW TEMPERATURES

For LDSTA coating purposes, "cold" conditions are below 35°F (1.7°C) for vinyls and below the curing temperatures for thermosetting coatings systems, usually 50 to 55°F (10 to 13°C) (Figure 6-45). For these conditions a constant

FIGURE 6-45. Lock gates, structures to which coatings may be applied at relatively low temperatures. Courtesy of US Army Construction Engineering Research Laboratories.



supply of heat during the application and curing process is necessary for several reasons: to keep the coating materials in good and more easily applied condition; to allow drying and curing; and for operator comfort. Basically, there are three ways that heat is supplied to coating operations under cold conditions: by circulating hot air through the work area, by preheating areas to be coated, and through the use of hot spray equipment. (Note: Although there are coatings that can be applied and will cure below 32°F (0°C), application at such low temperatures multiplies difficulties and pitfalls and should not be attempted unless no other viable alternative exists.)

Hot air supplied at the intake end of the structure or enclosure is the best and safest method of heating. If heating is to be carried out within the structure or enclosure during coating operations, it must be accomplished without open flames or exposed heating elements.

Areas to be coated may be preheated with combustion or electric heaters. When preheating the area, there should be no solvent-containing coatings stored in the area. Also, combustion heaters should not exhaust undesirable products that could contaminate the surface to be coated. Surface temperature and dew point checks are more important under supplied heat or low temperature conditions.

Hot spray equipment can be used for applying vinyl coatings at low ambient temperatures, in which case it is not necessary to heat the structure. The Corps of Engineers has applied vinyl coatings at temperatures as low as -20°F (-29°C).

VIII. SUMMARY

Since the time frame of coating operations on LDSTA is often limited by economic and climatic constraints, one of the prime concerns of the coating inspector on these structures is advance planning, i.e., the pre-bid and pre-job conferences are critical. Coating operations and inspection are further complicated on LDSTA by the existence of various exposure zones. Some structures are exposed to the atmosphere only, some are immersed, and some (swing zones) have to perform in both exposures. In addition, the inspector must be concerned with access to the structure, protection of adjacent structures, containment of debris (even non-hazardous debris), compliance with VOC regulations and, sometimes, application of coatings at low temperature.

In addition to obtaining safe access to structures, the coating inspector's safety concerns when working on LDSTA include adequate ventilation and working safely around gates and other structures that control water flow.

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Gary L. Tinklenberg - Corrosion Control Consultants & Labs

BIOGRAPHICAL SKETCH

John S. Baker is retired from the U.S. Bureau of Reclamation, where he held the position of Materials Engineer. Earlier in his career, he worked for trade sales and indus

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Mr. Baker has been active in various professional societies. He is a member of SSPC and is active on several SSPC committees. He is a member of ASTM and the American Institute of Chemical Engineers (AIChE). He is Past President of the Philadelphia and Rocky Mountain Societies for Coatings Technology and is currently the Chairperson of the RMSCT Technical Committee. He is also Past President of the Engineering and Technical Societies Council of Delaware Valley (ETSCO).

Mr. Baker received a BA in History from Temple University in 1952 and a BS in Chemical Engineering from Drexel University Evening College in 1963. He served in the Army during World War II and the Korean War.

Chapter 6.7

Offshore Facilities

by Timothy M. Conlin

OUTLINE

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I. SCOPE

This sub-chapter describes fundamental procedures and unique considerations for effective coatings inspections on offshore facilities. (Note: Further information relevant to coatings inspection on offshore facilities can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

SSPC: The Society for Protective Coatings (SSPC)

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

SSPC-PA 1 Shop, Field, and Maintenance Painting

III. THE OFFSHORE WORK ENVIRONMENT

The nature of the offshore work environment exposes the inspector to a variety of unique situations. A competent coatings inspector enhances the quality and cost effectiveness of an offshore coatings project. His knowledge of surface preparation, coatings, and application procedures is of significance to the project's successful completion. Equally important is his understanding of common offshore practices, concepts, and his key job responsibilities as defined by the owner.

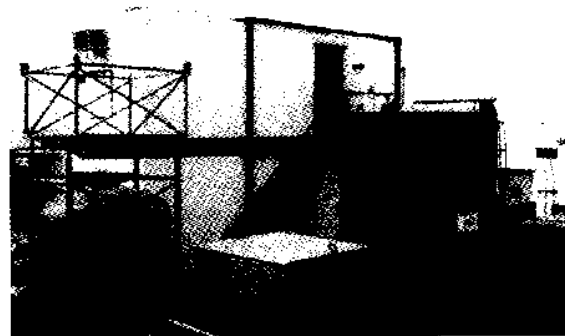
A. CONFINED QUARTERS

Offshore coatings projects are highly visible operations that may affect the work routines of many individuals for months at a time. The inspector, paint crew, and platform operations personnel are housed together in confined quarters for several weeks at a time (Figure 6-46). These individuals must work and live together 24 hours a day. This sometimes causes sensitive situations, especially if personality and/or job-related problems develop. The inspector is often in a precarious position, and should operate in a positive and tactful manner during both working and after work hours to maintain good working relationships with the paint crew and platform personnel. He should be aware of individual personality profiles, and exercise discretion at all times during both job-related and personal discussions. He should be aware of his specific responsibilities and not overstep his authority limits.

B. LOGISTICS

The inspector should be aware of how the logistical problems associated with offshore operations affect the project. All phases of the work are affected by the platform's

FIGURE 6-46. Typical platform camp setup. Courtesy of Chevron USA.



remote location (Figure 6-47). Familiarity with work and material requirements is necessary regardless of who is assigned the responsibility to order materials and plan supply boat runs. Awareness of transportation schedules for personnel to and from the platform in case of emergencies, or for routine crew changes is important. The inspector's familiarity with scheduled transportation helps the applicator plan work activities to minimize job downtime.

C. SIMULTANEOUS ACTIVITIES

Coating operations are conducted simultaneously with other activities on a platform. This limits accessibility and confines work areas. All of these operations must be completely coordinated in order to ensure worker safety and reduce downtime. The inspector often is assigned the role of liaison between the paint crew and the remainder of the platform work groups. In this role, his interaction with the various work groups helps coordinate the sundry platform activities. This is essential for safe, cohesive, and cost effective operations for the paint job as well as all other platform operations.

D. PLANNING AND COORDINATION OF PAINTING ACTIVITIES

Offshore painting activities are adversely affected by incomplete planning and coordination. Factors such as

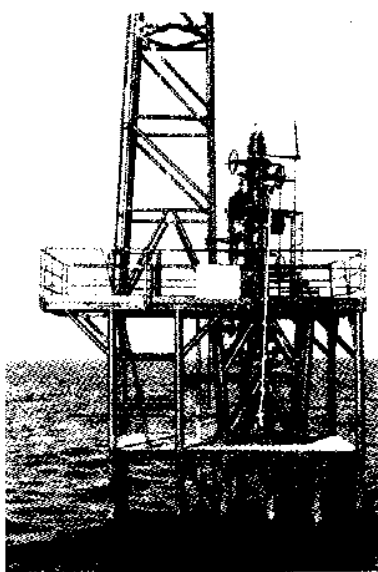


FIGURE 6-47.
An offshore
platform.
Courtesy of
Chevron USA.

adverse weather conditions, unanticipated boat or helicopter traffic, and simultaneous priority operations may have significant financial impacts on the project. The paint crew, equipment, inspector, and caterers are normally on the payroll from job start-up until completion, except when the crew is shut down for anticipated periods of long term adverse weather conditions or priority operations. It is cost prohibitive to transport the crew back and forth to the shorebase each time routine interruptions occur in the work schedule. It is necessary to work with the contractor to adopt contingency plans that include alternate work options to maximize productive time.

E. ENVIRONMENTAL CONCERNS

Environmental concerns are significantly impacting offshore coating operations. Issues such as VOC and dust emissions, abrasive containment, and abrasive disposal have not been a major concern of the regulatory agencies in the past. However, over the past several years, offshore operators have been mandated to comply with many of the existing laws governing land-based operations. This has prompted many offshore operators to review their existing programs and adopt many of the same procedures that are now common practice in other parts of the industry, i.e., monitoring air quality, containment and disposal of spent blasting abrasive, etc.

The coatings inspector should be thoroughly familiar with the environmental and regulatory programs established for the project. His responsibilities regarding these matters should be defined by the specification and/or clarified in the pre-job conference. If there are any questions or concerns relating to specific issues, the inspector should contact his immediate supervisor or the owner for guidance.

IV. PRE-INSPECTION OF THE PLATFORM

If at all possible, the inspector should examine the platform prior to job start-up. His primary concern is to check all items listed in the coating schedule to verify that the specification is workable and communicate any perceived problems to the owner. Additionally, it is good practice to consider other aspects of the job in regard to platform specific items.

There are many items that could have significant impact on the successful outcome of the project. If any potential problems are observed, the owner should be notified. The following lists a variety of items for consideration:

A. PERCENTAGE OF COATING BREAKDOWN AND SEVERITY OF CORROSION

- Do the platform and equipment items need to be spot or 100% blasted and painted?
- Are there any severely corroded items that need changeout (Figure 6-48)?
- What is the condition of the clamps and u-bolts?
- What is the condition of the sight glasses, valves, etc.?

B. TYPE OF EXISTING PAINT SYSTEM

- What is the general condition of the coating?
- Is the specified system compatible?
- Is the specified surface preparation standard appropriate?
- Are there any items that need specialty coatings such as hot or submerged equipment and piping?

C. GENERAL PLATFORM LAYOUT

- Is there sufficient space for equipment and supplies (Figure 6-49)?

FIGURE 6-48. Corrosion on an offshore platform. Courtesy of Chevron USA.



- What is the rigging configuration? Are there any special considerations?
- What is the crane capacity?
- What is the platform fuel capacity?
- Are there sufficient living accommodations for the crew?
- What are the potable and drinking water capacities?
- Is the platform in a high boat and helicopter traffic area?

D. PLATFORM EQUIPMENT LAYOUT

- Are there any equipment items that need filtration or wrapping (Figure 6-50)?
- Will any equipment items have to be shut-in for blasting and painting? If so, what is the estimated amount of downtime?
- Are there any special considerations for overblast protection?
- Are there any drains that need plugging?
- Are there any hot items that require special safety precautions?
- Are there any sweating items that will require platform shut-in or cause disruptions in blasting or painting activities?

V. START-UP PROCEDURES

The inspector's responsibilities regarding the project start-up will vary from job to job depending on the specification requirements. Normally, a time and materials contract situation gives the inspector a more active role in the work scheduling and execution processes than a fixed price type contract. In general, however, the inspector should observe and report on the daily job activities, and provide informa-

FIGURE 6-49. Congested platform layout. Courtesy of Chevron USA.

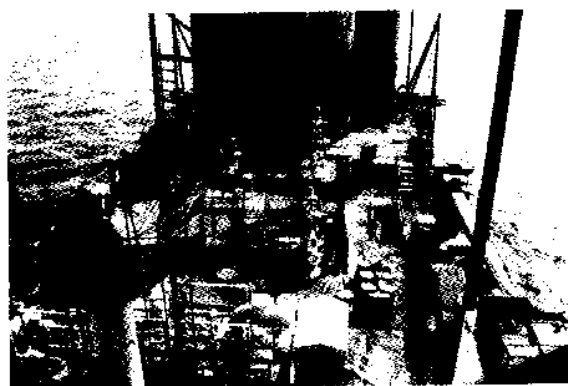


FIGURE 6-50. Production area layout. Courtesy of Chevron USA.



tion to the applicator and/or owner regarding specification deviations.

Mobilization of a large platform job includes the time starting from loadout at the shorebase until the paint crew is ready to begin blasting. This normally requires about 3 days. During this time, it is necessary for the inspector to become familiar with details of the work schedule and platform equipment layout. He should also solidify working relationships with paint and platform crews by creating an atmosphere of trust and confidence between the work groups and establishing necessary communication channels. A skillful inspector builds a solid foundation for a successful job during the first several days on location. Once the mobilization phase has been completed, the project work direction shifts from start-up mode to a daily routine which focuses on blasting and painting.

A. LOADOUT

Loadout is the first critical phase of the project (Figure 6-51). This operation involves loading personnel, equipment and materials on a cargo boat at the shorebase; traveling to the offshore platform; offloading the cargo boat at the platform; then setting up equipment and supplies. This accomplishment requires coordination of a number of individuals whose contributions are critical to the success and safety of the operation. In general, the key players involved in the loadout operation are as follows:

- Paint crew foreman
- Paint crew members placed on the boat to hook up equipment and material loads, and on the platform to position the offloaded items
- Cargo boat skipper and deck hands
- Crane operator
- Platform operators

Typically, offloading equipment for an eight to ten man crew requires 10 to 12 hours to make approximately 60 lifts from a 165 to 185 foot (50 to 56 meter) cargo boat. The equipment list usually consists of a variety of items, which could include several 850 CFM (24 m³/min) or larger air compressors, 8-ton (7 Mg) bulk abrasive blast pots, scaffolding, hoses, and other blasting and painting equipment.

FIGURE 6-51. Loadout. Courtesy of Chevron USA.



B. BEFORE THE VESSEL DEPARTS FROM THE SHOREBASE

The inspector should:

1. If possible, inventory and inspect the applicator's equipment before loadout to ensure it is complete, operational, and meets all specification requirements. In many cases the equipment is inspected at the applicator's yard prior to shipment to the shorebase. Regardless of the checks performed beforehand, pre-loadout inspection at the shorebase is still necessary to check for shipping damage and verify that the equipment to be loaded is the same as what was checked at the yard.
2. Inventory all materials including Product Data Sheets and Material Safety Data Sheets. Any shortages or deliveries of improper materials should be reported immediately. Verify that all paint cans, abrasive containers, equipment, and all other water sensitive items are wrapped and positioned accordingly on the cargo boat. Improperly placed items could incur water damage while the vessel is underway to the platform. Paint cans and abrasive shipments should be wrapped in plastic sheeting and placed on pallets prior to shipment.
3. Verify that the vessel's current fuel and water supplies are of sufficient quantity for transfer to the platform to meet the increased demand required by the extra personnel and project work scope.
4. Record weather and sea conditions prior to the vessel's departure.

5. Verify that the platform operators have been notified regarding the vessel's estimated time of arrival at the location.

C. INSPECTION EQUIPMENT

An offshore inspection instrument kit should include all specialty items that are required by the specification, as well as all of the standard equipment (described in Appendix I'). The inspector should check the instrument kit prior to departing for the platform. The high cost and limited availability of offshore transportation could delay delivery of a forgotten item for an extended period of time.

D. ARRIVING AT THE PLATFORM

The inspector should:

1. Attend the safety and mobilization meeting. A safety and mobilization "tool box" meeting is routinely held between the platform operators, inspector, paint crew, boat crew, and crane operator to coordinate the offloading sequence prior to starting the operation.
2. Observe as the equipment is offloaded and is being positioned. Check with the platform operators to verify that equipment and material items are placed in an acceptable area (Figure 6-52).
3. Re-inspect equipment and materials. Once the equipment and materials have been positioned, it is again necessary for the inspector to inventory and check all items for damage. The inspector should ensure that the paint is stored in a protected area on the platform if possible. Paint cans should not be placed on a solid steel deck. If necessary, store them on pallets to prevent heat damage to the coating.
4. Review the equipment setup sequence with the crew foreman. The first priority is to connect temporary lodging facilities, i.e., bunkhouse, potable water tank, sewage lines, etc., prior to other equipment items. This is necessary to provide the crew with living accommodations as soon as possible.
5. Monitor the connection of filler hoses. Once all equipment items have been offloaded, filler hoses for platform fuel and water tanks should be connected, then used to fill the tanks. Any unnecessary equipment such as empty cargo baskets should be backloaded onto the boat to increase the availability of usable platform deck space.

FIGURE 6-52. Equipment at the platform. Courtesy of Chevron USA.



6. Perform a platform walkthrough to revisit areas which were viewed during the pre-job inspection, checking for any changes to the work areas such as newly welded items, immediate hazards, and any other items which may affect coating activities. The inspector should consult with the platform operator at this time for guidance concerning wrapping and protecting sensitive platform equipment, i.e., compressor intakes, sight glasses, shut-in safety devices, etc. It is necessary to identify all items on the platform that require protection. Record and photograph any items that were previously damaged prior to job start-up.
7. Meet with the platform operators to review work and transportation schedules, safety requirements, subsistence and lodging arrangements, and general platform living requirements. Any perceived conflicts should be addressed at this time.
8. Verify that all work permits are reviewed and signed if not already done.

VI. AREAS REQUIRING SPECIAL ATTENTION

Offshore platforms have many areas that warrant special attention by the inspector. The splash zone, congested areas of piping and equipment, areas of multi-deck level piping that pass through pollution rings, and areas rigged with cables and nets on the platform undersides and overhangs, are hard to access. These are areas where inadequate surface preparation is most likely to occur. Usually

FIGURE 6-53. Typical splash zone area on an offshore platform. Courtesy of Chevron USA.



some degree of re-work is required to achieve the desired blast standard.

The structural and equipment layouts of most platforms are extremely congested due to space limitations. During blasting, previously painted areas are likely to sustain overblast damage if preventive measures are not taken. Tarps, plywood, and rubber matting are commonly used for this purpose.

VII. COATINGS USED ON OFFSHORE FACILITIES

A. COATINGS ABOVE THE SPLASH ZONE

Many new construction systems for structural and equipment items above the +10 foot (3 meter) splash zone level consist of an inorganic zinc-rich primer, high-build epoxy intermediate coats, and a polyurethane topcoat. Maintenance systems are usually two coats of high-build epoxy with a polyurethane finish coat. Total dry film thickness for these systems are normally 9-12 mils (230-300 micrometers). Five-coat solvent-based vinyl systems were frequently used in the past, but are being phased out due to VOC limitations. Waterborne epoxies and vinyls have not yet gained wide acceptance due to restrictive ambient condition requirements during application and limited performance data.

B. COATINGS IN THE SPLASH ZONE

Protective coating systems in the splash zone areas are exposed to severe conditions and do not receive cathodic protection (Figure 6-53). They must be able to withstand intermittent immersion type service. Surfaces are at times immersed completely in highly conductive salt water. During the dry cycles, salt deposits accumulate on the surfaces. This creates conditions favorable for the formation of highly active localized corrosion cells. Splash zone systems are subject to abnormally high levels of wear and tear due to constant wave action and impact with floating debris. Systems on boat landings receive substantial damage from routine contact with offshore support boats.

Many of the splash zone coatings are similar to the upper level systems. Frequently more dry film thickness is required, which is normally attained by adding another intermediate coat. Considerable corrosion protection and enhanced durability has been achieved by using one and two coat high build epoxy systems (24 to 80 mils; 0.6 to 2 mm) and polyesters. Monel cladding and high-build epoxy grout materials are frequently used on the structural legs down to the 20 foot (6 meter) level.

VIII. HEALTH AND SAFETY

A. DAILY SAFETY AND WORK LINE-UP MEETING

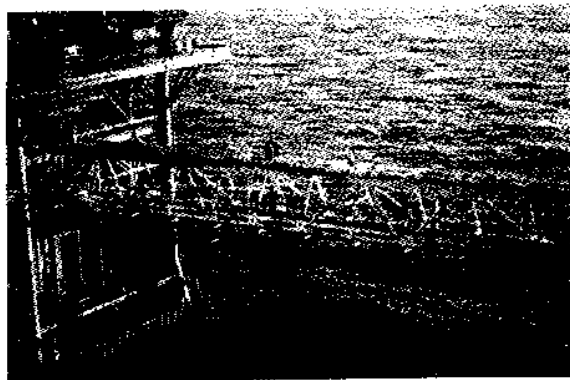
A safety meeting involving all work groups is usually held each morning before outside work activities begin. The platform operators review each simultaneous operation scheduled for the day and prepare a "Simultaneous Operations" plan to safely coordinate the activities. The applicator's internal safety and work line-up meeting is normally conducted after the general meeting has adjourned.

The inspector's role in each meeting is to contribute, but not conduct the meeting. He should discuss any safety concerns and review the applicator's work schedule.

B. PRE-INSPECTION OF THE WORK AREA

As the contractor prepares for the day's scheduled activities, it is good practice to pre-inspect the work area. Pri-

FIGURE 6-54. Rigging for painting a platform bridge.
Courtesy of Chevron USA.



many concerns are items that might affect the integrity of the surface application and coating application. Any surfaces to be blasted are to be checked for any contamination that might require a prewash. Oil, grease, salt, and other substances often contaminate surfaces between work intervals.

Newly applied coatings, existing coatings, or sensitive equipment, should be protected from overblast or overspray damage. Any items that are insufficiently protected should be noted and this information communicated to the foreman. If the inspector has the authority, he should delay the startup of blasting or painting activities until all these items are protected.

The inspector's pre-inspection may reveal unsafe or potentially unsafe areas. In these cases, the person in charge should be notified immediately so that corrective actions can be taken. The inspector must be fully cognizant of the fact that he has no direct responsibility regarding the safety of the contractor or operator personnel. Correcting the unsafe condition is normally the responsibility of the party who created it.

Several of the more common unsafe conditions that may be encountered on an offshore project are as follows:

1. Severely pitted or corroded pressurized process equipment
2. Gas or other volatile fume leaks (can be determined by hand-held air monitor)
3. Missing grating or deck plates

4. Exposed sight glasses, gauges, or level indicators
5. Inadequate ventilation
6. Inadequate lighting
7. Lack of adequate rigging, i.e., nets or sufficient cable amounts (Figure 6-54)
8. Slippery surfaces
9. Close proximity of other activities
10. Obstruction of walkways by hoses and/or rigging

IX. BEFORE SURFACE PREPARATION AND COATING APPLICATION

A. INSPECTION OF MATERIALS

Monitor the condition of the abrasive and coating materials to determine effects of transportation and environmental factors. Abrasive is usually shipped in either vinyl or disposable 4,000 pound (1800 kg) bulk bags. Bulk bags should be wrapped with plastic sheeting and shipped on pallets.

Bulk bags of abrasive are easily damaged by loading operations. If holes or tears are discovered, the contents should be discarded, since they are probably wet and contaminated with salt water. There is also the possibility of the bags splitting in mid-air while being transferred from the boat to the platform. Falling abrasive could land on workers below and cause a serious injury or fatality.

B. INSPECTION OF APPLICATOR'S EQUIPMENT

The inspector should:

1. Verify that the equipment is operational and of the type and/or quantity which is specified. The majority of the protective coating systems used in offshore operations are applied using conventional airspray equipment. *Airless setups are rarely used.*
2. Check the air supply from the air compressor(s) for oil and moisture contamination.
3. Inspect the safety equipment, i.e., spark arrestors on the compressors, dead man controls, shut-down devices, carbon monoxide monitors, etc., to verify that these items meet specification requirements.

4. Inspect all hoses and connections for wear. Verify that all blast hoses are wired together, and are rigged in a manner which will not cause tripping hazards.
5. Measure blast nozzle orifice sizes.
6. Check paint pots for separate gauge and regulator set-ups as well as agitators if required. Verify that they are working properly.
7. Ensure that in-line moisture traps are placed upstream of the paint pots, and that air and fluid lines are sized according to manufacturer's recommendations and specification requirements.
8. Ensure that all paint guns, fluid tips, and air caps are sized according to manufacturer's recommendations and specification requirements.
9. Check the applicator's rigging and report any obvious unsafe practices and/or non-compliance with OSHA and/or client requirements.
10. Check each equipment item. It is necessary for the inspector to check each equipment item to verify that it is operational and meets specification and/or manufacturer's requirements. It is good practice to check equipment before each use and ensure that ample supplies of spare parts are on hand.

C. PROTECTION OF PLATFORM EQUIPMENT

The inspector should verify that platform equipment is protected as follows:

1. Drains Plugged
2. Sight glasses, gauges, or level indicators wrapped
3. Equipment ID tags covered
4. Chart boxes wrapped
5. Emergency Shut Down (ESD) Devices and Actuator Stems protected
6. Filter media on all air intakes
7. Protection of non-scheduled blast and paint items from overblast and overspray (Figure 6-55)
8. Lighting is wrapped
9. Containment screens hung as required

FIGURE 6-55. Protection of platform equipment. Courtesy of Chevron USA.



D. MEASUREMENT OF AMBIENT CONDITIONS

Ambient conditions on an offshore platform can change several times a day. These conditions should be monitored closely and as frequently as conditions warrant, but not less than three (3) times a day. Routine measurements on a good weather work day should be taken and recorded in the morning prior to work start-up, during the lunch break, and in the afternoon just before painting.

X. SURFACE PREPARATION AND COATING APPLICATION

Most work scopes specify either selective (spot work) on specified areas, or (100%) work on all areas of from the heliport to the splash zone. The type of job which is specified determines the overall work strategy for the project. General strategies to be followed by the inspector are as follows:

A. SELECTIVE SPOT JOBS

1. Locate items to be worked
2. Verify that specified areas are isolated from the remainder of the platform with containment screens, plywood, tarps, etc.

3. Verify that several areas are rigged at a time so that alternative work areas are always available.
4. Ensure that workers concentrate specified blasting and painting activities in one area rather than overextending into several different areas.
5. Observe that work is done from the top of area, proceeding downward where possible.
6. Ensure that the area is kept squared off within normal platform area partitions.
7. Ensure that all items in one area are completed before moving to the next.

B. 100% JOBS

1. Verify that all areas to be worked including the heliport and the splash zone are rigged according to specification.
2. Verify that as many hoses and airlines as practical are rigged to the various work areas to minimize moving and set-up time once blasting and painting work has started.
3. Observe that work starts at the heliport and moves downward. An exception to this would be when seas are conducive to splash zone work.
4. Verify that all work is done with the prevailing wind for the particular time of year the project is being conducted.

C. INSPECTION OF SURFACE PREPARATION

It is important for the inspector to understand his responsibilities for reporting specification deviations. Surface preparation requirements are usually described by the specification's references to SSPC/NACE standards. In the offshore environment, however, it is difficult to achieve 100% compliance with several of the abrasive blast standards - specifically white (SSPC-SP 5) or near white metal (SSPC-SP 10). A variety of factors, which include soluble surface salt contamination, deep pitting, and high humidity, can cause blasted surfaces to turn (discolor) considerably by paintout time. Many times it is difficult to prevent this from occurring without incurring expensive rework time to remove salts completely by pressure and/or steam washing, then reblasting. It is also difficult to remove all oxidation from severely pitted steel without reblasting numerous times. It is absolutely necessary for the inspec-

tor to clarify the acceptable parameters of the specified blast standard with the appropriate job authority.

Inspection of the surface preparation work in progress should occur frequently during the workday. The primary inspection periods are during the morning, lunch and after noon breaks. Additional checks should be conducted during all other work stoppage periods and immediately before paintout time. Timely inspections of surface preparation activities help the contractor reduce "square up" time by minimizing amounts of worker movement required to pick up rejects in areas where surfaces were prepared earlier during the day.

The contractor should ensure that all work areas are kept square by blasting all items in a particular area so that no additional blasting or shielding is required once paintout has started. Considerable effort is necessary to ensure that previously painted areas are protected prior to blasting other areas. When inspecting newly blasted surfaces, check for overblast on adjacent areas and mark accordingly. It is good practice to repaint these areas on the same day that the overblast occurs.

Application of products over surfaces contaminated with salts is one of the leading causes of offshore coating failures. Checks for soluble salt contamination by using a recognized test method prior to painting (see Chapter 8) may be required.

During surface preparation, the inspector should verify that:

1. All contaminated areas are adequately cleaned by pressure washing, steam cleaning, and/or solvent washing prior to additional surface preparation activities.
2. Detergents are of adequate quality to remove grease, oil, salts, glycol, etc., from all surfaces, and do not leave residual contaminants on the cleaned substrate.
3. Adequate supplies of shielding materials are available to prevent overblast.
4. All necessary items are protected prior to and during blasting.
5. Blasting areas are monitored continually for product leaks.
6. Abrasive is dry and of the size and quality specified.

7. Air is clean, dry, and of adequate pressure for abrasive blasting.
8. Specified surface profile and cleanliness are achieved on all items.
9. Tie-in areas are "feathered" properly - all loose coating should be removed and edges are tapered toward the blasted surface.
10. Overblast is minimized by use of proper blasting techniques.
11. Blast areas are kept square.
12. Blasting operations are halted in the splash zone area when wind and sea conditions cause salt water contamination on the substrate.
13. All containment requirements are achieved.
14. All dust and residual abrasive is removed completely prior to painting.

D. PRE-PAINTING INSPECTION

On a routine blast day, final blowdown occurs at approximately 2 pm. Once this process is complete, the inspector conducts final inspection while the crew prepares to paint.

All residual dust must be completely removed before the blasted surface is accepted. Dust contamination is checked using the scotch tape test. Areas that are not completely square (those requiring reentry and additional overblast protection for re-blasting) should be reviewed with the foreman. A decision whether to reject and reblast this area during the next blasting cycle, or accept for painting should be made at this time.

All previously coated areas require additional inspection for overblast damage. Damaged areas should be marked for recoating, and then discussed with the foreman.

E. INSPECTION OF COATING APPLICATION

Monitoring the coating application process is a critical aspect of an inspector's job. If the coating is not applied properly, it will fail prematurely. During the application process, emphasis is placed on equipment set-up, mixing techniques, application techniques, and verification of the applied coating integrity.

XI. WORK AREA INSPECTIONS

A. AM WORK AREA INSPECTION

The paint crew normally breaks at or about 9 am. Blasted and/or painted areas should be inspected at this time. During blasting operations, non-acceptable blast or over-blasted areas should be marked for reblasting. Surface profile readings and ambient condition checks are necessary. The inspector should check for holidays and other defects in recently applied coatings that are fully cured.

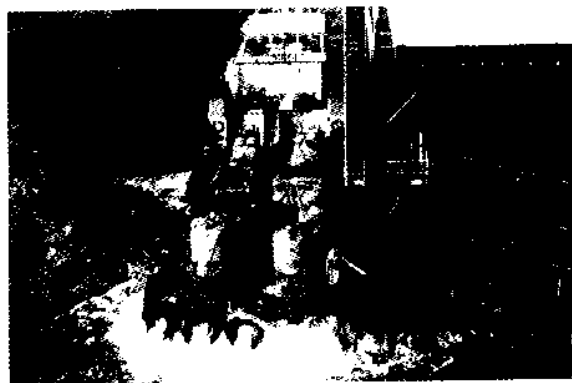
B. NOON WORK AREA INSPECTION

1. It is good practice for the inspector to eat lunch before the remainder of the crew. This enables him to inspect the work area while the crew is eating. Plans for square-up and final blowdown should be discussed with the foreman at this time.
2. Newly blasted and/or coated areas are checked first and marked for reblast or repair. Next, previously marked areas are rechecked and remarked if necessary. If any overblast or coating irregularities are detected they should be marked, noted, and corrected.
3. The inspector should conduct another thorough walkthrough of the work area and check once again for morning pre-inspection type items. Once again, ambient conditions are measured and recorded.

C. FINAL WALKTHROUGH

1. A final walkthrough of the work area is necessary upon completion of each day's activities. The objective is to ensure that the crew has secured the location for the night. Any potentially hazardous conditions should be noted and reported.
2. During the final walkthrough, the inspector should verify that:
 - a. Covers are removed from the navigation lighting.
 - b. Ropes and tarpaulins are removed from any potential ignition sources.
 - c. Paint cans, trash, and small equipment items are removed from walkways and work areas.
 - d. All stairwells are clear from tripping hazards, i.e., hoses, cables etc.

FIGURE 6-56. Paint boat. Courtesy of Chevron USA.



- c. Heliport is clear of all items.
- f. Splash zone area is clear of all paint cans, trash, and equipment items excluding secured rigging.
- g. All partially filled paint cans are stored in one designated area.
- h. All valves on fuel tanks and filler hoses are closed and capped to prevent leakage.
- i. All excess water and/or oil accumulations are drained from the compressor drip pans.
- j. All removed hatch covers are replaced.

XII. PAINT BOAT PROJECTS

Some offshore coating projects are conducted from the deck of a paint boat (Figure 6-56). This is necessary when the platform does not have adequate crane capacity or space to accommodate the paint crew and equipment. The inspector's duties are basically the same as on a deck job. There are some unique concerns and situations; however, that may be encountered while working a boat job.

A typical boat job set-up requires a cargo boat in the 125 to 185 foot (38 to 56 meter) class. The blasting and painting equipment, abrasive, and coating materials are positioned on the aft work deck. The equipment and material list could include as many as two 850 CFM ($24 \text{ m}^3/\text{min}$) or larger diesel air compressors, two 8 ton (7 Mg) or larger bulk abrasive blast units, and fifteen to twenty 4000 lb. (1.8 Mg) bulk abrasive storage bags. In addition, four to

five 4 ft. x 4 ft. x 10 ft. (1 m x 1 m x 3 m) cargo baskets are needed to store the remainder of equipment and materials.

The paint crew can include up to twelve men. During the work day, the boat is secured to the platform and blasting and painting activities are conducted from the aft work deck.

This type of work is much more difficult than platform work because the problems encountered during boat work are much more numerous than on platform jobs. Boat work is also much more dangerous than platform work. Personnel have to transfer by swing rope to and from the boat and platform many times a day. The work deck on the boat is not stationary, and rough seas contribute to marginally safe working conditions.

It is very important for the inspector to understand his authority limits and chain of command regarding the captain and the boat crew. The boat captain is in charge of the boat crew, and responsible for safely operating the vessel. The inspector has absolutely no jurisdiction over the boat crew, other than communicating pertinent job information to the captain, i.e., platform name, work schedules, etc.

The equipment and materials are extremely susceptible to damage from salt water. It is critical to monitor materials carefully. The equipment should also be carefully monitored to ensure that salt water does not contaminate blast hoses and paint lines.

The inspector should be aware of the personality profiles of paint crew members. In general, they are a "rougher cut" version of platform crews. They are highly independent and remarkably adaptive to the paint boat's harsh living and working conditions. Boat work is extremely labor intensive, physically demanding, and dangerous. Because of these factors, boat crews typically exhibit good work habits.

XIII. SUMMARY

The nature of the offshore environment presents the coatings inspector with many unique concerns. In addition to the activities usually associated with the inspection of a coating or coating system, the inspector on an offshore facility must contend with the confined quarters, logistics, planning, and coordination of coating activities (in such a

way that they do not interfere with simultaneous activities) and environmental concerns.

The inspector can begin to address these concerns through a pre-inspection of the platform. This familiarizes him with the platform layout. Later, the inspector monitors the loadout procedure, which includes a thorough inventory of all equipment and materials. Once the cargo boat reaches the platform, the inspector is responsible for monitoring the offloading and placement of materials and equipment and equipment set-up. At the platform, materials should again be inventoried and inspected for damage that may have occurred during transport.

As on other coating inspection jobs, the inspector is responsible for monitoring ambient conditions, rigging, masking and protection of sensitive equipment, surface preparation, coating application, and testing of applied coatings. Throughout these activities, special attention should be paid to ambient conditions, which may change abruptly, and surface salt contamination, a problem arising from the offshore location. In addition, inspections should be scheduled regularly throughout each day.

The coatings inspector on an offshore facility may be required to operate out of a paint boat. This presents even more harsh living conditions, more confined living quarters and work areas, and more danger. In addition, inspection of materials and surfaces is even more critical.

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Timothy M. Conlin is a Facilities Representative for Chevron Production Company's Gulf of Mexico Business Unit. He has been employed by Chevron USA since 1980. In his present position, he has been responsible for managing offshore coatings maintenance activities and the quality assurance/quality control program for new fabricating

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Mr. Conlin is a member of SSPC, NACE International, and the American Petroleum Institute (API). He has written several articles for the JPCL and has presented papers at SSPC, NACE, and the American Society of Safety Engineers conferences.

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Chapter 6.8

Refineries and Petrochemical Plants

by John F. Delahunt

OUTLINE

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- II. References
- III. Pre-Job Responsibilities
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 - B. Offsite Coating and Blasting Facilities
 - C. Scheduling/Completion Requirements
- IV. Design and Layout of Refineries and Petrochemical Plants
- V. Coatings Used in Refineries and Petrochemical Plants
- VI. Health and Safety
- VII. Inspection of Prefabricated Structures
 - A. Shop Blasted and Primed Steel
 - B. Vessels
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 - A. Surface Contamination
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 - E. Structural Steel
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I. SCOPE

This sub-chapter describes the several specific areas that should claim the coatings inspector's attention during the fabrication and construction of a refinery or petrochemical plant. It also outlines the recommended procedures for inspecting paints, protective coatings, and linings applied to refinery and petrochemical plant equipment. (Note: Further information relevant to coatings inspection at refineries and petrochemical plants can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Petroleum Institute (API)

API RP 652 Lining of Aboveground Petroleum Storage Tank Bottoms

American Society for Testing and Materials (ASTM)

ASTM C 661 Test Method for Indentation Hardness of Elastomeric Type Sealants by Means of a Durometer

ASTM D 2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor

ASTM D 3363 Test Method for Film Hardness by Pencil Test

ASTM D 3486 Installation of Vulcanizable Rubber Tank and Vessel Linings

ASTM D 4414 Practice for Measurement of Wet Film Thickness of Organic Coatings by Notched Gages

American Water Works Association (AWWA)

AWWA/ANSI C203 Coal Tar Protective Coatings and Linings for Steel Water Lines - Hot Applied

AWWA/ANSI C213 Fusion Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines

AWWA/ANSI C215 Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines

NACE International (NACE)

NACE RP0178-95 Fabrication Details, Surface Finish Requirements and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service

NACE RP0188-90 Discontinuity (Holiday) Testing of Protective Coatings

NACE RP0287-95 Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using a Replica Tape

SSPC: The Society for Protective Coatings (SSPC)

SSPC Applicator Training Bulletin

SSPC-PA 1 Shop, Field, and Maintenance Painting

SSPC-PA 2 Measurement of Dry Coating Thickness with Magnetic Gages

SSPC-SP 1 Solvent Cleaning

SSPC-SP 2 Hand Tool Cleaning

SSPC-SP 3 Power Tool Cleaning

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

SSPC-SP 8 Pickling

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

SSPC-SP 11 Power Tool Cleaning to Bare Metal

III. PRE-JOB RESPONSIBILITIES

A. ITEMS TO BE REVIEWED

As discussed in Chapter 3, it is vital that the coatings inspector reads and understands the job specification and all submittals, such as relevant standards, coating manufacturer's product data sheets, and Material Safety Data Sheets (MSDSs). For work on refineries and petrochemical plants, it is also important that the inspector reviews the following:

- Properties and application procedures for specialty protective coating and lining systems, such as those applied to concrete underground ductwork, concrete water treatment sump facilities, and internal vessel or tank linings.
- Local Safe Operation Practices of the refinery or chemical plant. This defines the owner's permitting procedures as well as procedures that must be followed when abrasive blast cleaning, applying coatings, and entering and working in confined spaces. This set of practices or standards may vary depending on location; therefore, it must be reviewed for each facility.

B. OFFSITE COATING AND BLASTING FACILITIES

The inspector should visit offsite, as well as onsite, coating and blasting facilities to ensure that work is carried out satisfactorily in compliance with the job specification.

C. SCHEDULING/COMPLETION REQUIREMENTS

During new construction, paints and protective coatings are frequently the last or nearly the last phase of the project. The inspector should make a conscious effort to ensure that the painting schedule is maintained, and that the quality of work is maintained within the specified criteria.

IV. DESIGN AND LAYOUT OF REFINERIES AND PETROCHEMICAL PLANTS

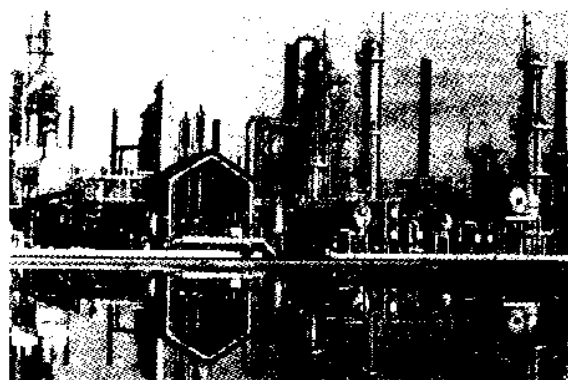
The facilities at refineries and petrochemical plants are a complex network of structures, vessels, equipment, and above and below ground piping, as shown in Figure 6-57. A large refinery may contain 30 million square feet (2.8 million square meters) or more of exposed carbon steel facilities that must be protected from corrosion. The process units may include distillation, reforming and cracking, hydroheating, lube oil, treating and sweetening, ethylene, synthetic rubber, chemical additives, and solvent manufacturing units. Additionally, refineries and petrochemical plants can include storage tanks, spheres, and bullets, as well as water treating facilities, cooling towers, boiler feed water plants, marine docks and piers, boats and tugs, and offshore equipment. In addition, the bottoms and shells of aboveground storage tanks and processing vessels may require an internal lining to prevent corrosion and/or protect stored product quality.

V. COATINGS USED IN REFINERIES AND PETROCHEMICAL PLANTS

To accomplish the extensive coating and lining work at a refinery or petrochemical plant, many generically different types of protective coatings and linings may be used. At a refinery or petrochemical plant, over twenty different paint and coating systems may be used for corrosion protection. In addition, there may be some specialty protective coatings or linings used, such as intumescent epoxy coatings for fireproofing, or complex rubber or plastic internal linings applied in water or chemical treating equipment. Temperature indicating paints can be used as a process aid to detect upset conditions.

Commonly used external coatings include alkyds, epoxies, epoxy copolymers, water/solvent borne inorganic zinc-rich coatings, water-borne acrylics, silicone-acrylics, silicones, and one and two-pack polyurethanes. The linings commonly used include epoxy, phenolic, epoxy copolymer, and various polyesters, as well as various rubber and heat-cured linings. Underground or sub-sea piping is commonly coated with hot-applied coal tar, extruded polyethylene, and fusion bonded epoxy (see Chapter 6.2). For fire protection, concrete, shotcrete (gunite; see Chapter 5.10), and lightweight cementitious and intumescent coatings are

FIGURE 6-57. Top - A refinery. Courtesy of S.G. Pinney & Associates, Inc. Bottom - A petrochemical facility. Courtesy of KTA-Tator Inc.

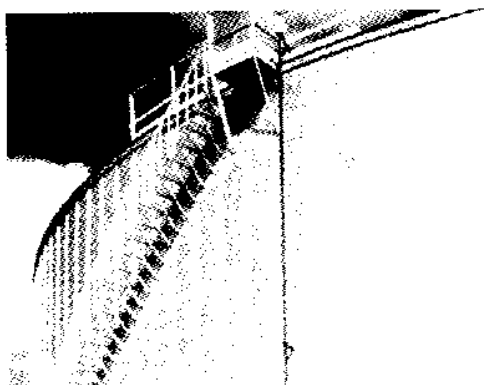


frequently employed. In marine service, coal tar epoxy, antifouling, as well as inorganic zinc-rich (see Chapter 5.14), epoxy, and polyurethane systems are used. For underground and sub-sea service, the coatings are supplemented with cathodic protection.

VI. HEALTH AND SAFETY

As discussed in Chapter 7, the coatings inspector is not directly responsible for the safety of personnel at a jobsite within a refinery or a petrochemical plant. This is usually the responsibility of the owner's safety professional and/or the coating applicator, who must ensure that all safety rules and procedures are followed. However, safety is

FIGURE 6-58. Storage tank painted white. SSPC file photo.



everybody's business, and the inspector must be informed and take all precautions necessary to protect himself and those around him. The inspector should be especially cognizant of requirements for eye, ear, and foot protection, as well as the need for protective clothing, gloves, and face protection if handling noxious chemicals.

Coatings inspection in refineries and petrochemical plants often involves working in confined spaces. During lining application and cure of linings in confined spaces, specific procedures must be followed to reduce the risk of fire and explosion. These include:

- Adequate ventilation
- Correct grounding of blasting and coating equipment
- Use of explosion-proof lighting
- Requirements regarding lower explosive limits (LEL)

Chapter 7 provides further information on working in confined spaces, and other general safety information for the coatings inspector.

VII. INSPECTION OF PREFABRICATED STRUCTURES

A. SHOP BLASTED AND PRIMED STEEL

The inspector should thoroughly check all prefabricated piping, pipe, and structural steel that has been blasted,

shop coated, and shipped to the field. These items should be checked for film thickness and damage. Film thicknesses may be substantially below specified minimums or exceed maximums. Such deficiencies or damaged areas may usually be corrected by cleaning (if needed to get rid of any contaminants) and lightly abrading the existing coating before applying a corrective coating.

B. VESSELS

Thin film heat cured and/or elastomeric linings may be applied to pressure vessels, water treating vessels, vacuum degasifiers, and other equipment during fabrication and prior to shipment to the site. Generally, a detailed specification is issued concerning the lining, be it air-cured, baked, or a vulcanized rubber. Such a document will contain the required inspection procedures and testing. Such inspection will be carried out by the owner's representative or a third party inspector. In addition to the above, specific instructions concerning shipping to prevent damage during transportation may be included in the specification. These should be rigidly followed.

At arrival, the inspector should inspect such linings to verify that no mechanical damage has occurred. Once erected, they should again be inspected and, if found satisfactory, all openings should be shut to prevent any accidental damage. Depending on the type of lining, vessels located outdoors may be required to be painted white and/or filled with water to prevent thermal solar damage (Figure 6-58).

VIII. SURFACE PREPARATION AND COATING APPLICATION

A. SURFACE CONTAMINATION

Prior to surface preparation, the steel surface should be inspected for oil or chemical contamination. If present, it must be removed by appropriate means such as solvent degreasing or water washing. This is especially appropriate if the steel structures or equipment have been delivered to the site by ocean transport.

B. APPLICATION TECHNIQUES

In refineries and petrochemical plants, coating application is primarily carried out by conventional air or airless spray



FIGURE 6-61. Failed fireproofing on a pipe at a petrochemical facility. Courtesy of KTA-Tator Inc.

the process operation is frequently below the dewpoint. This may include gas storage and handling, wax manufacturing facilities, and plastic manufacturing units. In general, when such equipment operates within 25-300°F (-4 to 150°C) or is thermally cycled within that range, it must be protected with a corrosion resistant coating system. The inspector should verify that such coating systems are applied as specified before the insulation or fireproofing is applied.

G. COLD THERMAL INSULATION

The inspector may be required to inspect the installation of cold thermal insulation systems including vapor barrier coating systems. Materials used for vapor barriers are usually elastomeric caulks and reinforced elastomeric coatings, which require critical application skills.

IX. SUMMARY

During new construction of a refinery or petrochemical plant, the coatings inspector should ensure that both the schedule and the quality of the work are maintained. In preparing for the job, the inspector should become familiar with the properties and application plans for any specialty coatings that will be applied. For a complex structure such as a refinery or petrochemical plant, this can include many different types of coatings, such as fireproofing, rubber or plastic sheet linings, and cold thermal insulation. The

inspector should also monitor surface preparation and coating work done at offsite facilities, as well as the condition of prefabricated structures such as lined vessels and cement-lined pipe.

When monitoring on-site coating operations, the inspector should ensure that sensitive equipment is protected from overblast and overspray, that no painting is done on surfaces specified as "not to be painted," and that adequate ventilation is provided for proper curing and for safety. The inspector should also ensure that the necessary permitting has been obtained for entry into confined spaces, and that all other necessary precautions are taken to protect himself from fire and explosion hazards.

ACKNOWLEDGEMENTS

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BIOGRAPHICAL SKETCH

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Mr. Delahunt has BS/MS in Mechanical Engineering. He is a NACE Accredited Corrosion Specialist and a NACE Coating Inspector.

Chapter 6.9

Food and Beverage Processing Plants

by William S. Jenkins

OUTLINE

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 - B. Definitions of Indirect and Direct Food Contact Surfaces
- IV. Jurisdiction Over Food and Beverage Processing Plants
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I. SCOPE

This sub-chapter covers the inspection of protective coatings applied to different types of "food and beverage" processing plants. Regulations pertaining to coating of food and beverage processing plants are discussed, and the various environments found in these facilities are highlighted. (Note: Further information relevant to coatings inspection at food and beverage processing plants can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

Code of Federal Regulations

21 CFR 175 Indirect Food Additives: Adhesives and Components of Coatings

21 CFR 177 Indirect Food Additives: Polymers

21 CFR 178 Indirect Food Additives: Adjuvants, Production Aids, and Sanitizers

SSPC: The Society for Protective Coatings (SSPC)

SSPC-SP 1 Solvent Cleaning

SSPC-SP 2 Hand Tool Cleaning

SSPC-SP 3 Power Tool Cleaning

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

SSPC-SP 10 Near White Blast Cleaning (NACE No. 2)

US Department of Agriculture (USDA)

USDA, Food Safety and Quality Service, Agriculture Handbook No. 562, Guidelines for Obtaining Authorization of Compounds to Be Used in Meat and Poultry Plants, September 1979.

USDA, Food Safety and Inspection Service, FSIS Directive 11,000.4, Rev. 1, "Paints and Coatings Intended for Use in Official Establishments," 11-24-95.

US Public Law

Public Law 90-201 Federal Meat Inspection Act and Wholesome Meat Act of 1967

Public Law 90-492 Poultry Products Inspection Act and Wholesome Poultry Products Act of 1968

III. ABOUT FOOD AND BEVERAGE PROCESSING PLANTS

A. DEFINITION OF FOOD AND BEVERAGE PROCESSING PLANT

The term "food and beverage processing plants" is extremely broad in that it includes facilities for handling meat and poultry (Figure 6-62), fish, dairy products, fruits and vegetables, grain, baked goods, juices, soft drinks, beer, wine, and spirits. Plants that produce pharmaceuticals intended for human consumption are also considered a member of this class.

B. DEFINITIONS OF INDIRECT AND DIRECT FOOD CONTACT SURFACES

The surfaces inside food and beverage processing plants are classified as "direct" and "indirect" (or "incidental") food contact surfaces. A direct food contact surface is one which, at some point during processing, comes into inten-

tional direct contact with products meant for human consumption. Liners for grain hoppers or flour bins are examples of direct food contact surfaces. An indirect contact surface is one which is in close proximity to the product being processed, and as such could incidentally come into contact with the product. Warehousing areas and ceilings and upper walls in actual food processing areas are examples of indirect food contact surfaces.

IV. JURISDICTION OVER FOOD AND BEVERAGE PROCESSING PLANTS

Two government agencies have jurisdiction over food and beverage processing plants: The Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA). The FDA controls the use of coatings on direct food contact surfaces--in all types of "food and beverage processing plants." The USDA has jurisdiction over meat and poultry plants.

A. FDA

Coatings for direct contact food surfaces in all types of food and beverage processing plants must be certified to have been formulated only with raw materials that are listed as acceptable to the Food and Drug Administration (FDA). The FDA does not approve coatings for use in food and beverage processing plants, but does issue letters of "no objection" if all substances or compounds that make up the coating are listed as acceptable under CFR, Title 21, paragraph 175.300 and the coating passes the extractables test outlined in that same paragraph. FDA acceptance does not mean that the coating will resist long term exposure to any given food stuff. It signifies that the coating passes an extractables test and is formulated only with approved materials.

Note: Other organizations/facilities usually take it upon themselves to specify and use FDA acceptable coatings on direct food contact surfaces. This voluntary conformance to industry standards is much the same as the voluntary conformance of municipalities to NSF International standards when lining potable water tanks. The actual laws dealing with coatings can be found in CFR, Title 21, sections 175 and 177.

FIGURE 6-62. Inside a meat processing plant. SSPC file photo.



B. USDA

The USDA is responsible for inspecting meat and poultry plants, and has the power to shut down a plant with peeling or loosely adherent coatings in process areas. The USDA derives this power from the Federal Meat Inspection Act (as amended by the Wholesome Meat Act of 1967) and the Poultry Products Inspection Act (as amended by the Wholesome Poultry Products Act of 1968), which require that meat and poultry plants be kept in safe and sanitary condition. (These acts are enforced through the Meat and Poultry Inspection Program (MPI) by the Food Safety and Quality Service.)

Historically, the USDA has been responsible for approving coatings used for direct food contact surfaces in meat and poultry plants. The USDA also has also been responsible to ensure that coatings do not contaminate surfaces in incidental food contact (e.g., walls, ceilings, posts, partitions, doors, ceilings, coverings, and floors) in meat and poultry plants. Prior to November 1995, the USDA required coating manufacturers to provide a list of all the ingredients in the formulations or certify that the coating would withstand daily cleaning, cyclic temperature, and wet conditions. However, under Food Safety and Inspection Service (FSIS) Directive 11,000.4, Revision 1, 11-24-95, this requirement (which had been established under FSIS 11,000.4, 8-12-94) was eliminated. This directive is in effect at "official establishments," which are federally-inspected meat or poultry packing facilities.

All cleaning solutions, even those containing abrasive materials, are subject to approval by the resident USDA inspector. For guidelines on coatings or surface cleaning solutions for use in meat and poultry processing plants, the inspector may refer to the USDA, Food and Quality Service, Agriculture Handbook No. 562, September 1979. The actual laws dealing with cleaning and sanitizing compounds can be found in CFR, Title 21, section 178.1010.

V. ENVIRONMENTS FOUND IN FOOD AND BEVERAGE PROCESSING PLANTS

The coatings inspector should be familiar with the different types of environments found in food and beverage processing plants and the difference in levels of corrosiveness associated with them. Two types of areas normally found in food and beverage processing plants are warehouse/storage areas and processing areas. Most food and beverage processing plants also have cold rooms or large freezer rooms.

A. WAREHOUSE/STORAGE AREAS

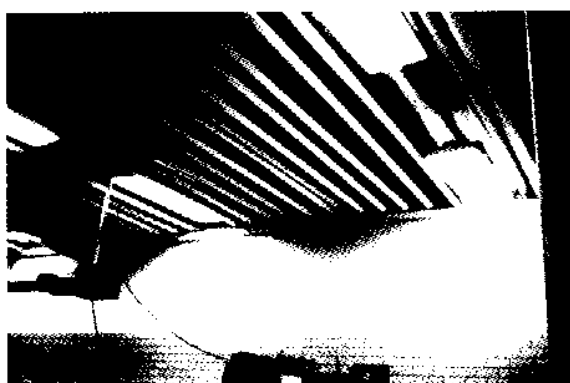
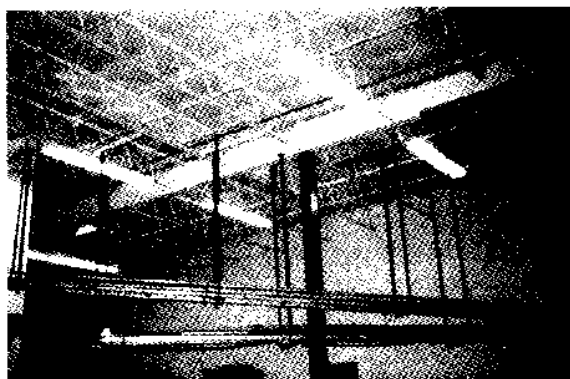
The warehouse and storage areas are typically non-aggressive, spacious areas with high ceilings (Figure 6-63). These areas often consist of galvanized, coated or insulated metal ceiling panels; supporting structural steel frame; fire control system usually constructed of carbon steel or cast iron piping; galvanized conduit; and concrete floors.

B. PROCESS AREAS

The process areas in most plants are similar in that they are usually very wet and may be subjected to such aggressive reagents as acids, caustics, salts, sugars, animal fats, high pressure hot water, and cleaning chemicals (Figure 6-64). These areas are also very susceptible to bacterial growth such as mold or mildew because of the presence of moisture, heat, and food ingredients. Mildew may be treated with a solution containing sodium hypochlorite or a blend of sodium hypochlorite and sodium hydroxide.

Non-ferrous metals such as stainless steel and copper are widely used for process equipment for the purpose of product purity in areas where flaking paint would cause a major problem. They have outstanding resistance to corrosion, and are also chosen for heat resistance and resistance to animal fats, amino acids, acetic acids, and other

FIGURE 6-63. Warehouse areas. Top - Courtesy of Courtaulds Coatings, USA. Bottom - SSPC file photo.



reagents naturally occurring in foods and beverages. The use of non-ferrous metals is mostly limited to piping, vessels, and process equipment which comes into direct contact with the product during processing. In most cases, these non-ferrous surfaces are left uncoated; however, in some cases they are coated to protect them from reagents such as acids and chlorides.

VI. COATINGS USED IN FOOD AND BEVERAGE PROCESSING PLANTS

As described in Section IV, the coatings used in food and beverage processing plants must meet all applicable FDA and USDA requirements. In addition, coatings may have to conform to local and/or state VOC regulations. The coat-

ing systems used in process environments tend to be new technology low VOC, low odor epoxy materials.

For work in food and beverage processing plants, the inspector should become familiar with waterborne epoxies, waterborne acrylics, high-solids epoxy mastics, 100% solids self-leveling or trowel applied epoxy floor coatings, and high solids polyurethane coatings. The inspector should note that solvent odors are not tolerated in areas where food and beverages are being processed.

Coating systems in process areas must promote an atmosphere of cleanliness while affording the substrate the protection that was designed into the coating. Great care should be taken to eliminate cracks, crevices, rough surfaces, etc. where bacteria can get a foothold. The coating system, once installed, must be somewhat inhibitive to the growth of bacteria and have a smooth surface which can be easily cleaned by normal maintenance procedures. Alkyd and other oil base coatings contain oils which may serve as a nutrient for mold and mildew. This imparts poor resistance to caustic cleaning solutions, and makes them a very poor choice for process areas.

VII. HEALTH AND SAFETY

A. WAREHOUSE/STORAGE AREAS

These areas are usually accessed by rolling scaffolds and/or mechanized manlifts. The inspector should be aware of OSHA guidelines concerning the erection of suitable rigging, scaffolding, or working platforms. (Note: OSHA guidelines for the erection of rigging and scaffolding are general throughout the industry, i.e., the same guidelines apply to the food and beverage processing industry as apply to the chemical industry.)

Normally, due to the spacious nature of warehouse areas and the lack of open containers of food stuff, ventilation while painting is not a key factor; however, wrapping machines, palletizers, finished goods or raw materials should be protected from fallout.

FIGURE 6-64. Process area. Courtesy of Courtaulds Coatings, USA.



B. PROCESS AREAS

Most coatings work in process areas is done from ladders or from low scaffolding. Care should be taken to see that all food stuff is removed from the process areas before any rigging, surface preparation, or coating work takes place. All process equipment should be well protected from any fallout that might take place during any phase of the job to protect the equipment from mechanical failure and help insure product purity when the process goes back on line. Normally, it is good painting practice to erect plastic barriers around an area being worked in to protect adjacent areas from being contaminated with either debris or solvent odor.

Most food and beverage processing facilities use very aggressive cleaning solutions in their process areas. These chemicals are used for general cleaning and will cause serious burns to skin and eyes. In addition, many plants use 20% and 50% solutions of sodium hydroxide to flush closed systems and during shut down periods; some of these systems may be opened for scheduled maintenance. The inspector should interact closely with the plant safety engineer to avoid coming into contact with potentially harmful chemicals, learn established safety procedures, and locate the emergency eye wash and shower stations.

VIII. SURFACE PREPARATION AND COATING APPLICATION

The inspector should verify that the specified level of surface preparation is attained in all areas.

A. WAREHOUSE/STORAGE AREAS

Normally these areas are specified to be prepared in accordance with SSPC-SP 2 or SP 3 ("Hand Tool Cleaning" or "Power Tool Cleaning") respectively, and then to receive an alkyd or acrylic dry fall coating system. The inspector should make sure the surfaces are free from loosely adherent paint or corrosion products, dirt, mildew, or other contaminants prior to coating.

B. PROCESS AREAS - STEEL SURFACES

Continuously wet areas are a problem in food and beverage plants and extra care must be taken during coating application to successfully protect the substrates from corrosion in these areas. The key to successfully coating these areas lies in the surface preparation. Severely corrosive environments require that the surface be more aggressively prepared. The goal is to remove all surface contaminants, achieve a sound substrate, and provide a suitable means for bonding of the specified coating system. At the same time, the surface preparation must leave time for the proper application and cure of the coating system prior to placing the process area back on line.

Abrasive blasting is usually considered the best cleaning method for the longevity of any of the coating systems used. However, this is not always feasible due to the possibility of contaminating the process equipment or food stuff. Sometimes vacuum blasting or slurry blasting is considered a suitable alternative. It should be noted that unless inhibitors are added to the water while slurry blasting, it may be impossible to achieve a surface cleanliness as described by SSPC-SP 5, SP 10, or SP 6 (White Metal Blast Cleaning, Near-White Metal Blast Cleaning, or Commercial Blast Cleaning, respectively).

Often, the only surface preparation feasible for the time available is SSPC-SP 2 or SP 3 (Hand Tool Cleaning or Power Tool Cleaning, respectively). When marginal surface preparation is specified, the inspector should take great pains to ensure that all loose or undercut coating is

removed, as it will contribute to premature failure, especially with the added surface stress of another coating system.

C. PROCESS AREAS - NON-FERROUS SURFACES

When non-ferrous metals such as stainless steel and copper are coated, the inspector should ensure that the surfaces are properly prepared, the surface is dry before coating, and the coating system is applied correctly. Wet film thicknesses should be regularly monitored during coating application and the dry film should be measured with an eddy current dry film thickness gauge.

D. PROCESS AREAS - CEMENTITIOUS SURFACES

Concrete floors, concrete and concrete block walls, and other cementitious surfaces make up the bulk of the coated surfaces in food and beverage processing facilities. These surfaces can also pose the greatest challenge due to their porosity, which allows them to absorb contaminants readily. The inspector should realize that cementitious surfaces can become too contaminated to ever be successfully coated.

The most common contaminant and possibly the hardest to remove is oil, which is most frequently found on floors. Oil can sometimes be removed by the use of caustic cleaners, or in extreme cases by using 13 ounces (380 milliliters) of lye to 1 gallon (3.8 liters) of water, then adding saw dust until the mixture reaches the consistency of a thin paste. The mixture is applied to the contaminated floor and allowed to react for a period of time before being removed. The substrate is then flushed with copious amounts of fresh water. Note that the mixture is very hazardous and should be treated as such.

After a floor has been cleaned or treated for oil contamination, the inspector should verify the absence of oil as follows:

1. Allow the floor to dry.
2. Place a 250-watt light bulb (or explosion proof equivalent, if required), close to the substrate for 30 to 45 minutes.
3. Apply a few drops of clean water on the floor.

4. Observe the absorption of the water by the concrete. (If there is residual oil on the surface, the water will not be readily absorbed.)

E. COLD ROOMS AND FREEZER ROOMS

Temperature can play an important role in the successful application of a coating system. Cold rooms and freezer rooms are often maintained from 0 to 35°F (-18 to 2°C). There are several epoxies now available that will cure at those temperatures; however, the presence of moisture on the substrate in the form of ice can be extremely difficult to detect.

One method for detecting surface moisture in this type of environment is to tape a small area with 3 mil (26 micrometers) plastic sheet, warm the substrate with a small infrared heater or 250 watt light bulb, then check the plastic sheet for moisture condensation.

IX. SUMMARY

The term "food and beverage processing plant" covers a broad range of facilities. Coatings for direct-contact food surfaces in all types of food and beverage processing plants must meet FDA requirements. The USDA also has some requirements concerning coating that must be met by meat and poultry processing facilities.

In food and beverage processing plants, there are two basic types of areas: warehouse/storage areas and process areas. The environment in warehouse/storage areas is typically non-aggressive (although moisture can be a problem in cold rooms and freezer rooms). On the other hand, the environment in processing areas is typically wet and aggressive, with exposure to acids, caustics, salts, sugars, fats, high pressure water, and chemicals. In addition, there may be many concrete, stainless steel, galvanized steel, and copper surfaces. This, plus the nature of the processing environment, has an impact on surface preparation, coating application, and inspection. Of particular concern is protecting processing equipment from fallout.

The hazards in a food and beverage processing plant include exposure to acids and caustics. The inspector must take precautions to avoid contact with these. The inspector should also be sure that any scaffolds, rigging, and work platforms he must use for the inspection work are safe.

Chapter 6.10

Water and Wastewater Treatment Plants

by James Graham

OUTLINE

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- III. About Water and Wastewater Treatment Plants
 - A. Major Components
 - B. The Specification
 - C. Planning and Scheduling Operations
- IV. Environments Found in Water and Wastewater Treatment Plants
- V. Coatings Used in Water and Wastewater Treatment Plants
 - A. Submerged Surfaces
 - B. Severe (Damp) Atmospheric Service
 - C. Mild Exterior Exposure
 - D. Mild Interior Service
 - E. Hot Steel Surfaces
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- VII. Surface Preparation and Coating Application
 - A. Masking and Protection of Sensitive Equipment
 - B. Lead in Paint
 - C. Treatment of Various Exposure Zones
 - D. Holiday Detection
 - E. Disinfection of Potable Water Tanks and Piping
 - F. Clean-Up of Waste Debris
- VIII. Summary

I. SCOPE

The purpose of this sub-chapter is to acquaint the reader with the special problems associated with the coating and inspection of coating operations in water and wastewater treatment plants. It includes:

- Descriptions of the environments and service conditions found in water and wastewater treatment plants
- Materials and practices used to protect water and wastewater treatment plants
- An overview of coatings inspection procedures
- Hazards that may be encountered by the coatings inspector

(Note: Further information relevant to coatings inspection at water and wastewater treatment plants can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American Water Works Association (AWWA)

AWWA/ANSI C652 Disinfection of Water - Storage Facilities

NSF International (NSF)

NSF/ANSI 61 Drinking Water System Components - Health Effects

SSPC: The Society for Protective Coatings (SSPC)

SSPC Paint 16 Coal Tar Epoxy-Polyamide Black (or Dark Red) Paint

III. ABOUT WATER AND WASTEWATER TREATMENT PLANTS

A. MAJOR COMPONENTS

Major components of a water treatment plant include storage and chemical treatment tanks, buildings, pumps, piping monitoring distribution systems, flocculation basins and settlement ponds.

Major components of a wastewater treatment plant include digestion, sedimentation, chlorination/dechlorination, and air flotation tanks; buildings and associated filters, pumps, ponds, electrical generators and control centers, piping, and cableways. All of these structures must be coated to protect them from corrosion (Figure 6-65 and 6-66).

B. THE SPECIFICATION

The job specification for a water or wastewater treatment plant should reflect the many demands of the plant being coated. It should specify systems that are easily maintained, since coating damage from the severe environmental and service conditions can be expected. Inspection items normally present in the specification include:

- Monitoring requirements for surface preparation (surface free of oil, grease, rust, and other contaminants, and surface profile)
- Storage, mixing, and application of coatings
- Curing and dry film thicknesses of coatings.

The job specification may also address requirements for monitoring of ambient conditions and surface temperatures; correction of substrate irregularities such as steel laminations, rough welds, weld slag, spatter and excessive undercutting along welds; and detection of holidays and other film imperfections.

FIGURE 6-65. Parts of a wastewater treatment plant. Top - Sludge thickener unit. Bottom - Clarifier unit. Both SSPC file photos.



C. PLANNING AND SCHEDULING OPERATIONS

As with all structures involved in continuous operations, care must be taken to minimize time when components of water and waste water plants are taken out of service for coating. Even though alternative equipment may be available during periods of shut-down for repairs, such work should be completed as rapidly as possible lest there be failure of alternative equipment or overloads. The inspector should work closely with the owner and applicator to avoid unnecessary delays. When inspection hold points are required, they should be coordinated between the owner, applicator, and inspector to minimize any down time.

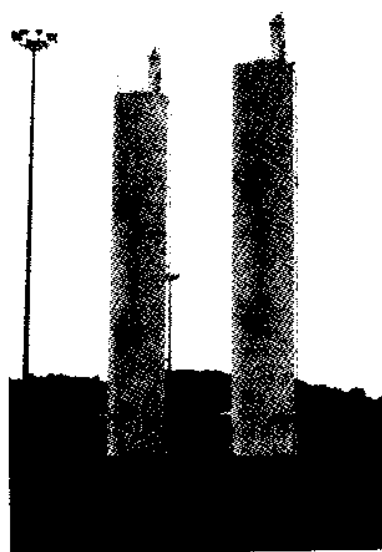


FIGURE 6-66.
Lime towers.
SSPC file photo.

- Ease of maintenance
- Acceptable appearance

Within a single water or wastewater treatment plant, several coating systems are usually required because of differences in substrates and environments.

When selecting coatings that may come in contact with potable water, the coating must be approved by NSF International (NSF) in accordance with ANSI/NSF 61. They are the current authority for determining the safety and toxicity of products that come in contact with food and drinking water.

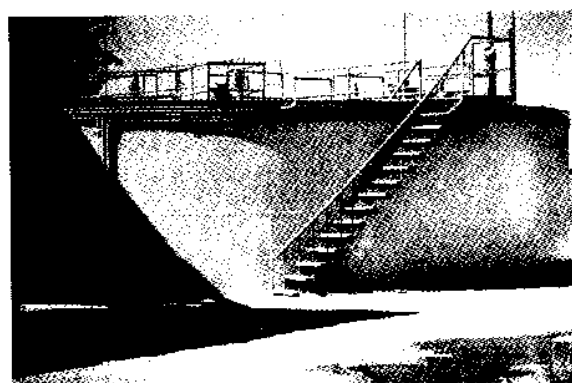
A. SUBMERGED SURFACES

A system consisting of two coats of coal tar epoxy (e.g., SSPC Paint 16) totaling 20 mils (500 micrometers) dry film thickness has been used successfully for many years on both steel and concrete submerged surfaces (Figure 6-68). In wastewater treatment plants, this system is typically used for concrete pipe interiors handling raw sewage, where hydrogen sulfide (H_2S) is present.

More recently, a system consisting of two coats of high-build epoxy totaling 15 mils (380 micrometers) has become the preferred system for submerged surfaces. Compared to the coal tar epoxy system, the high-build epoxy system has the following advantages:

- A larger time window for recoating and wider range of cure temperatures

FIGURE 6-67. Sewage treatment tank. SSPC file photo.



IV. ENVIRONMENTS FOUND IN WATER AND WASTEWATER TREATMENT PLANTS

There are several types of environments in water and wastewater treatment plants. There are submerged surfaces, items in severe (damp) atmospheric service, mild exterior exposures, items in mild interior service, and hot steel surfaces. Some items also receive chemical exposure. For example:

- Chlorine, used in both types of plants, is very aggressive.
- Hydrogen sulfide gas (from raw sewage), present in wastewater treatment plants, is very aggressive to both steel and concrete (Figure 6-67).
- Heavy concentrations of chlorides, primarily from industries, are present in most wastewater treatment plants. The chloride is a much larger problem when the plant is located near coastal waters. Salt-laden air is very aggressive to steel components, as well as to the steel rebar imparting strength to reinforced concrete.

V. COATINGS USED IN WATER AND WASTEWATER TREATMENT PLANTS

Selection of coating systems for water and wastewater plants is usually based on the following considerations:

- Long-term, economical protection

- Good wetting when rolled on concrete
- Available in a variety of colors
- May be certified by NSF International for lining of potable water systems.

Modified phenolics are also used as tank linings. They provide good service, especially at elevated temperatures. They also provide excellent abrasion resistance. Their main drawback is their poor acid resistance and short recoat time.

B. SEVERE (DAMP) ATMOSPHERIC SERVICE

Chemically-curing epoxy enamels are used for severe damp atmospheric service on steel and concrete surfaces. They provide good protection as well as high gloss. When specified for exterior atmospheric service, these epoxy systems are usually coated with an ultraviolet-resistant finish, such as aliphatic polyurethane, which minimizes chalking and loss of gloss. Striping is frequently specified for sharp edges, welds, hard to access places, and rafter/plate interfaces before a full coat is applied.

Vinyl systems have also been used successfully for severe atmospheric service for many years. However, the use of vinyl systems is being eliminated because of restrictions on VOCs.

C. MILD EXTERIOR EXPOSURE

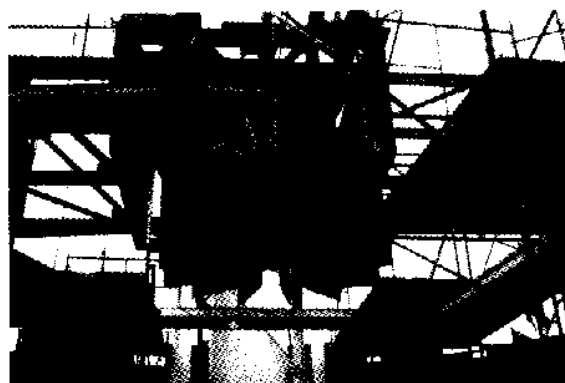
Alkyd coating systems are normally used on exterior steel surfaces in mild environments. They have good color selection and gloss, and are compatible with most other coating systems. However, the use of alkyd systems may become eliminated because of restrictions on VOCs.

Acrylic emulsion systems are usually used on exterior concrete surfaces. They provide a pleasing appearance and reduced porosity. An acrylic emulsions can also be used as an exterior finish over other exterior coating systems.

D. MILD INTERIOR SERVICE

Alkyd coating systems are commonly used on interior steel surfaces of buildings and other structures. They are relatively easily cleaned and maintained. Epoxy systems

FIGURE 6-68. Clarifier baffles. SSPC file photo.



are more appropriate for severe service, such as damp areas and where spill or splash of chemicals is likely. Interior concrete block walls can be filled with an emulsion block filler and coated with two coats of acrylic emulsion paint. Again, for more severe service, two coats of epoxy enamel can be used.

For esthetics and for protection from chemicals, concrete floors are coated with a thick, chemically-resistant epoxy or polyurethane enamel. This increases the reflectivity of light and provides a surface that is easy to clean. Because of the inherent slipperiness of such surfaces, it is a common practice to broadcast granules, e.g., aluminum oxide onto the wet coating to produce a non-skid surface.

E. HOT STEEL SURFACES

Corrosion of hot steel surfaces (pipes, stacks, etc.) can be controlled to some degree by an aluminum-filled silicone (or other generic type) coating. Normally, two coats are applied to room-temperature surfaces, and subsequent heat from them fuses the resultant aluminum-pigmented silicone film to a 2 mil (50 micrometers) dry film thickness. This relatively thin film is unable to provide effective long-term corrosion protection.

Inorganic zinc and thermally-sprayed zinc coatings can provide excellent corrosion protection to hot steel surfaces up to 600°F (316°F). Thermally-sprayed aluminum coatings provide good protection up to 1,500°F (816°C). These metallic coatings are best applied in a shop.

VI. HEALTH AND SAFETY

There are several hazards associated with water and wastewater treatment plants that are of concern to coatings inspectors and other workers in the area:

- Hydrogen sulfide gas produced in the anaerobic digester is very toxic. At low concentrations, hydrogen sulfide has a strong "rotten egg" smell. Before entering confined areas containing hydrogen sulfide, the concentration levels of the gas should be carefully monitored (Figure 6-69).
- Methane gas is also produced in anaerobic digesters. Although comparatively nontoxic, it is highly flammable in air in a wide range of concentrations. Thus, no smoking or open flames should be allowed in digester areas. Chlorine gas used in both types of treatment plant is also very toxic. Appropriate care should be exercised during its use.
- Oxygen deficiencies may occur in confined spaces. Before entering confined spaces, oxygen levels should be monitored.
- Facilities may be wet or slippery. Dampness may also pose a hazard with inspection lights and other electrical equipment.
- The structures to be coated may have many and complex configurations, requiring special rigging to make all areas accessible. All safety requirements established for rigging must be followed.

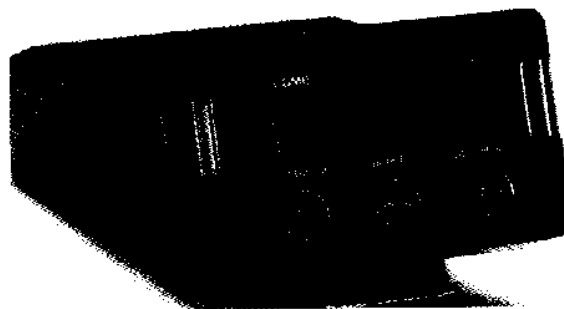
Further information on hazardous gases, oxygen deficiency, and rigging, as well as other general safety information for the coatings inspector can be found in Chapter 7.

VII. SURFACE PREPARATION AND COATING APPLICATION

A. MASKING AND PROTECTION OF SENSITIVE EQUIPMENT

Water and wastewater treatment plants have many controllers and other pieces of sensitive equipment that must be masked for protection during blasting and coating operations. The inspector should make a checklist for such items and then be sure that all are adequately protected.

FIGURE 6-69. Three-way monitor. Courtesy of Mine Safety Appliances Company.



B. LEAD IN PAINT

If it has not been done previously, existing coatings should be analyzed for lead content, using either an approved x-ray fluorescence (XRF) procedure or laboratory procedure. This test must be done in various areas and surfaces to provide a good representation of the coatings. The soil on the jobsite should also be checked for lead both before and after the coating project. As discussed in Chapter 7, lead testing is not normally the responsibility of the coatings inspector; however, the inspector may have some responsibilities for assisting the safety professional who monitors the operations.

C. TREATMENT OF VARIOUS EXPOSURE ZONES

The inspector should ensure that each cleaned surface receives its specified level of surface preparation. General procedures for inspection of surface preparation are described in Chapter 4.

The inspector should verify that all surfaces are degreased and cleaned in accordance with SSPC-SP1 (Solvent Cleaning) prior to any abrasive blasting. This is a part of all SSPC blasting requirements. Surfaces should be checked for residual chlorides, as described in Chapter 8.

1. Submerged Surfaces

Steel surfaces to be located in submerged areas usually require abrasive blasting to a white metal condition (SSPC SP-5) before priming with either an epoxy or a coal tar epoxy coating.

2. Hot Steel Surfaces

Hot steel surfaces that will receive inorganic zinc-rich coatings, or thermally-sprayed zinc or aluminum coatings are usually required to be as clean as possible. (SSPC-SP 5 is usually preferred.)

3. Other Steel Surfaces

Steel surfaces not mentioned above should be cleaned and coated to the proper degree, as stated in the job specification or coating manufacturer's product data sheet.

4. Concrete Surfaces

Concrete surfaces usually require a brush-off blast for cleaning. Any grease or oil present should first be removed by alkaline cleaners or steam.

A muriatic acid wash may also be used in areas where blasting is not feasible. A pH test should be done on the surface after acid cleaning and rinsing to ensure that it has been completely neutralized. If the surface is acidic, a wash with an ammonia solution is recommended.

D. HOLIDAY DETECTION

On critical coated surfaces, holiday detection may be required by the job specification. A low-voltage holiday detector is normally used on steel and concrete surfaces coated with up to 20 mils (0.5 mm) of coating. High-voltage holiday detectors must be used on coatings with a film buildup of over 20 mils (0.5 mm). These instruments are described in Chapter 8.

E. DISINFECTION OF POTABLE WATER TANK AND PIPING

Upon completion of the final inspection of a potable water tank and piping, the tank must be disinfected in accordance with American Water Works Association (AWWA) Standard C652.

F. CLEAN-UP OF WASTE DEBRIS

The job specification details technical requirements for the collection, handling, storage, treatment, transportation, and disposal of waste debris. If it is possible that the debris contains one or more hazardous materials, it must be tested by laboratory analysis to determine the proper disposal methods.

VIII. SUMMARY

The major components of water and wastewater treatment plants include tanks, piping, ponds, buildings, control centers, cableways, and electrical generators. These structures include both steel and concrete surfaces. Surfaces within water and wastewater treatment plants can be classified as follows: submerged surfaces, severe (damp) atmospheric service, mild exterior exposure, mild interior service, and hot steel. These environments and the various coatings used in them present the coatings inspector with many concerns, for example, the protection of sensitive equipment, special treatment of concrete surfaces, holiday detection, lead in paint, and clean-up of waste.

The complex configuration of a water or wastewater treatment plant may require special rigging for coating operations and inspection. Other hazards that may be encountered by the coating inspector in a water or wastewater treatment plant are entry into confined spaces, exposure to toxic or flammable gases, and wet, slippery surfaces.

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Chapter 6.11

Pulp and Paper Mills

by Richard H. DeWolf

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I. SCOPE

This sub-chapter is about coating and coating inspection operations in pulp and paper mills. It describes the basic structure and organization of a pulp and paper mill, and illustrates how the local mill environment can influence the inspection procedures.

In order to present the individual coating and inspection requirements for each area of the mill, this sub-chapter is divided into the following sections:

- Wood processing area (woodyard and screen room)
- Digesters and brownstock areas

- Bleachmaking area
- Bleach room
- Stock preparation
- Paper machines
- Recovery boiler area
- Causticizing and liquor storage areas

Pulp and paper mills also include power generation and wastewater treatment facilities; however, these are not included here since they are discussed in other sub-chapters of this chapter (6.1, 6.10, and 6.13). (Note: Further information relevant to coatings inspection in pulp and paper mills can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

SSPC: The Society for Protective Coatings (SSPC)

SSPC-PA 2 Measurement of Dry Coating Thickness with Magnetic Gages

III. ABOUT PAPER MILLS

A paper mill is an integrated operation of specific chemical processes all supporting the conversion of wood fiber from logs or chips to a final paper product (Figure 6-70). Coating operations for pulp and paper mills, as for other chemical environments, require individual approaches based on the chemicals in a given area and the process operation present. In a paper mill, the following process factors must be considered when choosing a materials system or inspecting coatings operations:

- Different chemicals are used in different areas of the mill
- Raw materials and chemicals change in concentration and form throughout the process
- Process streams are recycled--this is done extensively for conservation of resources and protection of the environment

FIGURE 6-70. A paper mill. Courtesy of S.G. Pinney & Associates, Inc.



IV. WOODYARD AND SCREEN ROOM AREAS

A. THE WOODYARD AND SCREEN ROOM ENVIRONMENT

The woodyard is the beginning of the papermaking process. Equipment is usually massive in design and subject to impact loadings and rubbing abrasion. Structures are typically massive plate-to-flange stitch-welded members. Much of the area is outdoors, and depending upon prevailing wind patterns, can be considered a rural environment. Wind can transport airborne contaminants and gases from area to area. For instance, a woodyard downwind of a bleaching area may be exposed to significant levels of gaseous chlorine not normally associated with the open air yard.

B. COATINGS USED IN WOODYARD AND SCREEN ROOM AREAS

Protective coating selection in woodyard and screen room areas should emphasize a tough (abrasion resistant), and flexible film. Many of the high solids epoxy systems meet this requirement. Also, some highly flexible, tough polyurethane thick-film coatings have both properties.

The coatings used in woodyard and screen room areas must also be resistant to ultraviolet radiation. They may

require resistance to mild acetic or formic acids, formed from long-term storage and chemical breakdown of wood chips. If the area is in operation, surface contamination may be limited by substituting fast drying versions of the same coating.

C. SURFACE PREPARATION AND COATING APPLICATION

During surface preparation and coating application in the woodyard and screen room areas, the inspector should:

1. Verify that surfaces are prepared appropriately, as specified, to receive the selected coating system.
2. Verify that insides of chutes, drums, screens, etc. are masked to prevent overspray contamination.
3. Verify that coatings are not applied to surfaces where the continued movement of the logs and chips will wear away the coating and contaminate the wood. In small quantities, such contamination of the wood would probably be insignificant.
4. Verify that welds, laps, and stitch welded areas are stripe-painted with a low viscosity or reduced solids primer brush coat before spray coating a full coat.

NOTE: Seal welding is not an appropriate approach since a certain amount of flexibility must remain in the equipment. In addition, as a plate wears or needs to be replaced, seal welding hampers maintenance. The use of silicone or other sealants with the stitch welds may also cause a contamination problem later on.

5. Verify that areas to be in operation during coating application are isolated with screening, if necessary, to prevent substrate or coating contamination.

V. DIGESTERS AND BROWNSTOCK AREAS

A. THE DIGESTER AND BROWNSTOCK AREA ENVIRONMENT

The digester area is where the woodchips are "cooked" with caustic under steam pressure to produce the pulp. The digester, whether continuous or batch, is essentially a large pressure cooker where the lignin, the "glue" that holds the wood fibers together, is cooked out of the chips. The resulting brown-colored fibers are cleaned of the black liquor in a series of open washers in the brownstock area.

This environment exposes the building steel to high levels of moisture, caustic fumes, and black liquor spillage. Typical corrosion problems with structural steel in this area include edge thinning on flanges, exfoliation corrosion of flanges and webs, and severe undercutting of protective coatings.

B. COATINGS USED IN DIGESTERS AND BROWNSTOCK AREAS

Critical to coating selection for the digester and brownstock areas is the resistance to undercutting. Splash and spillage of hot caustic solutions/liquors is a major concern. Coating selection should consider edge build characteristics, as many failures in this process area start at edges. Since edge failure is the prominent type of coating failure, coatings that are more resistant to undercutting are preferred. Protective coatings in the digester and brownstock areas must be resistant to hot sulfide vapors. The coatings must have a higher temperature resistance; and, because of the humidity found in these buildings, should function as barrier coatings and not sacrificially. Many of the high-build, thicker film two-component epoxy coatings may be successfully applied in these areas.

The high operating temperatures near the process equipment necessitate close attention to coating film thickness. While a good coating barrier is desirable, excessive film thicknesses may lead to internal stresses during expansion, which can result in delamination. The coating dry film thickness (DFT) should be no less than 12-15 mils (300 - 380 micrometers), with 15-18 mils (380 - 460 micrometers) being typical.

C. SURFACE PREPARATION AND COATING APPLICATION

During surface preparation and coating application in the digester and brownstock areas, the inspector should:

1. Verify that the specified level of surface cleanliness is attained. Cleanliness will be more difficult to achieve because of the hot vapors present.
2. Test for salt or caustic contamination. Commercially available kits provide all the necessary testing materials and procedures for surface contamination testing (see Chapter 8). Steel around and over process equipment, especially open-topped vats, should be tested for surface sulfate salt and caustic contamination. Steel at

the base of columns also should be tested for sulfate salt and caustic contamination.

3. Make sufficient dry film thickness measurements. The number of measurements required depends on several factors including steel shapes, location of the steel (such as over equipment, in a vapor-rich plume, in a splash or spill area, at the base of columns), and the desired film thickness. The coatings inspector must reach a "level of confidence" that the values obtained truly represent the condition of the coating DFT for all the geometries present. This level of confidence may be achieved under the requirements of SSPC-PA 2; however, some situations may warrant additional measurement.

4. Verify that the specified tolerances for dry film thickness are maintained. The tolerances for under specified film thickness should be minimal and over specified film thickness tolerances closely followed. Excessive over-build of coating thickness will most likely lead to delamination or cracking.

NOTE: Adherence to film thickness is most critical to the success of the coatings in this area. Too thin a coating will not provide a sufficient barrier to sulfide ions carried in the vapors. Too thick a film barrier will lead to internal stresses with resultant cracking and delamination.

5. Verify that connections and projections are brush coated before spray application. Where practical, sharp edges should be rounded to allow for greater film build.

VI. BLEACHMAKING AREA

A. THE BLEACHMAKING AREA ENVIRONMENT

Wood pulp is bleached in oxidizing solutions. Chemicals are added to change the pulp fiber color from dark to a bright white. These bleaching solutions are made from strong concentrations of aggressive chemicals, such as sodium chlorates, sodium hypochlorite, hydrogen peroxide, liquid sulfur dioxide, sulfuric acid, chlorine, and chlorine dioxide. The strongest concentrations of the most aggressive chemicals are found in this area.

Acids and caustics are unloaded, transported, stored, diluted, and again stored in vats and tanks in close proximity to each other. Chlorides and chloride salts are also present in abundance. Hot vapors may be either caustic or

acidic. Splash and spillage is a major concern, especially near unloading stations.

Process and design functions can help significantly in protecting the structures in this area. Extensive use of drains, use of containment slabs with proper pitch, location of approach piping, extended overflows, etc. can all contribute to the protection of the structural steel. Of course, the concrete surfaces also should be protected.

B. COATINGS USED IN BLEACHMAKING AREAS

Zinc-rich primers are used in bleachmaking areas; however they must be protected from the bleachmaking environment by barrier topcoats. A wide range of epoxy coatings work well as topcoats or total systems.

C. SURFACE PREPARATION AND COATING APPLICATION

During surface preparation and coating application in the bleachmaking areas, the inspector should:

1. Test surfaces, especially those facing prevailing winds, for surface salt contamination.
2. Allow a wider leeway for over-specified film thickness tolerances. Under-specified thickness tolerances also may be slightly relaxed. Under-specified thickness tolerances are still critical when using zinc-rich primers near chloride solutions.
3. Ensure that film thickness is more tightly controlled in areas where strong acids such as sulfuric acid can collect or form. The exothermic reaction of sulfuric acid and water during clean-up should be considered when judging over-tolerance limits.
4. Check surface pH regularly. Low pH from acid contamination most likely will inhibit cure of any epoxy systems in use. High pH surfaces from caustic contamination and low pH from acid solutions could lead to early failure of zinc-rich systems.

VII. BLEACH ROOM

A. THE BLEACH ROOM ENVIRONMENT

The bleaching operation is where the wood pulp is treated with the bleaching chemicals to obtain the white pulp,

from which paper is made. This area is a series of tall towers and open vats.

The bleach room is where contamination of the pulp first emerges as a critical issue. The pulp is in its final form before becoming paper. Pulp is present in rapidly flowing quantities in open vats and process equipment. These high flow rates help suspend particles in the process stream. The pulp itself, consisting of a suspension of interlocking fibers, helps trap and suspend contamination, making separation difficult.

Bleaching sequences vary. Recent environmental concerns have resulted in the substitution or replacement of long-time standard sequences with newer, and usually more costly, technologies. Bleaching stages can be charged with oxygen, ozone, hydrogen peroxide, calcium hypochlorite, sodium hypochlorite, chlorine, chlorine dioxide, and caustic. Combinations of chemicals, counter-current washing, substitution, and other lesser known chemical complexes also can be found.

B. COATINGS USED IN BLEACH ROOM

Protective coating selection for the bleach room typically involves zinc-rich or epoxy-inhibitive primers topcoated with epoxies. (Zinc-rich coatings must be topcoated in these environments because of acidic or alkaline conditions.) Polyurethanes are successful on exterior exposed steel for ultraviolet resistance. Vinyl systems have also been successful but not used as much today because of their high VOC contents.

C. SURFACE PREPARATION AND COATING APPLICATION

During surface preparation and coating application in the bleach room, the inspector should:

1. Test all cleaned surfaces for chloride contamination. Surface contamination from chloride salts is a severe problem.
2. Verify that containment structures, if necessary for the operation, are erected and maintained. The purpose is two-fold: First, to protect the freshly exposed steel from turning with rust bloom due to humidity and chlorides; second, blasting is almost a minimum requirement for these surfaces. Therefore, the open vats must be isolated to prevent contamination of the pulp.

3. Closely monitor potential sources of contamination. For instance, blasting may shred the plastic wall of a containment structure. Repairs to a shredded containment wall cannot be put off to the end of a shift or break. To prevent contamination of the pulp stream, effective repairs must be undertaken immediately.

4. Ensure that film thickness tolerances are maintained. Thicker coating films are less of a problem than thin applications. The intermediate and topcoat applications should provide protection to both the steel substrate and the zinc-rich primer (if used).

5. Verify that no zinc overspray has occurred. This should especially be checked on hot steel surfaces. Above a certain critical temperature (approximately 60°C (140°F) for carbon steel), the polarity of the electrochemical potential between zinc and steel reverses. This may lead to accelerated corrosion of the steel. There are some indications, not fully documented, that this reversal of polarity may also occur for stainless steel.

6. Carefully monitor the use of slag-type abrasive grit and the clean-up of grit on stainless steel. The grit contains large amounts of iron that may produce galvanic corrosion on stainless steel surfaces.

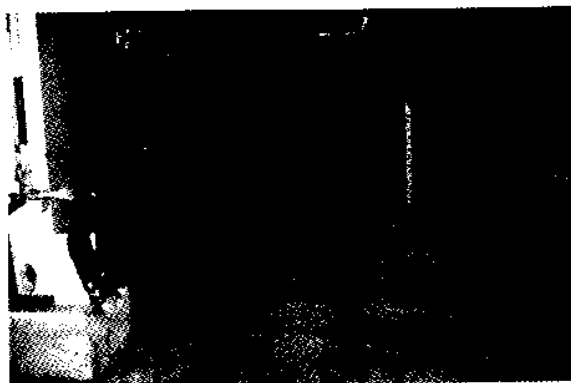
VIII. STOCK PREPARATION

A. THE STOCK PREPARATION AREA ENVIRONMENT

Stock preparation concerns include the areas and equipment referred to collectively as the beater room. The equipment in this area consists of open-topped and closed screens, refiners, and various pumps, motors, and vats. The equipment frames, castings, or bodies may be either stainless steel or carbon steel.

The stock preparation could be inside or outside a building, on the operating floor or in a basement (Figure 6-71). Beater rooms are usually located near the wet end of the paper machine. The environment is usually warm, some times dry, but normally humid and moist. Depending upon housekeeping, steel shapes may be a breeding ground for bacteria in rotting pulp.

FIGURE 6-71. Stock preparation area (wet end, basement). Courtesy of KTA-Tator Inc.



Another area similar to stock preparation but usually located in a separate building or area is the secondary fiber area. Different companies or mills may refer to this area in a variety of ways. In this paper process, old papers are recycled into pulp. This area may have deinking vats in addition to hydropulpers, conveyor equipment, etc. The chemical environment is generally considered similar to stock preparation.

B. COATINGS USED IN THE STOCK PREPARATION AREA

Coating selection for the stock preparation area is based on criteria for splash and spillage conditions. Depending upon building design and ventilation, vapors may condense on the structural steel.

C. SURFACE PREPARATION AND COATING APPLICATION

During surface preparation and coating application in the stock preparation area, the inspector should continuously monitor ambient temperature, surface temperature, and relative humidity. The inspector should also:

1. Verify that the proper level of surface preparation is attained, especially in critical areas, such as high moisture areas near ventilators, over vats, or close to the paper machine. Surface preparation at the base of columns and near wash-up hoses should also be checked

frequently. Stock preparation areas are typically washed down every shift so the concrete remains damp for several hours each day. The concrete-to-steel interface will usually be the site of undercutting of the coating film.

2. Verify the absence of surface contamination. Surface contamination results from chloride salts but should be less than that encountered in the bleach room area. Moisture at the steel surface also will be a contaminant due to its ready abundance in the stock preparation area.

3. Verify that the specified dry film thickness is attained. Coatings should serve as barriers between the steel and this environment, although sacrificial zinc-rich materials also have application here. Dry film thickness tolerances become more critical as the moisture content and temperature increase. A film thickness less than the required minimum is a greater concern than being over the specified film thickness.

4. Check the acidity of the surface. Basement areas may have biological growth and slime formation. To limit the formation of corrosion barnacles and pits from acidic attack induced by bacteria, apply the inspection principles used for acid exposures. Certain forms of bacteria generate hydrogen sulfide as part of the digestion process. This sulfide can form a weak sulfuric acid solution with a relatively low pH of 4.0 - 4.5.

IX. PAPER MACHINES

A. ABOUT PAPER MACHINES

The modern paper machine is one of the most complex, fully integrated, high-speed pieces of equipment devised. The paper machine, operating at a speed equal to 80 mph (129 km/hr), takes a loose suspension of pulp fiber and converts it to a sheet of paper in about 30 seconds. The chemistry involved during the trip from the headbox slice to the reel spool is extremely complex. The operating process of how this happens defines the "art" married to the "science" of papermaking.

Being a complex machine, specific sections along the machine's length perform different activities under a variety of local environments. Paper machines differ significantly by the product produced. For our purposes, we will consider a machine with a fourdrinier (wire), press sections, dryer sections, and coating stations.

B. THE ENVIRONMENT AROUND A PAPER MACHINE

The environmental conditions around a paper machine include excessive humidity, condensation, and high heat. These conditions are coupled with chemical carrying vapors and biological organisms. This, however, is just a basic description, and does not represent the full complexity of the paper machine environment. Furthermore, the conditions around a paper machine vary down the length of the machine and may vary due to operational changes or inconsistencies in the process.

C. COATINGS USED ON PAPER MACHINES

A modern paper machine typically has a stainless steel or stainless steel clad fourdrinier or wet end. In the past, fourdriniers were constructed from carbon steel and casting, but the protective coatings necessary on these construction materials did not give satisfactory performance. This lack of performance was, in part, due to an inadequate definition of the operating conditions. For paper machines that do not have a stainless steel fourdrinier, immersion grade coatings should be selected. Coatings designed for splash and spillage are not sufficient, and will most likely lead to an early failure and unsatisfactory performance. Immersion grade coatings also should be considered for the press sections.

D. SURFACE PREPARATION AND COATING APPLICATION

During surface preparation and coating application on paper machines, the inspector should:

1. Closely monitor possible sources of contamination. Contamination is the single most critical factor when working around the paper machine. Depending upon the type of equipment on the paper machine itself, a single piece of plastic or grit could result in the loss of several tons of paper production. This cannot be over-emphasized. The inspector should be extremely sensitive to contamination sources from the coating and blasting operations. Contamination sources include the blast media, overspray, possibly the coating itself, etc.
2. Be familiar with any specialty coating systems used. When using the patented suspension systems for coat-

ing over the fourdrinier, the inspector should be intimately familiar with the details of this installation. This is required for safety reasons, contamination control, protection of the operating machinery below, and protection of the product.

3. Ensure that the surfaces of the rolls, the journals, and other components of the paper machine receive layered protection. This is critical. The protection of the rolls should be coordinated and accepted by the owner or his representative. This protection should be a team decision agreed to among the operating supervisor, the area maintenance supervisor, the contractor, the inspector, and the appropriate mill superintendents.

NOTE: It is advisable that the paper machine supervisory personnel be fully briefed about the extent of protection provided. The machine supervisors and machine tender should be shown the protection measures in place so they may comment on their adequacy, lending tacit approval.

4. Ensure that bearings and journals at the housing are protected. These should be individually inspected, each journal, each housing, on each side, for every roll.
5. Verify that a final wash-up or clean-up plan is in place prior to starting any work. Almost all areas around the paper machine drain back into the process stream. This may require vacuuming and flushing flat boxes, seal pits, wire pits, couch pits, etc.

NOTE: This clean-up procedure is in addition to the one to be performed as normal start-up procedures around the machine.

6. Carefully monitor the surface preparation of hard-to-reach locations on the inside faces of press sections, dryer section frames, journal housings, etc. These are most likely not going to be open blasted. Vacuum blasting may be allowed, but surface preparation is often limited to needle gunning. These frames and housings, particularly on older machines can be ornate and multi-surfaced.
7. Gear the inspection to cleanliness. A combination of air blowdown and vacuuming can be used to collect the removed debris. Oil and grease inside the machine frame must be removed by solvent wiping. Care should be exercised in preventing the spread of debris during the cleaning process. For instance, solvent washing the inside faces of the frame should be accompanied with vacuuming so the grime is not spread to other areas that will subsequently need cleaning.

8. Ensure that the specified film thickness is attained. As an immersion coating application on the fourdrinier and press sections, the coating must act as a barrier. Lower specified film thickness limits should be very stringently adhered to, while more leeway can be accepted concerning upper specified thickness.

X. RECOVERY BOILER AREA

A. THE RECOVERY BOILER AREA ENVIRONMENT

The recovery boiler area is similar to a power generation station but it uses a different fuel. The black liquor burned in the recovery boiler contains a very high percent of sulfate salts. These salts are recovered and converted to usable caustic liquors for digesting the wood chips.

The environment is hot and dry except during frequent washdowns or boiler outages. The atmosphere may contain sulfate dusts, particularly toward the upper elevations. Carbon dioxide levels may be slightly higher than in the normal atmosphere.

B. COATINGS USED IN RECOVERY BOILER AREA

Typically, the same coating systems that are successful in power generation areas (see Chapter 6.13) are also effective in the recovery boiler areas.

C. SURFACE PREPARATION AND COATING APPLICATION

During surface preparation and coating application in the recovery boiler area, the inspector should:

1. Test surfaces for contamination. Surface contamination may be a problem due to the sulfate salts. Frequent checks on the surfaces, especially at the higher elevations of the building will be required.
2. Verify that ventilation is adequate. Ventilation may be necessary to limit or minimize entrapped dust on the surface or in the coating film. Also, the inside of the recovery boiler building and the evaporator building have extensive numbers of steam lines. The vessels themselves are operated at elevated temperatures. Ventilation may be required to cool the area.

3. Closely monitor surface temperatures. The elevated temperatures of about 100-120°F (38-49°C) may result in higher than normal surface temperatures. While relative humidity will not likely be a problem, the higher than normal surface temperatures may limit the application of coatings. The environmental conditions may place the surface temperature of the steel at the upper limits for a given coating.

4. Monitor the temperature of framing members. Significant temperature variations will exist between the floor elevations and the underside of the next elevation. The framing members beneath elevated floor slabs may be too hot to properly coat.

5. Ensure that temporary isolation walls, if required, are in place. These may be required, not to prevent contamination, but to provide an environmental condition where a coating can be successfully applied.

6. Monitor potential overspray problems. Dry overspray resulting from the radiant heat within the building may become a serious surface and film problem.

7. Ensure that the specified film thickness is attained. Less than specified coating thickness may be less of a problem than thicker film builds. Thicker film builds may glaze over, trapping solvents within the film leaving a pasty weak mass. Additionally, thicker films may generate higher internal stresses that could lead to premature failure. Again, these potential problems are temperature related.

FIGURE 6-72. Exterior, tiled tanks in liquor storage area. Courtesy of KTA-Tator Inc.



XI. CAUSTICIZING AND LIQUOR STORAGE AREAS

A. THE CAUSTICIZING AND LIQUOR STORAGE AREA ENVIRONMENTS

The causticizing area is where the spent liquor from the recovery boiler is chemically converted to cooking liquor (Figure 6-72). The process involves a series of chemical reactions and produces a by-product, calcium carbonate mud. This mud, in turn, is converted to quicklime by processing through a rotary lime kiln.

The process environment is hot and dusty. The fugitive dust generated from the kiln operation tends to deposit on all surfaces. The pH of the dust and vapors tends to be high. Caustic fumes are also present at the slakers and clarifiers.

B. COATINGS USED IN CAUSTICIZING AND LIQUOR STORAGE AREAS

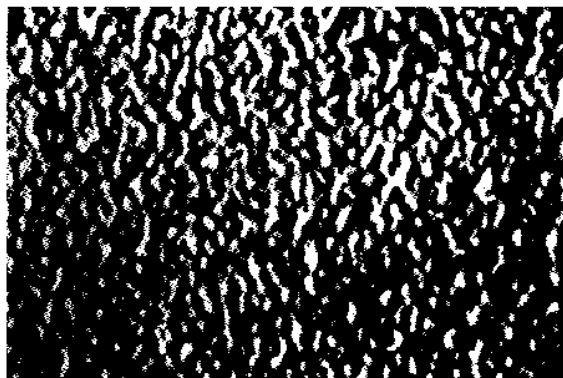
Coatings used in this area must typically function as barrier materials for extended periods of time. The fugitive lime dusts that coats most exposed surfaces eventually may build up to be several inches thick. Fortunately, the lime dust tends to keep a relatively high surface pH and may cause some limited beneficial effects as a form of passive protection. High-build epoxy systems with film thicknesses between 8 and 12 mils (200 and 300 micrometers) work well without the need for thicker film builds.

C. SURFACE PREPARATION AND COATING APPLICATION

During surface preparation and coating application in the causticizing and liquor storage areas, the inspector should:

1. Closely monitor potential sources of contamination. Surface contamination will be a problem, mostly because of large quantities of fine dust found in the area. The caustic dusts have less of an effect on the curing of coating films than acidic vapors; however, caustic dusts can cause a significant loss of adhesion both at the surface and between coats.
2. Ensure that the specified film thickness is attained. Film thickness tolerances are less of an issue here than

FIGURE 6-73. Orange peel surface. SSPC file photo.



in acidic environments. Even when the film is compromised, the settled dusts tend to have a high pH on the order of 8.5-10. This allows formation of a passive film on the steel.

3. Verify that measures have been taken to redirect caustic vapors away from uncured coatings. The caustic vapors near the slakers and clarifiers may cause water-borne coating films to improperly coalesce. This may appear as an orange-peel surface (Figure 6-73) or mud cracking.

XII. HEALTH AND SAFETY

In pulp and paper mills, a variety of chemicals are present in abundance. Many of these are acids or caustics and should be treated with the appropriate care. Some of the other primary chemical hazards encountered in pulp and paper mills are described below.

In bleached mills, the two primary chemical hazards are chlorine and chlorine dioxide. These chemicals are found through both bleachmaking and the bleach room areas. Extended exposure of several minutes can lead to death.

Chlorine is a strong oxidizer used to bleach the wood pulp. Chlorine is a green liquid when pressurized that becomes a green colored gas at atmospheric pressure. Chlorine is heavier than the surrounding air; consequently, it can collect in low spots. Therefore, chlorine will displace air. If a chlorine leak or pocket is encountered, personnel must immediately leave the area using the designated escape routes.

Chlorine dioxide is a yellowish-green to orange liquid or gas, depending on pressure, with a pungent, sharp odor. Its effects on the body are similar to those of chlorine. If a leak or trapped pocket of gas is encountered, personnel must immediately leave the area using the designated escape routes.

Hydrogen sulfide is present in the digester, brownstock, evaporator, liquor storage, and lime mud areas. Hydrogen sulfide is a colorless gas that becomes odorless in high concentrations. In small concentrations, hydrogen sulfide has a characteristic rotten egg smell. Unfortunately, in higher, more dangerous and lethal concentrations, hydrogen sulfide cannot be detected by the nose. Hydrogen sulfide can be detected by specially designed meters.

A new hazard has been recently recognized within the paper industry. This arises from the use of the new technology of alkaline papermaking. Within and over stock chests and whitewater chests, bacteria present can generate significant amounts of hydrogen gas, usually during shutdown situations. This is not a problem with normal acid papermaking because the whitewater pH does not support the growth of this hydrogen generating bacteria. The hydrogen gas is explosive and numerous incidents have been reported in the literature.

This brief review of the potential chemical hazards is not intended to replace the paper mill's safety/hazard communication program. Thousands of man hours of safe activity occur daily throughout the world's paper mills. The inspector needs to be aware of the hazards to be part of the pro-active approach to workplace safety. Further information is available from Material Safety Data Sheets (MSDSs), OSHA and NIOSH, mill safety departments, and Chapter 7 of this book.

XIII. SUMMARY

There are many individual areas of a pulp/paper mill, each with specific exposure environments. In addition to coated steel surfaces, these areas contain concrete and stainless steel surfaces. From the beginning to the end of the process, these areas and exposure environments are:

- Woodyard - Outdoors, with massive equipment, subject to impact and abrasion
- Brownstock areas - Hot sulfide vapors and high temperature and humidity

- Bleachmaking area - Oxidizing solutions, strong/aggressive chemicals, both liquid and vapor
- Bleach room - Bleaching agents such as hydrogen peroxide, ozone, sodium hypochlorite, and chlorine
- Stock preparation area and secondary fiber area - Warm, may be moist, microorganisms may be present
- Paper machines - Excessive humidity, condensation, high heat, vapors, microorganisms may be present.
- Recovery boiler area - Caustic liquors in vats, hot, dry, sulfate dusts, high CO₂ levels
- Causticizing/liquor storage area - Hot, dusty, high pH dust/vapors

Since there are many corrosive and harmful chemicals in the environment, ventilation and cooling are very important for safe and proper coating application. Other special concerns for safety, surface preparation, coating application, and inspection include:

- Masking/overspray prevention
- Surface cleanliness and dryness
- Striping
- Critical film thickness

During many steps of the papermaking process, it is very important to avoid contamination of processing equipment. Therefore, there may be limitations on surface preparation, and it may be necessary to install containment structures or screening to isolate areas.

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In these positions, he has been responsible for corrosion and corrosion control, materials selection, specification development, quality assurance of process equipment, equipment and component inspection, and failure analysis. He has developed inspection and repair guidelines, procedures, and protocols for pressure vessels, storage tanks, and auxiliary components. His activities have encompassed stainless steel, carbon steel, alloy steel, fiberglass reinforced plastics, concrete, brick and tile, plastic components, linings, vessels, and thin film and thick film coatings.

Mr. DeWolf is a member of TAPPI, NACE International, and several other professional organizations. He has taught continuing education classes on Protecting and Coating Concrete for SSPC.

Mr. DeWolf is a 1978 graduate of Alfred University with a degree in ceramic engineering.

Chapter 6.12

Nuclear Power Plants

by Bryant W. Chandler

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VIII. Summary

I. SCOPE

This sub-chapter discusses the general requirements for coatings inspections in the nuclear power industry. It includes an overview of the basic systems and components of nuclear power plants, regulations and standards that govern the coatings work, definitions of the different service levels, and special health and safety issues when working in a nuclear power plant. It also outlines the specific inspection requirements for safety related Service Level 1 coating areas. (Note: Further information relevant to coatings inspection in nuclear power plants can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes

inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

American National Standards Institute (ANSI)

ANSI N5.12 Protective Coatings (Paints) for the Nuclear Power Industry (withdrawn)

ANSI N45.2.6 Qualification of Inspection, Examination, and Testing Personnel for Nuclear Power Plants (replaced by ANSI/ASME NQA -1-1994)

ANSI/ASME NQA -1-1994 Quality Assurance Requirements for Nuclear Facility Applications (replaces ANSI N45.2.6)

ANSI N101.2 Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities (withdrawn)

ANSI N101.4 Quality Assurance for Protective Coatings Applied to Nuclear Facilities (withdrawn)

Note: Although ANSI N5.12, N101.2, and N101.4 have been withdrawn, nuclear plants are continuing to use them. This is both because new standards have not yet been completely established and because of the high cost of updating all QA/QC documents, licenses, etc. The information in these ANSI documents is still appropriate for the intended use.

American Society for Testing and Materials (ASTM)

ASTM D 3843 Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities

ASTM D 3911 Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design Basis Accident (DBA) Conditions

ASTM D 3912 Test Method for Chemical Resistance of Coatings Used in Light-Water Nuclear Power Plants

ASTM D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

ASTM D 4082 Test Method for Effects of Radiation on Coatings Used in Light-Water Nuclear Power Plants

ASTM D 4256 Test Method for Determination of the Decontaminability of Coatings Used in Light-Water Nuclear Power Plants

ASTM D 4227 Practice for Qualification of Journeyman Painters for Application of Coatings to Concrete Surfaces of Safety Related Areas in Nuclear Facilities

ASTM D 4228 Practice for Qualification of Journeyman Painters for Application of Coatings to Steel Surfaces of Safety Related Areas in Nuclear Facilities

ASTM D 4537 Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coatings Work in Nuclear Facilities

Code of Federal Regulations (CFR)

10 CFR 50, Appendix B Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

10 CFR 21 Reporting of Defects and Noncompliance

Nuclear Regulatory Commission (NRC)

NRC Regulatory Guide 1.58 Qualification of Nuclear Power Plant Inspection, Examination, and Testing Personnel

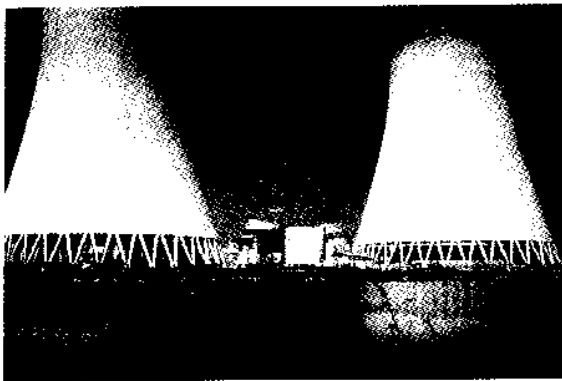
III. ABOUT NUCLEAR POWER PLANTS

A. BASIC SYSTEMS AND COMPONENTS OF A NUCLEAR POWER PLANT

Before discussing the details required for coating inspection, it is necessary to understand the basic systems and components of a nuclear power plant and the purpose and effects of coatings on these systems.

In the U.S., the nuclear power industry developed around the "light water" reactor technology. The heat transfer medium or "coolant" used to absorb the thermal energy and translate it into kinetic energy in a steam turbine is water. There are two types of light water reactors: pressur-

FIGURE 6-74. Cooling towers at a nuclear power plant. Courtesy of S.G. Pinney & Associates, Inc.



ized water reactors and boiling water reactors. A brief description of their designs is provided below.

1. Pressurized Water Reactors (PWR)

The PWR concept utilizes a closed coolant loop to circulate high-pressure liquid water, at more than 2200 psi (15 MPa) and 650°F (343°C), through the reactor vessel to pick up heat. This heat is then transferred to steam generators (a type of heat exchanger), which furnishes steam to conventional turbine-generators to produce electric power.

There are variations in the designs, but all rely on providing enough containment expansion space in the primary containment structure to accommodate the high-energy steam and water released in the event of a "loss of coolant accident" (LOCA). (Note: LOCA is discussed further in Section B, Engineered Safety Systems.)

2. Boiling Water Reactors (BWR)

The BWR concept utilizes a high pressure water feed to produce steam within the reactor vessel at about 1000 psi (6.9 MPa) and 550°F (288°C). This steam is then piped directly to a turbine-generator to produce electric power. The steam condensate from the turbine is piped to a processing facility for decontamination prior to recirculation in the main coolant loop.

BWRs utilize a large volume of water in a suppression chamber, or wet well, to suppress a pressure rise in the containment, in the event of a LOCA, by absorption of thermal energy. Steam released after a LOCA is directed from the drywell, where the reactor is contained, into the suppression pool of water where the steam is quenched and the energy absorbed. The three basic designs of BWR's are the Mark I, II, and III.

For the Mark I and Mark II configurations, steam resulting from a LOCA in the dry well is vented down through steel downcomers into the suppression pool of water. For the Mark III, steam from the drywell is vented down between a reinforced-concrete weir wall and the drywell reinforced-concrete wall and horizontally into the suppression pool of water. In all three configurations, the suppression pool of water is used to rapidly condense steam from the LOCA.

B. ENGINEERED SAFETY SYSTEMS

Although an unlikely event, if a reactor system suddenly depressurizes, as can occur if the pressure boundary is ruptured, the heat capacity of the system is drastically reduced and the latent heat is released. The coolant water "flashes" to steam and expands. If this happens, and water spills from the system to the extent that the fuel in the reactor is no longer immersed, heat builds up rapidly--since the core is deprived of the cooling influence of the water (a LOCA) (Figure 6-74). In the event of such an accident, control rods used to moderate the reaction rate in the core can be inserted to the "shut down" position; however, heat-up continues for some time after this. Accumulated heat can deteriorate and warp fuel elements, which can impede the control rod entry between the fuel bundles. The accumulated heat can also melt the metal "cladding" that encapsulates the fuel, vaporizing it, and thus grossly compounding the contamination threat and release of radiation.

1. Design Basis Accident

In the evolution of a rational approach to qualifying materials and systems for nuclear plants, normal standards of good engineering practice caused the designers to consider the worst potential accident that could occur in a given system or component. The governing accident became known as the "design basis accident" (DBA). The design basis accident for the containment, since it is a pressure

vessel, was the circumstance that created the worst pressure, the LOCA.

2. Emergency Core Cooling System

Reactor designers consider significant de-watering of the fuel an intolerable situation and from the outset made provisions for a backup system to inject water into the core in the event of a LOCA. Core flood capability or "safety injection system" was the keystone for what became known as the "emergency core cooling system." Another emergency core cooling system was designed to extract heat from the coolant spilled in the accident and thus gradually depressurize the containment. Coolant collected at sumps in the containment is piped outside the containment to residual heat removal heat exchangers. Waste heat from the "cool side" of these heat exchangers is discharged and the coolant is recirculated back into the containment to the ruptured reactor system through the safety injection system.

The engineers responsible for designing nuclear power plant emergency core cooling systems recognized, early on, the importance of keeping these systems free from debris. Material inadvertently ingested into these systems could block the flow channels in the residual heat removal heat exchangers or the reactor core and thermally fuse to the heat transfer surfaces, thereby impeding thermal conductivity; or they could clog the containment spray system spray nozzles. Screens are required to keep debris out of pressurized water reactor sumps and boiling water reactor suppression chambers. The dramatic failure of thermoplastic coating systems (paint), in the earliest tests suggests that these coatings, if detached in sufficient quantities and of sufficient particle size, could clog the pump suction screens and compromise post-accident heat removal. Through this reasoning, containment coatings became recognized as "safety-related," a term intended to signify that their failure, i.e., detachment, could theoretically compromise systems designed to mitigate the consequences of postulated accidents; however, this theory has been challenged by some facilities.

C. QUALIFICATION AND CERTIFICATION IN THE NUCLEAR INDUSTRY

The nuclear power industry in the United States is unlike any other industry when it comes to the qualification of equipment, systems, designs, materials and the personnel

performing the installation or application and inspection. Coating inspection of nuclear power plants requires certain unique documentation and material testing in order to comply with the various regulatory requirements. Additionally, there are regulations pertaining to the qualification and certification of application and inspection personnel for the nuclear industry. All inspection personnel must be qualified and certified to perform inspections on a nuclear power plant. Guidelines for the certification of inspection personnel are included in ANSI/ASME NQA-1-1994 (which replaces ANSI N45.2.6) and ASTM D 4537.

D. INDUSTRY STANDARDS FOR ESTABLISHING WORK PROGRAMS

Throughout this sub-chapter, references are made to various industry standards that outline methods for establishing programs for work on a nuclear power plant; however, this sub-chapter does not discuss in detail the requirements for compliance with these standards. Extensive research is necessary to determine if these standards are acceptable guidelines for program development to meet the requirements for a particular project. These requirements can be found in the plant's Final Safety Analysis Report (FSAR). This multi-document report details the level of compliance required for each activity or process. It should be reviewed to determine the level of commitment by the owner to the Nuclear Regulatory Commission (NRC) concerning the application of protective coatings.

Note: There are Regulatory Guides issued by the NRC that endorse the use of certain standards, with any exceptions, as a means of complying with the requirements of 10 CFR 50 Appendix B. For example, Regulatory Guide 1.58 endorses the use of ANSI N45.2.6 as an acceptable means of complying with the requirements of 10 CFR 50 Appendix B as it pertains to the qualification and certification of examination and test personnel for nuclear power plants. This guide details the regulatory position on the use of this standard and describes any exceptions or clarification required to comply with the requirements.

E. NUCLEAR FACILITY TRAINING AND SECURITY BADGING

All workers at nuclear facilities are required to undergo special training prior to starting work. This training includes general and facility-specific training, safety,

FIGURE 6-75. Corrosion in an underwater area of a nuclear power plant.



proper dressing and undressing with protective clothing, quality assurance requirements, and other facility-specific requirements. The training program takes three to six days, depending on the facility program(s).

Security badging entails a complete worker background check, drug testing and a psychological test. Receiving the security badge can take four to five days; however, it can take as many as three weeks, depending on the difficulty of obtaining the background information and other processing requirements.

F. REPORTING OF NONCONFORMANCES OR DEFICIENCIES

All personnel at a nuclear power plant have a responsibility to the public for reporting of nonconformances or deficiencies. This reporting responsibility is described in 10 CFR 21, and is a federal law. All work on safety related items or activities must be performed under the provisions of 10 CFR 21, and all personnel must be familiar with the responsibilities outlined in this document. A copy of 10 CFR 21 must be displayed in a conspicuous location so as to allow review by all personnel involved with the safety related project.

IV. PROTECTIVE COATINGS IN NUCLEAR POWER PLANTS

A. REASONS FOR COATING IN A NUCLEAR POWER PLANT

There are several major reasons for applying protective coatings to nuclear facilities.

- **Decontamination.** Protective coatings are used to improve the ability to remove radioactive nuclides (contamination) from a metallic or concrete surface.
- **Corrosion Control.** Protective coatings are used to protect the substrate from deterioration caused by a chemical reaction with its environment (Figure 6-75).
- **Esthetics.** Protective coatings are used to enhance plant appearance, provide better light reflectance, reduce dusting of concrete surfaces, and facilitate housekeeping.
- **Identification.** Coatings are used for "color coding" to more readily identify components, systems, and piping. A unique unit or system identification is obviously more important where two or more units are side by side. Hazardous or sensitive areas are highlighted as are safety equipment or warnings.

B. EFFECTS OF FAILURE OF PROTECTIVE COATING SYSTEMS

In a nuclear power plant, failure of a coating system may affect the engineered safety system (ESS) following a DBA or LOCA. Two ways this can happen are:

1. Coatings subject to flaking, peeling, or delamination may clog strainers, flow lines, pumps, spray nozzles, and core coolant channels. This can jeopardize the residual heat removal capability of the core or reduce the pressure suppression and radioactive iodine removal effectiveness of the containment spray system.
2. Products from coating or exposed metal surfaces reacting with containment spray solutions may plate out within the residual heat removal (RHR) system or on the nuclear fuel in the core. Plating out in either of these areas could reduce the effectiveness of core cooling after an accident.

Plant-specific engineering evaluations have been made of the above criteria. They have determined that failure of a coating would neither adversely affect the performance of the post-accident fluid systems, nor would it contribute to increasing the consequences of any design basis accident (DBA).

V. COATINGS USED IN NUCLEAR POWER PLANTS

A. SERVICE LEVELS

The selection of coatings for use in nuclear power plants is based on requirements for normal operations as well as established accident requirements. Within a nuclear power plant, there may be one, two, or three service levels. These are defined below. (Note: These definitions are general in nature and are intended as a guide. Each nuclear station has an engineering, quality assurance, or licensing group that can give specific reference as to what constitutes the various service levels or quality categories at their respective plant.)

Coating materials in each service level require specific exposure and physical property tests depending on their location within the facility (Figure 6-76). These tests are also listed below under "Criteria for Coatings."

FIGURE 6-76. Nuclear torus covered with one coat of inorganic zinc-rich primer. Courtesy of S.G. Pinney & Associates, Inc.



B. SERVICE LEVEL I

1. Definition - Service Level I is defined as areas where coating failure could adversely affect the operation of post fluid systems, and thereby impact safe shutdown of the plant. The areas that are included in Service Level I for pressurized water reactors (PWR) and boiling water reactors are:

Pressurized Water Reactors:

- Reactor containment building liner plate
- Structural steel, steam generator support steel, and gallery steel inside the containment
- Concrete surfaces inside the reactor containment building.
- Exposed uninsulated carbon steel surfaces of mechanical equipment, piping, and electrical equipment inside the containment

Boiling Water Reactors:

- Drywell interior
- Suppression chamber interior
- Structural steel and gallery steel inside the containment
- Concrete surfaces inside the containment
- Exposed uninsulated carbon steel surfaces of mechanical equipment, piping, and electrical equipment

2. Criteria for Coating Systems in Service Level I

- Design basis accident (DBA) or loss of coolant accident (LOCA). The coating system is subjected to a simulated DBA test and must meet specific criteria. Test required only for coatings inside containment.
- Radiation tolerances and decontamination
- Chemical resistance
- Physical properties

Standards used for testing material are ANSI N101.2, ANSI N5.12, ASTM D 3911, ASTM D 3912, ASTM D 4060, ASTM D 4082, and ASTM D 4256.

C. SERVICE LEVEL II

1. Definition - Service Level II is defined as areas where coating failure could impair, but not prevent, normal operating performance. The function of a coating in a Service Level II area is to provide corrosion protection and decontaminability in those areas outside of containment subject to radiation exposure and radionuclide contamination. The areas in Service Level II may include:

- Auxiliary building (only those portions subject to radiation)
- Radwaste building
- Safeguard building

2. Criteria for Coating Systems in Service Level II

The nuclear facilities final safety analysis report (FSAR) or other appropriate technical document details the specific test requirements, which may include all of those listed for Service Level I above, or only some of the tests listed.

D. SERVICE LEVEL III

1. Definition - This includes coating work outside of primary containment, but which in the event of failure could adversely affect normal operation or orderly and safe shutdown of the plant. Service Level III areas are may include:

- Fuel pools and canals
- Circulating water lines
- Condenser water boxes
- Condensate water tanks
- Emergency diesel fuel storage

In some instances these items listed as Level III are designated as Level I due to their safety significance. If deemed safety related (Level I) by the stations final safety analysis report (FSAR), a quality assurance program is required as well as compliance with any applicable regulatory requirements and standards.

There is another category designated "Balance of-Plant." This applies to normal painting work procedures that are not included in Service Levels I, II, or III.

Many facilities are reclassifying or downgrading their coating systems in an attempt to reduce costs, radiation

exposure, and paperwork. Thus, the inspector must research the criteria applicable to coatings inspection.

2. Criteria for Coating Systems in Service Level III and Balance of Plant

Service Level III and Balance of-Plant coatings, depending upon the specific environmental condition, may not require high performance properties and thus specific testing is waived.

NOTE: The specific requirements for testing can be found in the station final safety analysis report, job specification quality assurance program, or other controlling documents.

VI. HEALTH AND SAFETY

A. RADIATION AND RADIONUCLIDE CONTAMINATION

At a nuclear power plant that has been operating, special hazards include exposure to radiation and radionuclide contamination. All nuclear power plants have the potential for contamination, be it airborne, fixed, or smearable.

Each facility has a training program to ensure that all personnel working in an operating plant are trained in the practices and guidelines for radiation work. The training program also ensures that all personnel have an understanding of radiation and contamination hazards, and how these hazards can affect workers and the general public. This training is mandatory and is provided for a safe working environment among other things. Some plants may have videos, photographs, or other visual aids of what is to be inspected. The inspector should inquire if such aids are available for preview.

Large projects may require the use of mock-ups for worker training. It is suggested that the inspector suit up in the expected protective clothing and perform all the inspection activities on the mock-up with bagged tools (see below), etc. prior to doing the "real thing." Also, if the inspector is required to witness the coating work in progress, he should be present when the workers are training on the mock-up.

B. ALARA PROGRAM

Every precaution should be taken to minimize personnel exposure to radiation. Programs are developed to keep exposure "as low as reasonably achievable." (These are known as ALARA programs.) Each facility sets goals to maintain the exposure of all personnel to an absolute minimum. The inspector should consult the plant's ALARA group if there is any doubt about exposure.

Before the inspector begins his work, the plant's health physics personnel will have performed a survey of the work area and prepared a written report of their findings. The inspector should review this report, which may indicate:

- Areas that need to be decontaminated to prevent the spread of smearable or airborne contamination.
- Areas that have a higher than normal radiation reading, which are to be avoided if possible.
- Details concerning the personnel protective equipment that is to be worn. This may include multiple layers of body clothing, boots, gloves, head gear and respirator.

It should be noted that the protective equipment required for work in a nuclear facility may cause retention of body heat. The inspector must therefore be conscious of heat stress, know where he is scheduled to work, and go directly there in order to minimize expended energy.

The inspector should take only the inspection tools he absolutely needs into the contaminated areas, since he might not get them back out. If possible, the inspector should try to protect the inspection tools in plastic bags and only leave the working end of the tool exposed. Cameras, if required, can be operated inside plastic bags with a taped opening for the lens only. Digital reading dry film gauges work well inside bags with the sensor tip penetrating the bag and taped to it. If the inspector's recording papers become contaminated and cannot be removed from the work area, they should be individually bagged for photocopying or verbally transmitted to someone on the "clean side." A solution may be to bag a tape recorder to record the inspection results; however, if this is done, a checklist should be used so information is not omitted. The inspector should work closely with health physics personnel to find out how to best protect inspection equipment and tools, and how to decontaminate them when the inspection work is done.

FIGURE 6-77. Diver entering immersion area at a nuclear power plant. Courtesy of Underwater Engineering Services, Inc.



C. STANDBY GAS TREATMENT SYSTEM

A nuclear power plant is required to have a standby gas treatment system. This system is designed to control the release of radionuclide airborne activity inside the reactor building in the event of an emergency. It utilizes activated charcoal filters to clean the contaminated air before it is released to the environment.

D. UNDERWATER INSPECTION

Underwater inspection of tanks, vessels, and BWR suppression chambers is gaining wide acceptance (Figure 6-77). The radiation dose rate to a diver underwater is considerably less than it would be in air since the water acts as an excellent shield. Also, underwater inspection of tanks and vessels can save costs and time since the plant does not have to empty and process the water. If necessary, bottom sludge can be vacuumed and filtered for better viewing and inspection.

For underwater inspection, almost all of the normal inspection tools can be used. In addition, underwater TV cameras can allow engineers real time viewing of the coating system or equipment in question. Chapter 6.3 provides further information on underwater inspection.

E. RIGGING AND ACCESSIBILITY

Rigging and accessibility on a nuclear power plant is usually accomplished without much difficulty thanks to the design parameters of the interior walls and supports. Some areas, however, are unique due to the congestion of equipment, structural steel piping, and supports; or the large expanse, such as in the upper portion of the containment. These areas often require special rigging or scaffold systems for proper and safe access to the work area.

The plant may have specific criteria with regard to erection of scaffolding or rigging systems. Such things as seismic stability, fire hazard (wood scaffold plank), proximity to critical safety systems and qualified scaffold erection crews may be governed by specific procedures.

When inspecting areas that are normally not occupied or traveled, the inspector should consult the plant's health physics group personnel before proceeding. Special surveys may be required to verify that there are no contaminated or high radiation areas, since conditions can and do change in any facility. Also, it should be noted that high radiation areas in nuclear power plants are cleaned and monitored for contamination from the floor to 8 feet (2 meters) above the floor. When working over 8 feet (2 meters) high, the inspector should inquire about special precautions or if a special health physics survey is required.

Radio communication is effective on large projects. Supervisors or workers can call for the inspector when they are ready and thus prevent either party from waiting for the other. The inspector should be sure to check with plant operations before using radios since there may be some restrictions. For example, radios might interfere with sensitive instrumentation that could affect plant operation.

VII. INSPECTION REQUIREMENTS FOR SERVICE LEVEL 1 COATINGS

If the nuclear plant considers coatings in Service Level 1 areas to be "safety related," then a quality assurance program must be developed to govern the protective coatings work performed on those areas. This quality assurance program must comply with the requirements of 10 CFR 50, Appendix B. Standards for establishing a quality assurance program for protective coatings work are ANSI N101.4 and ASTM D 3843.

The quality assurance program for Service Level 1 areas must address qualification and selection of coatings (see Section V). The following major activities must also be controlled and documented:

- Calibration of measuring and test equipment
- Documentation
- Coating manufacturing
- Surface preparation
- Coating application

(Note: Some facilities may require further activities in addition to those listed.)

A. CALIBRATION OF MEASURING AND TEST EQUIPMENT

All measuring and test equipment must be calibrated at prescribed intervals or prior to use against certified equipment having known traceability to nationally recognized standards. Most commonly, instruments must be traceable to the National Institute of Standards and Technology (NIST). Further requirements for calibration are:

- Procedures for calibration and the frequency of calibration must be developed for each instrument to be used.
- Calibrations must be performed by qualified individuals.
- Each instrument must have a calibration status label affixed (if possible) that shows the identification number, calibration date, calibration due date, and initials of the person responsible for the calibration.
- Calibration records must be maintained for all measuring and test equipment.

These procedures ensure that all measuring and test equipment is handled and stored properly such that the accuracy and fitness for use is not compromised.

B. DOCUMENTATION

Sufficient quality control records and documents must be maintained to furnish objective evidence of compliance with the specifications and the specified quality assurance procedures. Distribution and maintenance requirements for quality control and quality assurance records must be in accordance with the quality assurance program.

C. COATING MANUFACTURING

The coating manufacturer must maintain a quality assurance program and provide documentation to show the quality of a product supplied for Service Level I use is the same composition as the coating system previously tested.

D. RECEIPT INSPECTION OF MATERIALS

In order to assure the coating materials complies with the requirements of the specification, a receipt inspection must be performed before any material can be used in a Service Level I area.

There are several unique requirements for receipt inspection of materials used on a nuclear power plant. Specifically, the documentation requirements for the receipt, storage, and handling of coating materials must be governed by approved procedures to ensure the inadvertent use of improper or unacceptable material. This is accomplished by ensuring the material received is the material on the purchase order and all documents required by the procedure and the purchase order are present and accurate. The coating manufacturer must provide a product identity certification record for each batch of material shipped. This must include at a minimum:

- Established acceptance criteria ranges and batch characteristics for weight per gallon and viscosity
- Batch number
- Date manufactured
- Shelf life expiration date
- Certification that the product shipped is the same composition as the product tested for qualification

In addition, temperature and storage conditions should be verified by the inspector to ensure the material used is not damaged or has not been subject to unacceptable temperatures or inclement weather that could adversely affect coating performance or characteristics.

E. MASKING AND PROTECTING ADJACENT EQUIPMENT

Protection of adjacent equipment is critical on a nuclear power plant. Internal system cleanliness is mandatory. Protection, masking, and cleaning of equipment must be

accomplished with only approved materials. Even the masking tape has to be approved since some tapes contain chlorides or other halogens, which are restricted on a power plant due to the sensitivity of stainless steel to these elements.

When working inside piping or equipment systems, it is mandatory that final system cleanliness be verified. Dust, dirt, materials, tools and equipment must be removed from inside systems before they are closed for testing and operation. The plant may have a procedure for logging or recording what tools, equipment, materials or consumables are taken inside a closed system.

F. CONTROL OF SURFACE PREPARATION

As with any coating inspection project, controls have to be implemented on the surface preparation of substrates. The surface cleanliness and condition cannot be less than that criteria used to originally test the coating system.

Surface preparation procedures for each substrate must be prepared by the designated responsible party and approved by the engineering department and the quality assurance department to ensure compliance with the specification. Surface preparation procedures must include hold points to allow for inspection.

G. CONTROL OF COATING APPLICATION

The coating system(s) must be applied within controlled parameters to ensure that the system(s) can perform as designed (Figure 6-78). Coating application procedures for each substrate must be prepared by the designated responsible party and approved by the engineering department and the quality assurance department to ensure compliance with the specification. The manufacturer's written instructions must be incorporated as part of these procedures. Coating application procedures must include hold points to allow for inspection.

All application personnel must be qualified and their qualification documented in accordance with the quality assurance program. ASTM D 4227 and ASTM D 4228 describe procedures for qualification of application personnel.

H. TREATMENTS OF INACCESSIBLE AREAS

Any Service Level I areas that cannot be prepared, coated or inspected in accordance with the requirements of the specifications must be identified in writing and dispositioned by the responsible engineer. Most often an "unqualified coating log" or an "exempt log" is developed. This is used to record inaccessible areas and other items or com-

ponents that do not meet the specified requirements. The exempt log should not be used to record coating work that has not been done properly. Work that has not been done properly should be recorded as such on a "deficiency report" or other similar titled document, and corrected as instructed by the proper party, in most cases the responsible engineer.

I. VENTILATION FOR APPLICATION, DRYING, AND CURING

Before any solvent-borne coating systems are used inside plant buildings (specifically the reactor building), the inspector should consult with the plant's engineering department regarding proper procedures for ventilation of solvent fumes. Special ventilation may be required, for example, to avoid poisoning the filters of the plant's standby gas treatment system (see Section VI D). When painting complete rooms, tanks, or other enclosed areas, it may be necessary to ventilate through sacrificial activated charcoal columns or containers to remove solvent fumes before exhausting the air to the building ventilation system.

J. CONTROL OF INSPECTION

Hold points must be established to ensure that coating work is performed in accordance with the specified requirements (Figure 6-79).

K. CONTAINMENT OF DEBRIS

For all operations on a nuclear power plant, debris must be contained to ensure that adjacent equipment is not damaged or contaminated by coating operations. For a plant that has been operating, it is critical to ensure adequate containment to avoid airborne radioactive contamination. Containment criteria, personal protective equipment requirements (respirator and body covering), and any special monitoring requirements are usually established by the plant's health physics personnel.

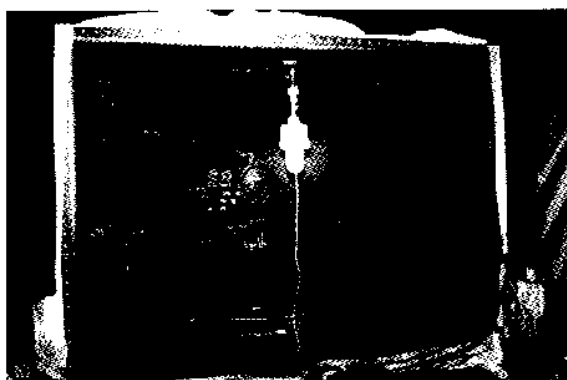
VIII. SUMMARY

There are two types of nuclear power plants: the pressurized water reactor and the boiling water reactor. Both have engineered safety systems to protect personnel and the public from the effects of a so-called "loss of coolant acci-

FIGURE 6-78. Rubber applicator is stitching (rolling) in rubber at manway. Courtesy of S.G. Pinney & Associates, Inc.



FIGURE 6-79. Rubber lined water box removed from condenser. Rubber has been spark tested and repair areas marked. Courtesy of S.G. Pinney & Associates, Inc.



dent" (LOCA). Coatings play an important role in these engineered safety systems. Containment coatings in particular cannot fail and detach or they will compromise the post-accident heat removal.

Because of the potential serious consequences of a LOCA, qualification of equipment, systems, designs, materials, and personnel is highly regulated. This includes coating materials and coating inspectors. There are three service levels defined for coatings in nuclear power plants. Coating materials in each service level require specific exposure and physical property tests depending on their location within the facility. Service Level I is defined as areas where coating failure could adversely affect the operation of post fluid systems; Service Level II is defined as areas where coating failure could impair, but not prevent normal operating performance; and Service Level III includes coating work outside of the primary containment, but which in the event of failure could adversely affect normal operation or orderly shutdown of the plant.

For safety-related Service Level I areas, a quality assurance program must be in place to govern the protective coatings work. The elements of this program must include calibration of measuring and test equipment, documentation, coating manufacturing, surface preparation, and coating application. There are also special inspection concerns for receipt inspection of materials, cleaning and protection of adjacent equipment, treatment of inaccessible areas, ventilation, and containment of debris.

The special hazards of working in a nuclear power plant that has been operating include exposure to radiation and radionuclide contamination. The coating inspector must receive training and remain in close communication with the health physics personnel in order to minimize his exposure to these hazards (and protect the inspection equipment). The inspector should also consult the health physics group when planning access to the various structures and areas within the plant.

ACKNOWLEDGEMENTS

The author and editors gratefully acknowledge the active participation of the following in the review process for this sub-chapter:

Don A. Hill - Consultant to Washington Public Power Supply

Michael J. Masciale - Valspar Corporation
George V. Spires - Advanced Corrosion Engineering, Inc.

BIOGRAPHICAL SKETCH

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Mr. Chandler is a member of various professional societies, including SSPC, NACE International, the American Society for Metals, ASTM, the American Water Works Association, the American Welding Society (AWS), and the International Concrete Repair Institute. He has been Chairman, Vice Chairman, and Secretary of the Delaware Valley Chapter of SSPC. He is a member of the ASM Thermal Spray and Surface Finish Committee, and ASTM Committee D33, Protective Coatings for Power Generation Facilities. He is the author of a chapter on Maintenance Painting and Coating in the McGraw-Hill "Maintenance Engineering Handbook" (5th Edition).

Mr. Chandler has a B.S. Degree in Metallurgical Engineering from California State Polytechnic University. He has taken the Krautkammer Ultrasonics, Inc. Ultrasonic Testing and Measuring Course, and the FMI & Rutgers University course on Total Quality Management in Construction. He is certified by the National Board of Registration for Nuclear Safety Related Coating Engineers and Specialists.

Chapter 6.13

Fossil Fuel Power Plants

by Bryant W. Chandler

OUTLINE

- I. Scope
- II. References
- III. About Fossil Fuel Power Plants
- IV. Environments Present and Coatings Used in Fossil Fuel Power Plants
- V. Health and Safety
- VI. Surface Preparation and Coating Application
 - A. Precleaning
 - B. Surface Preparation
 - C. Coating and Lining Application
 - D. Ventilation and Heating for Drying and Curing
- VII. Post-Application Inspection
- VIII. Summary

I. SCOPE

This sub-chapter is about coatings inspection in fossil fuel power plants. It outlines the various components of a fossil fuel power plant, and the environments present in each of them. (Note: Further information relevant to coatings inspection in fossil fuel power plants can be found in Chapters 3, 4, 5, 7, and 8. Chapters 3, 4, and 8 describe basic inspection procedures; Chapter 5 describes inspection procedures for specialty coatings; and Chapter 7 provides important information on safety for the coatings inspector.)

II. REFERENCES

Environmental Protection Agency (EPA)

Clean Air Act, Public Law 91-604, December 31, 1970

Clean Air Act Amendments of 1990, Public Law 101-549, November 15, 1990; and Public Law 102-187, September 4, 1991.

III. ABOUT FOSSIL FUEL POWER PLANTS

The majority of all the generating stations in the US are fossil fuel power plants. This classification includes plants that use coal, oil, and natural gas as fuel sources (Figure 6-80). Of all the fossil fuel sources, coal presents the most coating problems. It is dusty, can be abrasive, may contain heavy metals, and, when combined with water, can be highly acidic, especially if it has a high sulfur content.

Fossil fuel power plants are equipped with flue gas desulfurization (FGD) scrubbers. These are required by the Environmental Protection Agency (EPA) Clean Air Act to remove excess sulfur dioxide (SO_2) and sulfur trioxide (SO_3) from the boiler emission. These sulfur compounds, which can lead to acid rain and other adverse environmental effects, are generated when sulfur-containing coal or oil is burned.

FIGURE 6-80. Fossil fuel power plant. Courtesy of S.G. Pinney & Associates, Inc.



IV. ENVIRONMENTS PRESENT AND COATINGS USED IN FOSSIL FUEL POWER PLANTS

The coatings inspection requirements for a fossil fuel power plant are essentially the same as for any industrial or chemical plant; however, a unique concern is the exposure of certain areas to SO_2 . As described below, areas may also be subject to immersion, heat, abrasion, and acids. Such areas require special coating and lining considerations:

- FGD wet scrubbers are exposed to constant immersion, heavy abrasion and high acid concentration cells. If they are fabricated from carbon steels, FGD scrubbers require special coatings and linings. Lining materials include vinyl ester, siloxanes, novalac epoxies, multi-functional epoxies, metal spray and rubber linings. Some of the listed materials may be reinforced with fiberglass matting. (Note: High nickel alloy scrubbers do not require special linings, but require special welding, fabrication, erection, and final cleaning considerations.)
- Electrostatic precipitators and bag houses are exposed to high heat and abrasion. High temperature paints (e.g., silicone), which often require a heat cure after application, are used to coat them.
- Ash hoppers are exposed to immersion, heat, impact and abrasion. Coating and lining materials include vinyl ester, metal spray, novalac epoxies and siloxanes.

- Settling basins and neutralization tanks are exposed to constant immersion, acid and/or basic chemicals, and, in some cases, trace petroleum products. Coating and lining materials include vinyl ester, siloxanes, novalac epoxies, rubber and PVC.
- Aeration ponds and clarifiers are exposed to constant immersion and abrasion. Typical coating and lining materials include epoxies, thick film polyurethanes, vinyl esters, and coal tar epoxies.
- Ducts and stack liners are exposed to heat, abrasion, and acid concentration cells (Figure 6-81). Typical lining materials include borosilicate block applied over a flexible membrane, vinyl ester, siloxanes and novalac epoxies.

Note: The above is a generalization of coating and lining materials used in these areas. Other materials not listed may give excellent service.

V. HEALTH AND SAFETY

The special hazards to which the coatings inspector and other workers may be exposed in an operating fossil fuel plant are mostly associated with plant operations and exposure to combustion products or other chemicals, both

FIGURE 6-81. Hot stacks. SSPC file photo.

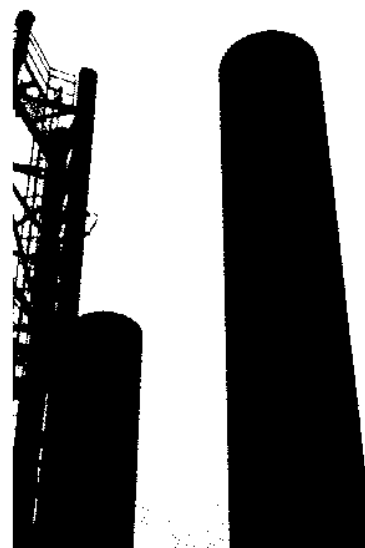




FIGURE 6-82.
Dehumidification
equipment.
Courtesy of
Munters Moisture
Control Services.

gaseous and liquid. Some of these hazards are:

- Sulfur oxides. These can form acids when breathed into the lungs. When working around FGD scrubbers, special provisions for SO_2 and SO_3 monitoring and evacuation plans should be incorporated into the safety plan.
- Carbon dioxide (CO_2). While it is not poisonous, CO_2 reduces oxygen availability in the flue gas.
- Chlorine compounds. These can form hydrochloric acid or carcinogens such as dioxin.
- Fuel ash. Heavy metals may be present in fuel ash in dangerous levels. In addition, residual combustion may continue in ash collected in hoppers. One should never step into flyash. It can be cold on the surface yet remain hot and smoldering underneath for weeks.
- Flames or furnace conditions. When viewing flames or furnace conditions, tinted goggles or a tinted shield should always be worn to protect the eyes from harmful light intensity and flying ash or slag particles.
- Hot furnace gases. When near operating boilers and furnaces, one should never stand directly in front of open ports or doors, especially when they are being opened. Furnace pulsations caused by firing conditions, sootblowers operation, or tube failure can blow hot furnace gases out of open doors, even on suction-fired units.
- Slag leaks. When combustion occurs with insufficient air, iron oxides in coal can be reduced to molten iron or iron sulfides. This molten iron can wash away refractory seals and tubes and leak out onto equipment or personnel.
- Heat stress. This may be a concern when working around operating boilers, baghouses, precipitators or in high humidity/hot conditions (Figure 6-82).
- Collapse of vessels during steam cure. If a rain storm occurs during a steam cure on a tank or vessel located outside (see Section V, D), the equipment must be opened up immediately to prevent collapse of the vessel. The rain rapidly cools the internal steam and creates a vacuum. If the equipment or vessel is not watched continuously during the cure, then vents, manholes, pipe flanges, etc., can be rigged with special devices that will cut the tarps or bags covering them, thus preventing a vacuum sufficient to collapse the vessel.
- Other hazards, such as high-voltage electrical shock, confined space, and operating mechanical equipment. Since the inspector may be the last person performing work (e.g., testing the cure) in an area, he should be included in all required lockout/tagging procedures. This is necessary to ensure that equipment is not started accidentally before the inspector's work is completed. It also allows the plant to know when it is safe to start up the equipment.

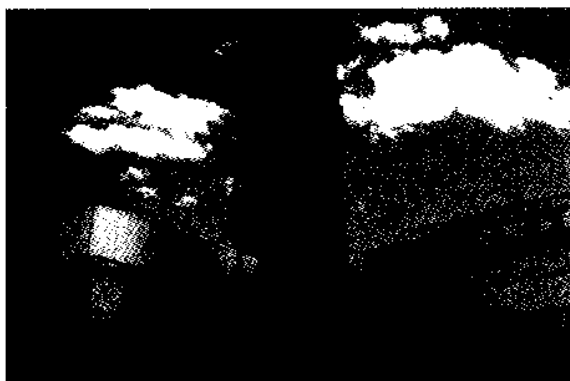
Chapter 7 provides further information on some of these hazards and general safety for the inspector. As with any work in a potentially hazardous environment, it is essential that the inspector be fully trained in all safety procedures. If not sure of something, he should ask about it.

VI. SURFACE PREPARATION AND COATING APPLICATION

A. PRECLEANING

Due to exposure to SO_2 and other corrosive and erosive chemicals, the equipment in a fossil fuel power plant requires thorough precleaning and testing of surfaces for contamination. High nickel alloy scrubbers in particular should be cleaned before operation to remove any chloride contamination. Cleaning techniques may include steam cleaning, ultrahigh pressure (>25,000 psi; 172 MPa) water

FIGURE 6-83. Ultra high pressure (40,000 psi) high production tool and vacuum collection system mounted on a man basket cleans an asbestos and lead based paint from a 250 ft. power plant stack. Courtesy of Valley Systems Inc.



blasting, wet abrasive blasting, caustic or acidic washes, or blasting with special additives.

B. SURFACE PREPARATION

The inspector should ensure that the specified level of surface preparation is attained (Figure 6-83). General procedures for inspection of surface preparation are described in Chapter 4.

In order to determine the profile of prepared surfaces, the inspector may need to obtain special comparative blast profile panels from the manufacturer. For some specialty coatings used in fossil fuel power plants, blast profiles of 4 - 5 mils (102 - 127 micrometers) may be required, and this is out of the range of usual replica tape measurements.

C. COATING AND LINING APPLICATION

Many special procedures are used for coating and lining of fossil fuel power plants. These include:

- Application by plural component and/or heated spray equipment
- Application by a combination of spray, hand lay-up, and troweling
- Hand laying of large rubber sheets over adhesives

- Preparation and layup of separate panels for adhesion testing (e.g., of rubber linings)
- Heat curing or steam curing

The inspector should be trained in how to monitor these special procedures. He should consult the specification and the manufacturer's application instructions for specific requirements (Figure 6-84). Chapter 5 of this book may also be useful. It contains some information about inspection of a variety of specialty coating and lining systems.

D. VENTILATION AND HEATING FOR DRYING AND CURING

Coating and lining work in fossil fuel power plants often takes place in confined spaces. In confined spaces, adequate ventilation/circulation and air temperature must be provided for proper curing of materials. In addition, for safety reasons, sufficient oxygen must be furnished and solvent concentration kept well below the lower explosion limit. When heavy solvent fumes are present, exhaust air should be taken from the lowest point in the confined space.

Special linings used in fossil fuel power plants may require heat, hot water, or steam curing. When steam curing rubber, not only is the sheet lining cured but the cements develop their full adhesive properties.

For heat curing, a manifold or distribution system should be used to introduce, at multiple points, the heat, hot water, or steam into the lower part of the vessel or equipment. The temperature should be monitored on the lowest point of the equipment or vessel (where it is usually coldest), as well as several other locations. It is imperative that the manufacturer's recommended curing temperatures be achieved and maintained throughout the duration of the cure. To keep equipment and vessels at the required temperature for curing, it may be necessary to temporarily insulate them.

VII. POST-APPLICATION INSPECTION

The inspector should perform all specified tests on each applied coating or lining. Adequate cure(s) can often be

FIGURE 6-84. Heater at power plant, coated with fluoroelastomeric coating. Courtesy of Colebrand, Ltd.



determined by hardness readings or other quantitative measurement, which should be taken at numerous locations and recorded. For heat cured linings, the inspector should be sure to allow the lining or coating to reach ambient temperature throughout its thickness before taking measurements or performing other tests. The manufacturer's instructions should be consulted for cure temperatures and times, and methods of checking for adequate cure.

VIII. SUMMARY

The structures and equipment in a fossil fuel power plant are exposed to a variety of environments including SO_2 and SO_3 (in flue gas desulfurization scrubbers), constant immersion, heavy abrasion, high acid concentration, heat, and impact. Consequently, many different specialty coatings and linings are used to protect the plant. The inspector must be familiar with these coatings and linings (and systems containing them) and their surface preparation, application, cure, and inspection requirements. Pre-cleaning procedures are frequently critical to remove surface contaminants. In addition, special ventilation procedures are required for some specialty coatings and linings.

Because of the many different environments in a fossil fuel power plant, the coating inspector can be exposed to many hazards. In addition to the sulfur oxides already mentioned, hazards include confined spaces and reduced oxy-

gen availability; chlorine compounds; excessive heat and hot materials (flyash, slag, hot gases); and high voltage equipment. The inspector must take all necessary precautions to protect himself from these hazards.

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BIOGRAPHICAL SKETCH

A biographical sketch of Web Chandler appears at the end of Chapter 6.12.

Fossil Fuel Power Plants

Chapter 7

Safety

by Tony Cunningham

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 - B. Contractor/Owner Responsibilities
 - C. Safety Monitoring
- III. Risks
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 - B. Personal Risks
 - C. Legal Risks
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I. SCOPE

This chapter presents a range of safety information for the coatings inspector. It is divided into several main parts:

- General safety responsibilities of the coatings inspector and other parties involved in the coatings work. Safety monitoring is also discussed.
- Risks involved in coatings work and coatings inspection.
- Safety and health regulations. Regulatory agencies and safety and health regulations are described. Guidance is provided on where to go for further information.
- Hazards that can be encountered in coatings inspection work. These are classified as hazardous materials, hazardous environments, and hazardous activities.
- Safety practices. The various safety practices that are used to protect the coatings inspector and those around him are described. This includes a discussion of areas where the coatings inspector may be required to provide assistance to safety/industrial hygiene personnel in enforcing safety regulations and procedures.

This chapter also includes an Appendix that describes various types of safety monitoring equipment.

II. GENERAL SAFETY RESPONSIBILITIES

A. INSPECTOR'S RESPONSIBILITY

The coatings inspector is classified as a worker. He is therefore held by law to be responsible, as far as is reasonable, for his own safety. To protect himself and to ensure safe working, the inspector should:

- Become informed about relevant safety and health issues, and keep the knowledge "up-to-date" by reading industry publications and journals
- Obtain copies of documents referenced by specifications. The inspector must be knowledgeable about safety rules, regulations, and practices.
- Discuss safety issues at the pre-job conference (if held) or at site meetings whenever possible and whenever safety problems arise. The inspector should make efforts to clarify his position and the safety-related duties expected of him before beginning to work at any location.

- Become familiar with the location of medical facilities, telephones, hazard warning systems, escape practices, etc., and obtain any specific safety training that is required
- Be conservative, and avoid unnecessary risks (Figure 7-1); if unsure of the appropriate action, take the safest one.

The inspector can take these steps to protect himself, but what responsibility does he carry to protect the other workers around him and the general public? The answer is that the inspector and all other workers are collectively responsible for their safety and the safety of the public. They should recognize the need to be aware of all safety risks, and take reasonable care to reduce risks wherever possible. Everyone at the jobsite should keep a look-out for unsafe acts or operations and report them to their supervisor or to the engineer in charge. If the engineer in charge cannot be reached immediately, a written message should be sent to him. If the inspector is aware of safety violations and fails to take action, he may be at risk to legal action and be judged partially responsible for any accidents that may occur (discussed further in Section III C).

FIGURE 7-1.
An unsafe operation that the inspector may encounter: Smoking near solvents. SSPC file photo.



B. CONTRACTOR/OWNER RESPONSIBILITIES

Although it is up to the inspector and other workers to safeguard themselves by becoming informed about safety issues, the prime responsibility for their safety is in the hands of the main contractor. Many specifications refer to safety issues by using statements such as:

"Contractor shall comply with all applicable laws and regulations of any public body having jurisdiction for the safety of persons or property, and shall take any and all necessary steps to protect workers or members of the public from damage, injury or loss."

However, the facility owner may also be responsible for worker safety. For example, the OSHA standard "Process Safety Management of Highly Hazardous Chemicals" (29 CFR 1926.64) declares that contractors and facility owners (referred to as employers in the standard) share responsibility for each other's employees when work is performed on processes regulated under this standard. Thus, when an inspector is employed directly by a contractor or facility owner, the contractor and the facility owner may share responsibility for the inspector's safety. The issue of who is responsible for the inspector's safety can become less clear when the inspector is employed through an independent inspection agency. In this case, responsibility rests in theory with the inspection agency (the inspector's actual "employer"), but often (in practice) with contractor or facility owner who has contracted the inspector's services.

C. SAFETY MONITORING

Coatings inspectors are often employed on (usually small) construction sites where safety is left to the discretion of the site engineer, or even to the individual worker. However, on permanent facilities such as oil refineries or petrochemical plants, there is usually a safety officer or safety department, whose job is to supply the necessary information, support, and guidance to workers. The safety group is also responsible for safety monitoring and can provide the inspector with information regarding safety rules and the "code of practice" of the facility.

Industrial hygienists are sometimes required to monitor the hazards of the working environment (Figure 7-2). Coatings inspectors are not normally assigned such responsibilities. Sometimes, however, the inspector may

be closely involved with the safety monitoring process. On a small site, for example, it is possible that safety restrictions apply, but the safety department or group are not able to be there to make necessary checks. In this case, the coatings inspector may be asked to use the equipment and make checks on behalf of the safety officer. The coatings inspector may also occasionally be required to act on behalf of the owner to enforce safety regulations and procedures, such as:

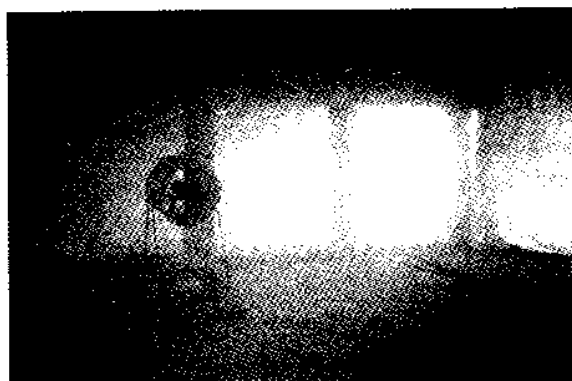
- Ensuring that warning/safety signs are in place (see Section IX. B.)
- Safe entry testing and issue of work permits (see Section IX. C.)
- Enforcing requirements limiting visible emission from a containment (see Section IX. H. 4.)
- Verifying that surface preparation or coating application equipment has the necessary safety features (see Section IX. I.)
- Monitoring the collection of samples for hazardous waste testing purposes and supervising the collection of hazardous waste material (see Section IX. L.)

The inspector should take care that he does not take authority for monitoring activities for which he is not trained or is not responsible, or make decisions that may affect other workers. If in doubt, the inspector should

FIGURE 7-2. Industrial hygienist performing safety monitoring. Courtesy of Mine Safety Appliances Company.



FIGURE 7-3. Dusty condition inside a containment. SSPC file photo.



insist on more training to ensure competency in safety monitoring techniques. The inspector should be prepared to use his own knowledge, initiative, and judgement to determine what actions are appropriate for him to undertake.

As safety requirements become more stringent, the coatings inspector will become more involved in safety monitoring and testing. Being up-to-date and knowledgeable on current regulations has become a significant part of the inspector's role.

III. RISKS

The coatings inspector can face general risks, personal risks, and legal risks. None of these risks can be eliminated entirely. The main responsibility of the inspector is to know what the risks are, and to take all reasonable steps to avoid or to minimize them. In each case, a better understanding of the risks allows them to be controlled or eliminated.

A. GENERAL RISKS

General risks affect the inspector, other workers and, perhaps, the general public. These include the risks of explosion, particularly in an enclosed space, because of the potentially explosive solvents used in many paint coatings. Other general risks include:

- Creating a hazardous environment, through solvent release or the creation of toxic dust (Figure 7-3).
- Providing a dangerous scaffold structure which could collapse, leading to injury to persons working on the structure or simply passing by.
- Failing to provide adequate warning of hazard, erect warning barriers around exclusion zones, or position a look-out, and so on.

B. PERSONAL RISKS

Personal risks are particular to the individual worker. The inspector may face the same personal risks as a blast-cleaning worker or painter. These risks may include:

- Entering a hazardous environment such as an inadequately ventilated enclosed space (whether for observation or working purposes).
- Falling from a height.
- Breathing toxic materials such as dusts or solvent fumes.

Personal risks may at times become compounded. For example, breathing solvent fumes can cause disorientation, leading to another problem such as falling, or may have a slow and cumulative effect, leading to long-term illness. In any event, simple risks, such as falling objects, inadequate access, or insecure staging are always a factor, and the inspector should never work where he personally feels unsafe.

C. LEGAL RISKS

Legal risks can be classified as secondary risks, arising from failure or neglect on the part of an individual such as an inspector or other worker who should know the prevailing rules. The importance of legal liability has to be emphasized, since the increasing tendency is for litigation to arise from any incident which could conceivably have been avoided. The litigation is typically directed at anyone who could be responsible in part and who is a possible source of money. Everyone is at risk from potential litigation. Although this is not, and should not be, the prime justification for working safely, it can be a significant factor in the work environment, and steps should be taken to avoid such problems.

IV. SAFETY AND HEALTH REGULATIONS

A. GOVERNMENT AGENCIES

Most nations have safety regulations to protect the worker. They are often similar in both form and content. In the US, the enforcement of safety regulations on site or in the factory is primarily the responsibility of the Occupational Health and Safety Administration (OSHA). NIOSH is an advisory research arm of OSHA. In many other countries, a government body similar to OSHA exists to perform the same function.

Agencies such as the Environmental Protection Agency (EPA) are charged with protection of the environment from contamination by hazardous materials in either the long or short term. Their actions also have a direct impact on the health and safety of workers.

B. HOW SAFETY REGULATIONS PROTECT THE WORKER

In the US prior to the 1960s, little legislative attention had been focused on occupational health. The Occupational Safety and Health Act (OSH Act) took effect in 1971, and with it, the Occupational Safety and Health Administration (OSHA) came into being.

The purpose of the OSH act is to protect every worker in the country. It gives OSHA the responsibility to:

- Promulgate, modify, and revoke, safety and health standards (29 CFR 1900 through 1999)
- Conduct inspections and citations, including proposed penalties
- Require employers to keep records of safety and health data
- Petition the courts in imminent danger situations
- Approve or reject plans for programs under the act

One OSHA standard that is directly relevant to inspectors and others who work around painting and coating operations is the Hazard Communication Standard (HAZCOM). HAZCOM includes requirements for Materials Safety Data Sheets (MSDSs), which provide safety-related information for materials and their ingredients. A discussion of HAZCOM and MSDSs follows.

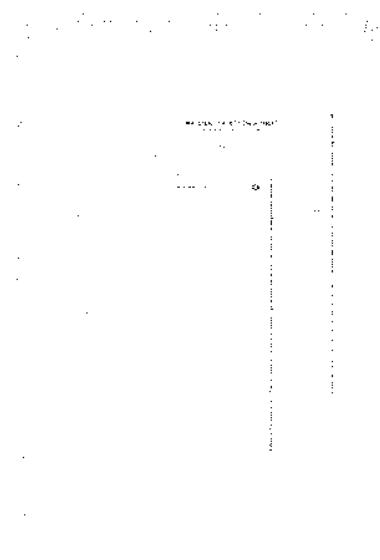
C. HAZCOM

Regulations governing hazardous chemicals in the workplace were first issued by OSHA in 1983. The OSHA Hazard Communication Standard (HAZCOM; 29 CFR 1926.59) is also known as the "Right-to-Know" regulations. Its purpose is to ensure that workers are informed about chemical hazards in the workplace, and that they are provided with information and training in how to safely handle the chemicals. The standard also requires that containers holding the chemicals are labeled, that material safety data sheets (MSDSs) are provided, and that emergency services are able to quickly identify hazardous materials (e.g., paints and solvents) being stored or used. HAZCOM also requires that chemicals in transport be registered with a central data source, and that the shipper provide a free telephone number to allow safety personnel access to the database.

Under HAZCOM, the manufacturer and the employer have distinct responsibilities:

- The manufacturer has the primary responsibility to conduct appropriate testing and to determine the nature and extent of all hazards. This information must be

FIGURE 7-4.
An example of an
MSDS.
Illustration by
Russell Davison,
SSPC.



made available to users of the manufacturer's product through MSDSs, test reports, and the like. A visual code is used to show explosion risk, fire rating, and specific risk information such as whether the material is corrosive.

- The employer is responsible for conveying the hazard information to employees in an organized and readily understandable manner. To comply with the standard, employers must have a comprehensive written HAZCOM program. HAZCOM contact phone numbers must be displayed.

D. MSDSs

Material Safety Data Sheets (MSDSs) provide safety-related information for materials and their ingredients (Figure 7-4). MSDSs must accompany products wherever they are stored or used. In addition, when coating materials are transported by road or rail, in whatever quantity, MSDSs are required to travel with the consignment, providing data which can be used in any emergency situation, such as a spill.

The MSDS also informs any worker handling a material of the health hazards of the components of the material, and guidance on safe handling (e.g., personal protective equipment required) and proper actions in the event of an emergency.

E. KEEPING UP-TO-DATE ON REGULATIONS

To know and follow safety regulations, the inspector and other workers must be aware of them and understand them. Unfortunately, they are often both complex and difficult to interpret. The legal position is that ignorance of the law is no defense, and any "expert" (i.e., one who has received formal training or has learned by experience) should be aware of regulations relevant to his area of work.

One of the prime difficulties with safety codes and regulations is the large number of different regulatory bodies. Regulations and codes for safe conduct may be generated by the federal government, by state or provincial regulators, or by local authorities. Many specifications refer to regulatory issues by using statements such as:

"All work shall be performed in accordance with current regulations. Where federal, state and local

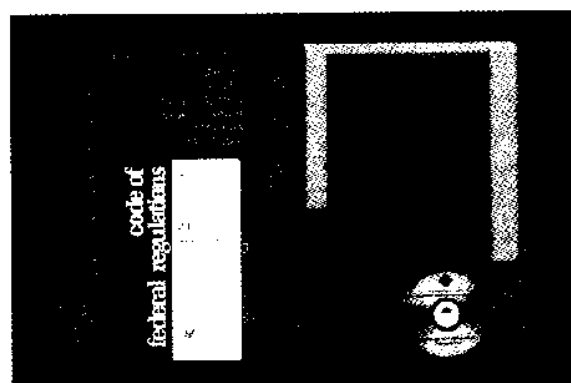
regulations conflict, the more stringent requirement shall apply."

It is the responsibility of the owner and the contractor to become aware of all the relevant regulations and codes. The inspector must also keep up-to-date with the regulations, but he may have fewer resources than the owner or the contractor.

Some information on regulations affecting health and safety is readily available (Figure 7-5). For example, OSHA provides a service intended to facilitate access to its regulations and other information it produces. This service includes access to:

- Quarterly updates on all new/additional OSHA activities occurring during the previous quarter
- The OSH act (and all revisions), all OSHA standards, preambles
- The Federal Register index (including a copy of OSHA Federal Register published materials)
- Citations, fines and Review Commission decisions, variances

FIGURE 7-5. Products and publications on various safety issues. Clockwise from upper right: a corporate Safety Program, NIOSH Pocket Guide to Chemical Hazards, OSHA CD-ROM, a volume of the Code of Federal Regulations, a National Fire Protection Association (NFPA) standard. Illustration by Russell Davison, SSPC.



- The Federal Inspection reference manual
- OSHA analytical methods, chemical sampling information
- The OSHA technical and field operations manual
- A listing of approved blood lead labs
- A listing of the national recognized testing labs
- MSHA (Mine Safety and Health Administration, US Dept. of Labor) regulations and documents
- OSHA documents including speeches, directives, fact sheets, compliance and other agency memos, compliance directives, standard interpretation letters, congressional testimonies, and hazard information bulletins

In addition, associations such as SSPC are excellent sources of information, issuing quarterly bulletins, printing regulations in the "Journal of Protective Coatings and Linings" (JPCL) and "SSPC Online (website)," and providing nationwide training seminars. Even so, an employer cannot send every one of his workers to seminars, and not everyone is able to follow the issue of new regulations and controls as they develop.

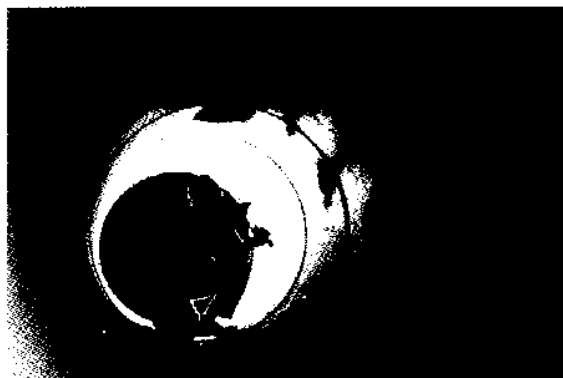
Clearly, an authoritative list of regulations, or the publications in which they appear, would cover many additional pages. The references listed in Section XII of this chapter, Further Reading, are representative of some of the more significant documents which may affect or be used by a coatings inspector.

V. TYPES OF HAZARDS

OSHA and other similar organizations throughout the world have specifically targeted the painting trade as one of the more hazardous occupations for workers. Although coatings inspectors may be less exposed to most hazards than the painters and other workers, the same hazards are encountered. In addition, the coatings inspector often works in inherently hazardous environments such as oil and gas production or storage facilities, fuel storage facilities, sewage treatment plants, and enclosed spaces such as tanks, pipelines or storage vessels (Figure 7-6).

The on-the-job hazards faced by the coatings inspectors and other workers may be classified as follows:

FIGURE 7-6. Inspection on the inside of a pipe. Courtesy of Mine Safety Appliances Company.



Hazardous Materials

Cleaning solvents
Coating components
Other hazardous materials in the work environment

Hazardous Environments

Heights
Confined spaces
Fire and explosion hazards
High voltages
Other hazardous environments

Hazardous Activities

Abrasive blast cleaning
High pressure water cleaning
Power tool cleaning
Airless spraying

VI. HAZARDOUS MATERIALS

The National Institute of Occupational Safety and Health (NIOSH) keeps a register of more than 60,000 toxic chemicals. The World Health Organization (WHO) and United Nations (UN) also keep registers of hazardous chemicals. Surprisingly, for many of the chemicals sold in large quan-



FIGURE 7-7. Air-purifying, half-mask, negative pressure respirator. SSPC file photo.

tities, there is little accurate or useful toxicity data available.

A. ORGANIC SOLVENTS

Organic solvents could be described as the villain of the coatings industry; they are often toxic, and most are precursors to photochemical smog and will burn when exposed to an ignition source. Some organic solvents are associated with more specific hazards. For example, many of the chlorinated solvents, such as trichloroethylene, 1,1,1-trichloroethane, perchloroethylene, and methylene chloride will form phosgene gas when burned. Phosgene is a highly toxic material that was used as a poisonous gas in World War I.

OSHA, working from data developed by the American Conference of Governmental Industrial Hygienists (ACGIH), specifies threshold limit values (TLVs) for selected chemicals (including solvents) in the working environment. They describe both a short-term exposure limit (STEL) and a longer-term working limit called a time-weighted average (TWA). The STEL (e.g., 300 parts per million for MEK) should not be exceeded at any time. The time-weighted average (e.g., 200 parts per million, over a duration of 8 hours for MEK) gives the average allowable exposure over the stated period. Some threshold limit values are shown in Table 1. (Note: TLVs are also

specified for mineral dusts, such as silica, graphite, mica, and perlite, all of which are used in coatings.)

Section IX, H, and the Appendix to this chapter discuss methods of monitoring exposure to solvents; however, continuous monitoring is difficult and not often encountered on site. How, then, do we know what our exposure to toxic solvents has been? The answer is, frequently, we don't! The inspector should stay out of the hazardous environment when possible, wear effective respiratory protection (masks, etc.) (Figure 7-7) and measure (or have measured) solvent concentrations at frequent intervals. This latter requirement is more easily said than done, despite being a major requirement of safety legislation, and this illustrates the difficulty of enforcing good safety practices.

There cannot be any doubt that long-term exposure to solvent vapors is damaging to the health, particularly when exposure exceeds the permissible limits.

B. COATING COMPONENTS

Coatings are made from complex chemical formulations of solid (non-soluble) powdered materials (pigments and fillers) dispersed in a film-forming liquid vehicle (resin binders and solvents). Safety authorities (e.g., OSHA)

TABLE 1. Threshold Limit Values of Some Common Solvents. (Source: Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment; see Bibliography)

Solvent	STEL (Short Term Exposure Limit), ppm	TWA (Time-Weighted Average), 8 hours, ppm
Mineral Spirits	-*	100
Toluene	150	50
Xylene	150	100
Methyl Ethyl Ketone (MEK)	300	200
Methyl Isobutyl Ketone (MIBK)	75	50

*Not specified

have rated them in terms of toxicity and/or other hazards. Information about these hazards can be found on Material Safety Data Sheets (MSDSs) provided by the coating manufacturer.

1. Pigments and Binders

Technical investigations have identified most heavy metals (e.g. chromium, lead, cadmium) as potentially hazardous to health, suggesting that their use should be limited as much as possible. In the paint industry, this has had immediate impact on some paint ingredients, particularly certain common pigments such as red lead and zinc chromate. Many other pigments that have been used in coatings could be, and often are, classified as suspected toxins, carcinogens or pollutants. Some of the common pigments known or suspected to be hazardous to health are listed in Table 2. There can be major problems with removal of

TABLE 2. Paint Pigments: Uses, Hazards, and Restrictions.

Pigment	Comment
Carbon Black	Carbon black (sometimes called lamp black) has been used as a color pigment. It is a suspected carcinogen and so finds reduced use today.
Chromium	Chromate pigments have been used as colored hiding pigments and/or inhibitive pigments. They are believed to be carcinogens, so their use is being greatly reduced.
Lead	Lead compounds have been used as hiding pigments and/or inhibitive pigments. Lead is well known to be hazardous to children, causing mental retardation as well as many other effects. It is also hazardous to workers creating lead-containing dust. Residential use of lead-containing paint pigments has been eliminated in the United States, and industrial use has been greatly reduced. (Note: Some zinc pigments can also be a source of lead. Lead levels as high as 0.2% have been noted.)
Mercury	Mercury compounds have been used in paints as mildewcides. Mercury is poisonous by inhalation. Its toxicity varies depending upon the compound.
Selenium	Selenium compounds have been used as fungicides. Selenium pigments, considered by some authorities to be hazardous, are seldom used today.
Tin	Organo-tin compounds, once widely used in anti-fouling paints, have been widely restricted because toxic tin compounds were picked up by marine organisms and got into their food chain.
Zinc	Zinc metal is used as a reinforcing pigment and corrosion resistant pigment. Zinc oxide and zinc phosphate pigments are used in coatings as corrosion inhibitors. Legislation in California is concerned about zinc in relatively high levels constituting a hazardous waste. No general restrictions on use of zinc pigments have been enacted to date. Some concerns have been expressed about trace heavy metal in some zinc pigments. Lead levels as high as 0.2% have been noted (see entry for lead, above).

TABLE 2. Paint Pigments: Uses, Hazards, and Restrictions.

Pigment	Comment
Antimony	Antimony oxide has been used as a white hiding pigment. Experimental data indicate that antimony is a suspected carcinogen.
Arsenic	Arsenic compounds are well-known poisons that were formerly used in antifouling paints. They are not used in coatings today.
Asbestos	Asbestos, once widely used to impart reinforcement to paint films, is no longer used for this purpose. Coating deterioration or removal can release asbestos fibers, and these are believed to cause lung disease.
Barium	Barium pigments are used for corrosion and mildew control. In general, the barium compounds used in paint have extremely low solubility and reactivity. However, when coatings containing barium are immersed in water, the barium can leach into the water, resulting in levels that exceed health limits.
Cadmium	Cadmium compounds have been used as color pigments. They mainly affect the kidneys and lungs. Their use in coatings is restricted by some governmental agencies.

existing coatings containing these pigments, and enclosure of structures during cleaning operations is now the norm in locations where limits of lead or other heavy metals apply.

The coatings industry worldwide is currently searching for adequate replacement pigments for those considered to be hazardous. Many alternate materials that have been found are more expensive than materials that have restricted use, less effective, or both.

The binders used in some coatings are potentially hazardous to health. For example, polyurethane coatings are formed by reactions involving isocyanate components, highly reactive compounds that are strong irritants and sensitizers (see Section D, below). Typical effects include skin reactions, eyes watering, respiratory difficulties and possibly cancer in the long term. Isocyanates have poor warning properties. Skin contact with isocyanates should be avoided and a supplied air respirator (Figure 7-8) should be used when working with isocyanates. Cartridge type air purifying respirators are not recommended, since isocyanates have poor warning properties, i.e., odor threshold is greater than the PEL.

2. Organic Solvents in Coatings

Organic solvents, commonly called volatile organic compounds (VOCs), are used in coatings to dissolve the binder and reduce viscosity. VOCs are a major concern today, because they are released into the atmosphere during curing of coatings, and undergo chemical reactions in sunlight to form ozone and other air pollutants. Coating manufacturers are now developing products that have a lower organic solvent content and/or use water as an alternative dispersion medium. Those coating materials that are formulated without added solvents (e.g., 100% solids products), are less damaging to the environment than those containing significant amounts of organic solvent.

Current VOC emission restrictions limit the total output of VOCs to a maximum level. Other governmental bodies have focused on the issue of "transfer efficiency," the capability of coating application equipment to apply the material with a minimum loss to the environment. One effect of limiting VOC content is that certain coating types, such as vinyl or chlorinated rubber coatings, have become virtually eliminated from use. Specification writers must be aware of the particular VOC emission limits and regulations for the work location.

C. OTHER HAZARDOUS MATERIALS THAT THE INSPECTOR MAY ENCOUNTER

1. Acids/Caustics

In certain industries, e.g., pulp and paper mills, food and beverage processing plants, and water and wastewater treatment plants, the inspector may be exposed to strong acids and/or caustics. Acids are also sometimes used to prepare concrete surfaces for coating (Figure 7-9). Both acids and caustics will cause eye damage and burn skin upon contact. Appropriate personal protective equipment should be used whenever working with or near acids or caustics. The type of personal protective equipment required can be determined by consulting the product's MSDS.

2. Cleaning Fluids

Many common industrial strength cleaning fluids may cause dermatitis, and some are detrimental to the environment. Cleaning specifications commonly require the use of "bio-degradable" cleaning fluids. Although they are less damaging to the environment, these products often contain caustic detergents, and may cause irritation. For all types of cleaning fluids, it is, as always, important that the inspector knows of the likely hazards and appropriate safety measures to reduce the risk. The type of personal

FIGURE 7-8. Worker wearing supplied-air respirator.



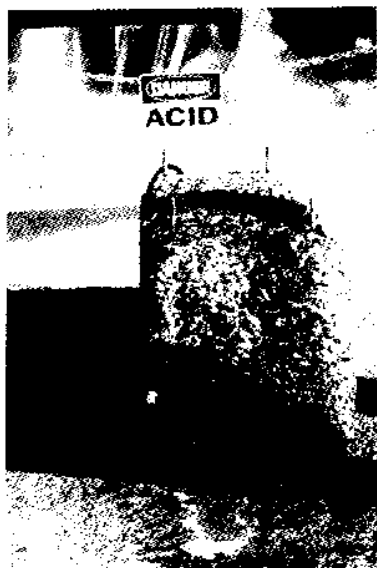


FIGURE 7-9. Sign denoting acid cleaning hazard. SSPC file photo.

protective equipment required can be determined by consulting the product's MSDS.

3. Mercury in Glass Thermometers

Glass thermometers, often used in sling psychrometers, can break and release toxic mercury into the environment. This is of special concern where the mercury may contact an aircraft or helicopter frame. Mercury can cause rapid and potentially catastrophic corrosion of aluminum or aluminum alloy parts. Although spirit thermometers are marginally less accurate, they are much safer, and can be transported on aircraft without any problem.

4. Nuisance Dusts

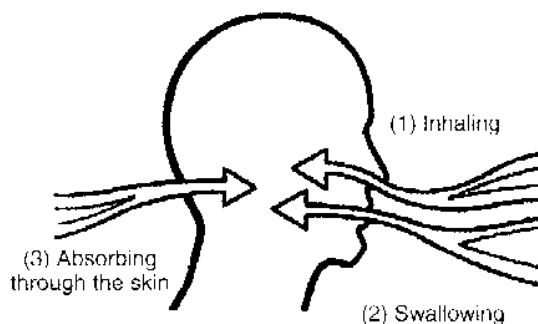
Abrasives are generally chosen in part for their inert properties, and, consequently, are relatively non-toxic. Breathing any fine dust, however, can be irritating to the linings of the throat and lungs, leading in extreme cases to irreversible long-term effects. Some abrasives, sand in particular, produce known toxic products when broken up in the blasting process; in many parts of the world the use of silica sand for blast-cleaning is not allowed because of the known occurrences of silicosis (a throat and lung disease) from blasting operations.

D. TOLERANCE AND SENSITIZATION TO TOXIC SUBSTANCES

The effect of hazardous materials on a worker's health depends on the route of exposure (Figure 7-10). For example, the body reacts differently to ingestion (direct entry into the body) of dusts and vapor than it does to skin contact with them. The reaction of an individual to each type of exposure cannot be accurately predicted.

The effect of hazardous materials on a worker's health also depends on the individual's tolerance level. When an individual worker's exposure to a toxic substance exceeds the tolerance of his body system, he becomes more sensitive to that exposure, and his reaction to it becomes more severe, sometimes instantaneous. This process, called sensitization, is similar to the development of an allergy in that it cannot easily be reversed. One case was reported where a painter suddenly became violently ill when spray painting, a task he had performed without problem for many years. The symptoms included sweating, skin irritation, vomiting, and shaking. After several days rest at home, he recovered and returned to work, where the symptoms returned immediately whenever a paint can was opened. Exposure to toluene paint solvent was identified as the cause, and the painter never was able to resume his normal line of work.

FIGURE 7-10. Routes of entry of toxins into the body.



VII. HAZARDOUS ENVIRONMENTS

A. WORKING AT HEIGHTS

Many structures require access equipment for painting, which may take the form of ladders, movable platforms or towers, or elaborate scaffold stagings constructed for the purpose. Temporary personnel support arrangements, like the "bosun's chair" or larger, motorized platforms may also be used. Thus, painting is an activity that may incur the risk of falling. As many as 70% of the physical accidents to painters are caused by falls. The potential risks to inspectors using the same access modes is evident.

Falls from more than 6 feet (2 meters) above the ground can cause severe injury. Inspectors are required to wear a safety restraining device, such as a full body safety harness, when making inspections above this height. Section IX, E. of this chapter provides further information on safety practices for staging, scaffolding, and safety harnesses. It also includes a brief discussion of the regulations pertaining to this type of equipment.

B. CONFINED SPACES

The coatings inspector may be required to work in confined spaces such as storage tanks (Figure 7-11). A confined space is defined (29 CFR 1910.146) as a space that:

- Is large enough and so configured that an employee can bodily enter and perform assigned work;
- Has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits); and
- Is not designed for continuous employee occupancy.

Hazardous conditions a coatings inspector may encounter when working in confined spaces include:

- Flammable gas, vapor, or mist in excess of 10% of its lower explosive limit (LEL).
- Airborne combustible dust at a concentration that meets or exceeds its LEL.
- Atmospheric oxygen concentrations below 19.5% or above 23.5%.
- Atmospheric concentrations of substances in excess of their OSHA permissible exposure limits (PEL)

FIGURE 7-11. Work area that might be classified as a confined space. Courtesy of Mine Safety Appliances Company.



Confined spaces can be classified as non-permit required or permit required confined spaces. Permit required confined spaces are those confined spaces that have one or more of the following characteristics:

- Contains or has the potential to contain a hazardous atmosphere
- Contains a material that has the potential to engulf an entrant
- Has an internal configuration such that an entrant could be trapped or asphyxiated
- Contains any other recognized serious safety or health hazard

Further information on permits for confined spaces is given in Section IX, C. of this chapter.

C. FIRE AND EXPLOSION HAZARDS

Fire hazards are often present when painting operations are in progress. All volatile liquids, including solvents, have a specific and characteristic flash point (temperature). When the flash point temperature is exceeded, the solvent vapors will ignite or explode when exposed to a spark or flame.

Explosions are likely wherever concentrations of explosive gases exceed their lower explosive limit (LEL). Defined as the lowest concentration of explosive gas in an environment that is capable of explosion, the LEL is different for each type of gas. It is usually determined for a

gas by measuring the quantity required in a gas/air mixture to give an explosive reaction to a spark or open flame. Typically this would be determined in terms of parts per million (ppm), which is sometimes expressed as a percentage (10,000 ppm = 1%). Gases also have an upper explosive limit (UEL), above which the concentration of the gas is too great for an explosive mixture, and the gas cannot be ignited. (See Section IX. H. and the Appendix for information on monitoring gas levels.)

Mixtures of some dusts can also explode when the concentration of dust in the dust/air mixture is within certain limits, particularly when the dust/air mixture is dry (i.e. the relative humidity is low). Metal dust (particularly aluminum) is extremely hazardous, but almost any dust containing metallic or organic materials may ignite.

The coatings inspector may be exposed to oxygen-enriched environments, such as exist around oxygen delignification or oxygen bleaching processes in pulp and paper mills. This also presents a significant fire hazard.

D. HIGH VOLTAGE

In some facilities, such as fossil-fueled electrical generating stations, the inspector may be exposed to the risk of high voltage electrical shock (Figure 7-12). In such cases, appropriate lockout/tagging procedures should be followed. Lockout/tagging is briefly discussed in Section IX. D.

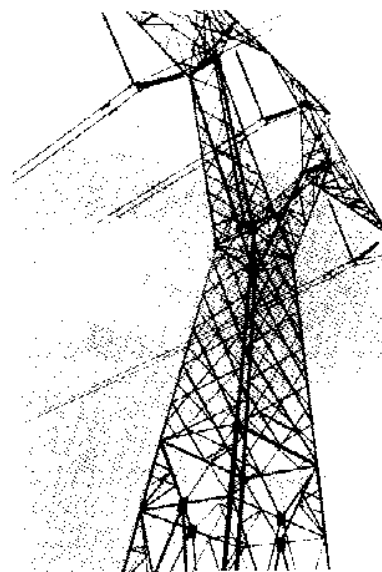
High voltage holiday detectors may pose an additional hazard to inspectors, particularly if they are working at a height--when any surprise may cause an inadvertent step--or when the user has heart problems, or wears a heart pacemaker.

E. OTHER HAZARDOUS ENVIRONMENTS

Other hazardous environments that the coatings inspector may encounter are:

- Slippery or obstructed walkways
- Excessive heat
- Inadequate lighting
- Excessive noise

FIGURE 7-12. High voltage areas that the inspector may be exposed to. SSPC file photo.



- Radiation
- Traffic

VIII. HAZARDOUS ACTIVITIES

At times, the inspector may work in the vicinity of hazardous activities. For example:

- Abrasive blast cleaning is a dangerous operation. The high-pressure compressed air through the system and the air-propelled abrasive from the nozzle can cause serious injury. Abrasive blast cleaning presents additional hazards when nuisance dusts and/or toxic dusts (from the removal of toxic coatings) are released into the atmosphere. Loud noise from blast nozzles and compressors may also be a problem.
- High-pressure water cleaning (also known as water jetting or hydroblasting) may use pressure as high as 40,000 psi (280 MPa) and water volumes of only 2 to 15 gallons per minute (8 to 56 liters per minute). The high-pressure water can be extremely hazardous: it can cut through concrete, or even steel, so the hazard to workers cannot be over-estimated.
- Power tool cleaning is a dangerous operation. All types of power tools used to clean a steel surface by impact or abrasion are clearly capable of harming workers. Power tools that are air-driven are generally safer than the electrically-driven equivalents.

For these and all other types of hazardous activities, it is essential that steps are taken to protect the workers, including the inspector if he is at risk, and other on-site personnel. Some information on safety practices for these hazardous activities is given in Section IX. I. Obviously, the worker must be familiar with the standard operating procedures for all hazardous equipment.

IX. SAFETY PRACTICES

A. TRAINING

The communication of safety related information has been recognized as a major component of job safety. It is important to both inform and train the worker to reduce the hazards he faces in the work environment. Safety information on materials used in the workplace is most often provided by the material manufacturer in the form of Material Safety Data Sheets (MSDSs). Training may take the form of seminars away from the job site, on-the-job training, or "tool-box talks." In all cases, it is important to both the worker and the employer that the effectiveness of training be demonstrated by examination or other means.

Employers are required to operate a comprehensive safety program that includes periods of instruction for all workers. Visitors to plants, factories and other work facilities must also comply with the restrictions of the program.

Coatings inspectors making short surveillance visits have been surprised to find that they need to undertake familiarization exercises, watch safety videos, or even shave beards (to ensure respirator fit) before they are allowed to enter the jobsite.

A number of OSHA standards require specific training for all individuals exposed to toxic materials or hazardous conditions (e.g., OSHA Lead in Construction Standard, 29 CFR 1926.62, paragraph I). Inspectors should be familiar with training requirements and the nature of the hazards.

B. RESTRICTED ACCESS AND SAFETY SIGNS

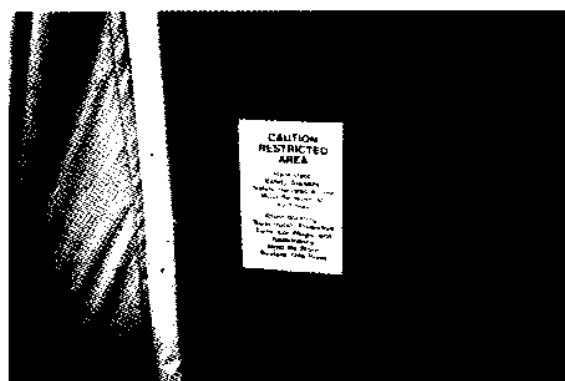
Whenever a generally hazardous activity such as blast-cleaning is taking place, access to the area should be restricted. Barriers should be erected around the exclusion zone, and a look-out posted wherever the general public

may be threatened by the site activity, or be faced with a warning that they may not be able to understand.

It is common practice to use warning symbols in addition to words, as much as possible, to ensure that warning messages are understood. Part of an inspector's specific job responsibility may be to ensure that appropriate warning and safety signs are in place (Figure 7-13):

- Warning signs about dangers such as blast-cleaning operations should be present and erected in such a way that they can be seen by all those concerned, whether operators, other workers, or members of the public. Tapes marking any exclusion zone should be properly placed and continuous.

FIGURE 7-13. Top - Lead hazard warning sign. Bottom - Restricted entry safety sign. Both SSPC file photos.



- Safety signs should be present and should be in one or more languages that the public can understand. Hazards should be correctly identified in conformance with any applicable OSHA or other regulations. Where contact telephone numbers are required, they should be current. The location of the nearest available telephone should be shown.

C. PERMITS

Working in a hazardous environment generally requires the owner of the facility to issue a work permit prior to commencement of work. The permit defines the conditions in which work may take place and the precautions which the workers must observe to work safely. Permits may include specific rules on safety equipment and clothing (Figure 7-14), instructions for ventilating enclosed spaces, grounding equipment to reduce static sparking, etc. The permit is issued and signed by a "responsible person," and the restrictions defined are mandatory. Prior to issue of such a permit, the owner may require the use of monitoring equipment to test for toxic or explosive gases, and may require monitoring of the environment during the performance of the work.

As described in Section VII. B., confined spaces are areas that may require special permitting programs. OSHA has introduced standards in the USA (29 CFR 1910.146) which present requirements for safe working practice in confined space work areas, including the preparation of complex standard entry permits, and the need for training of "authorized entrants." A "Permit Required Confined Space Program" protects employees from permit space hazards and regulates employee entry into permit spaces.

This program must include provisions for:

- Identifying permit-required confined spaces
- Testing/monitoring the hazards which may confront entrants of a permit space
- A permit system (a written procedure for preparing and issuing permits for employee entry into permit spaces)
- Rescue and emergency services
- Identifying the duties of authorized entrants, attendants, and entry supervisors
- Personal protective equipment
- Training

FIGURE 7-14. Individual equipped for work in a confined space. Courtesy of E.D. Bullard Company.



The coatings inspector may occasionally be required to act on behalf of the owner to control safe entry testing and issue of work permits.

D. LOCKOUT/TAGGING

Important safety practices called "lockout" and "tagging" may be required for inspection work in or around hazards such as confined spaces (tanks, boilers, etc.) or high voltage equipment (motors, breaker cabinets, transformers, overhead cranes, transmission structures, etc.) (Figure 7-15). Lockout and tagging are means of protecting workers from injury or death caused by the accidental start up or release of stored energy from equipment, and are defined in 29 CFR 1926.417.

- Lockout involves blocking the flow of energy from the power source to the piece of equipment by using a device such as a padlock or chain, or by removing a component such as a fuse or circuit breaker. Items typically locked out include electrical connections, steam lines, valves, and moving parts such as agitators, gears, and pistons.
- Tagging involves placing a tag on the power source as a warning not to restore energy to the piece of equipment.

Tags are commonly used along with lockout devices. When lockout is not possible, tagging is used alone.

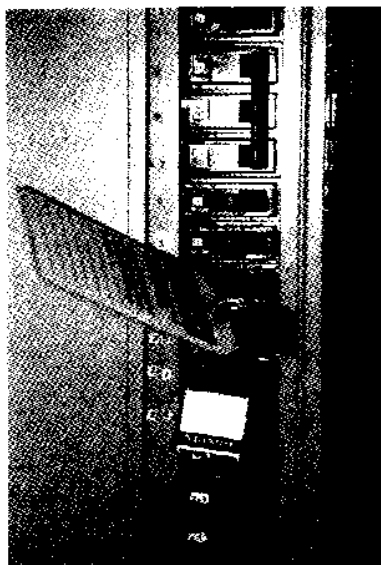
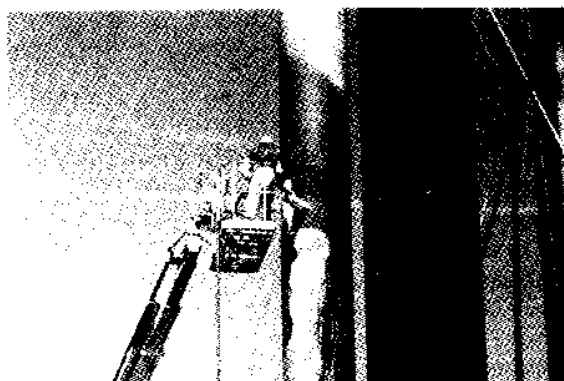


FIGURE 7-15. Example of locked and tagged equipment. Courtesy of KTA-Tator Inc.

FIGURE 7-16. Examples of different types of access equipment. Top - Courtesy of Tank Industry Consultants, Inc. Center - Courtesy of Five Star Products, Inc. Bottom - Courtesy of Valley Systems Inc.

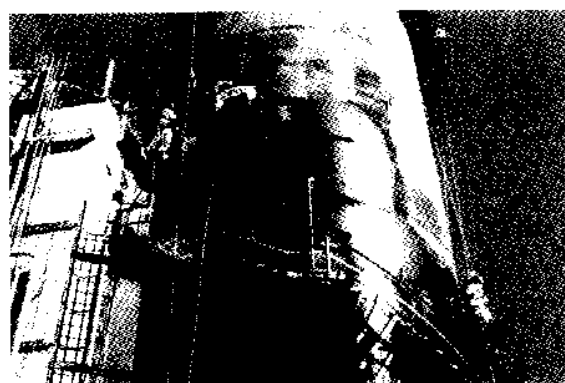


E. ACCESS AND FALL PROTECTION SYSTEMS

Supports such as ladders, scaffolds, lifts, and rigging are often used to provide access for painting and inspection when operations are beyond normal reach (Figure 7-16). To protect workers and the general public, scaffold boards, toeboards, and guard rails should be secured in place. They should also be designed to ensure that objects cannot fall through gaps in walkways or sidings onto the areas below. In addition, in some areas, scaffold poles are painted white or wrapped with marking tape to make them more visible. The OSHA requirements for scaffolding are found in 29 CFR 1926.451. The coatings inspector is generally not expected to know the regulations regarding scaffolding.

For some highly organized projects, a safety officer, or even a specialist scaffolding inspector may be responsible for assessment of the condition of the access system and for issuing permits allowing its use.

Falls on construction sites continue to be a leading cause of fatalities and injuries every year. Inspectors should therefore understand and use "fail safe" or backup safety devices wherever possible. The OSHA requirements for fall protection are found in 29 CFR 1926, Subpart M (29 CFR 1926.500-503). At construction sites, work levels six



feet (1.8 meters) or more above a lower level require the use of fall protection systems. Employers can select fall protection measures compatible with the type of work being performed. Fall protection can be provided by using guardrail systems, safety net systems, personal fall arrest systems, position device systems, and warning line systems. Where work platforms with guard rails are not feasible, personal fall arrest systems must be used.

A personal fall arrest system consists of an anchorage, connectors, a body belt or harness, and a lanyard attached to an independent lifeline. Body belts, however, will not be permitted by OSHA after January 1, 1998. This is because they can cause severe internal injuries to the worker who falls while wearing one. The most appropriate harnesses are fastened across the shoulders and around the legs, and attach to a safety line at the back (Figure 7-17). Since a falling body will fold around its support point, it is very important that the safety line be attached at the back. This allows the body to fold forwards (nose moving towards feet) when a fall is arrested, rather than the other way, which may lead to a broken back.

Safety harnesses should be certified as complying with national regulations, and should be checked at regular intervals to ensure that they are not chafed, cut or worn.



FIGURE 7-17.
A worker wearing
a safety harness.
Courtesy of KTA-
Tator, Inc.

When in use, they should be protected from chafing or exposure to harmful materials such as paint solvents, and always kept clear of any obstructions so that they may operate properly in the event of a fall. The best use of a harness is to connect it to a properly designed secondary support system, rather than to the access structure.

Vertical ladders on elevated structures should be fitted with gravity locking anti-fall devices coupled to a harness or belt worn by the inspector while climbing. Platforms suspended on wire should have a secondary wire, connected to a separate support point, and coupled to the inspector's safety harness. If there is no secondary support system, temporary access arrangements are probably in violation of safety regulations.

If there are any doubts as to the safety of the access arrangements, while in use by painters or by inspectors, the only safe action is to avoid use until the doubt is eliminated, by whatever means necessary. A difficult situation may arise when an inspector has to use access that painters are using, but that he considers to be unsafe. The inspector has to decide his proper course of action. The safe and recommended option is to establish the actual level of risk before using any doubtful access structure. It is better to risk some delay while on the ground than to risk a fall.

F. PERSONAL PROTECTIVE EQUIPMENT

Personal protection is a must for safe working. Like the other workers, the coatings inspector should wear safety equipment and clothing suitable for the process(es) to which he is exposed. Generally, the inspector receives a lower level of exposure to hazards than workers such as painters, since the inspector is seldom in the work area continuously. Nevertheless, the hazards are similar, and a wise inspector adopts at least the same level of personal protection as necessary for the other workers.

Material Safety Data Sheets (MSDSs) should always be consulted when chemical products are being used. The MSDS will list the component ingredients of the product, and will also indicate the types of personal protective equipment that are recommended to safely work with the product.

1. Respiratory Protection

In a hazardous environment, particularly in an enclosed space such as a tank or vessel, respiratory protection is required (29 CFR 1926.134). The two major categories of respirators are air-purifying (e.g., filtering face masks) and air-supplied.

All workers including the inspector should be tested individually to ensure that their face mask fits, and does not allow fumes other than the breathing air to enter. Many companies insist that workers and visitors should be clean-shaven (i.e., no beards and no moustaches) before even entering the premises. Workers may also be required to have their health tested and certified by a medical professional.

Air-supplied masks should be fed with fresh air, preferably from a remote area, upwind of site operations, so that there is no possibility of the site contaminants (solvents, diesel fumes, etc.) entering the inlet. In addition, air lines should pass through charcoal filters to clean any contaminants which may be incorporated in the air supply. Where air is supplied directly from a compressor (which generally compresses oil in the air-receiver), the machine must be fitted with automatic shut-down equipment and/or high temperature alarms, and air must pass through a carbon monoxide tester. There are many regulations and require-

ments that relate to breathing air, e.g., the Compressed Gas Association specification for Grade D breathing air (CGA G-7.1). According to this specification, the air is to be odor-free and have an oxygen content between 19.5 % and 23.5 % (Figure 7-18). This specification also limits the amount of oil mist, carbon monoxide, and carbon dioxide that can be present in breathing air. This aspect of personal protection is considered to be critical.

2. Eye Protection

Proper safety glasses should be worn whenever there is thought to be a risk to the individual from work, equipment or hazardous materials in the workplace. Safety glasses should be of the "wrap around" type, to fully protect the eyes, or may be goggles. Separate side protection pieces can be used by those who normally wear prescription eyeglasses.

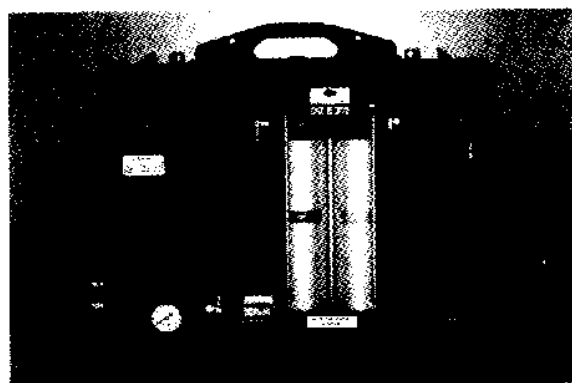
3. Ear Protection

OSHA's occupational noise standard for construction (29 CFR 1926.52) requires the use of feasible administrative or engineering controls when employees are subjected to sound levels exceeding the permissible exposure limit (PEL) of 90 decibels averaged over an 8 hour period. If such controls fail to reduce sound levels below the PEL, personal protective equipment must be provided and used to further reduce sound levels. Protective equipment against noise exposure may take the form of muffs, ear plugs, and canal caps.

The General Industry noise standard, 29 CFR 1910.95, also provides information on protection against noise exposure, in particular guidance for establishing hearing protection/conservation programs. This standard requires that employers implement a continuing, effective hearing conservation program whenever employee exposure equals or exceeds an 8 hour time-weighted average (TWA) of 85 decibels. Elements of a hearing conservation program include:

- Exposure monitoring
- Employee notification that exposure exceeds the PEL
- Annual audiogram testing
- Hearing protection that reduces exposure below the PEL
- Employee training

FIGURE 7-18. Purification and filtration system for compressed breathing air lines. Courtesy of MST, Inc./Modern Safety Techniques.



- Employee access to information and training materials
- Recordkeeping

Note: The construction industry noise standard (29 CFR 1926.52) also requires the employer to administer a continuing, effective hearing conservation program in all cases where sound levels exceed the PEL of 90 decibels averaged over an 8 hour period; however, it does not detail the elements of such a program. Employers in the construction industry can therefore use the general industry standard for guidance in establishing this program.

4. Protective Clothing

Workers should be protected from hazards by appropriate protective clothing. This may vary from a long-sleeve coverall and hard hat (safety helmet) for inspectors, to a full leather protective suit for a blast-cleaning operator. Each work process has its own requirements, contained in instruction manuals for workers, or displayed on signs in the work space for visitors.

G. CONTAINMENT AND VENTILATION

Removal of lead-containing coatings and other hazardous coatings may require erection of elaborate containment structures to prevent emission of dust and debris from the workplace (Figure 7-19). This creates an enclosed workplace that, in some sense, resembles a confined space (although it has not been considered such by OSHA). Levels of lead and other toxic dusts in this enclosed workplace can be very high because the containment prevents their escape. The resulting atmosphere can be hazardous in two ways: (1) The dust level may be so high that it is well in excess of the permissible exposure limit (PEL); and (2) the dust level may be so high that it reduces the worker's visibility. Typically, an industrial hygienist or other health or safety professional will be responsible for verifying conformance with environmental safety and health regulations. However, the coatings inspector should be aware of the processes and equipment for these activities, which include monitoring emissions from the containment (see next section) and verifying safe working conditions inside the containment.

FIGURE 7-19. Top - A containment, Bottom - Part of ventilation system of a containment. Both SSPC file photos.



H. MONITORING THE WORK ENVIRONMENT

Monitoring equipment includes meters used for sampling, where the test result gives a "yes/no" decision based on the sample taken, and meters used for constant monitoring, where the environment is constantly sampled. Constant monitor meters issue a warning if certain limits are exceeded.

1. Monitoring at representative location in the work area

LEL, oxygen levels, or other hazardous materials (e.g., methane, hydrogen sulfide) are sometimes monitored at representative locations in the work area. For example, it is possible to monitor a working environment for solvent levels using a sampling technique such as the Draeger Tube method (see Appendix). However, this requires both a knowledge of the solvents involved and a separate Draeger tube for each solvent, and gives only the solvent concentration at the time of measurement.

2. Personal monitoring devices

Meters for personal use, such as oxygen level monitors, are a type of constant monitor. When the work environment is considered to be (potentially) immediately dangerous to life or health (IDLH), workers should carry oxygen level monitors and emergency oxygen supplies which are adequate to allow the wearer to walk safely out of the space. Oxygen level monitors are used to alert workers to any situation which requires activation of the emergency breathing packs. Workers should be trained in the use of personal monitoring equipment and emergency breathing packs. In addition, if the hazardous environment is likely to contain any toxic gases, an appropriate monitor should be worn. (For more information on oxygen meters, see Appendix.)

3. Other meters for constant monitoring

Besides the oxygen level monitor, there are several other types of meters for constant monitoring. The "explosimeter" is used to test for concentrations of explosive gases.

The three-way monitor tests for toxic gas, combustible gas, and oxygen level. (For more information on the explosimeter and the three-way monitor, see Appendix.)

4. Monitoring emissions from a containment

The two basic approaches to monitoring emissions from a containment are visual and instrumental. These are described in SSPC-Guide 6. A coatings inspector may be asked to enforce a requirement limiting visible emission entirely or to a set number of minutes per hour. These should be spelled out in the job specification. Monitoring

emission using instruments requires special training beyond that normally required of a coatings inspector.

5. Monitoring ventilation systems

OSHA has prescribed several methods for reducing exposure to air-borne contaminants, including engineering controls (e.g., ventilation or alternate removal equipment) and administrative control (e.g., reduced time worked in high exposure zones). Monitoring ventilation requires familiarity with devices for measuring air pressure differential and air flow. It also requires familiarity with factors such as capacity of air-handling equipment; and placement and proper operation of ducts, dust collectors, and intakes. These are areas of specialist expertise. The inspector should, however, be prepared to recognize when ventilation equipment is required, and to ensure that the equipment is working properly when required.

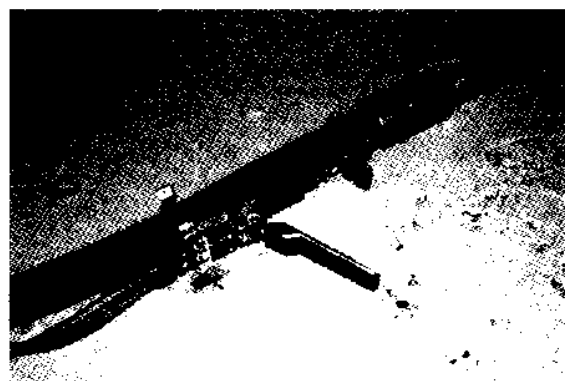
I. SAFETY DURING SURFACE PREPARATION

1. Blast Cleaning

Some of the safety precautions for blast cleaning are:

- Only the operator should be allowed in the immediate vicinity of the blast cleaning operation.
- Warning notices should be displayed.

FIGURE 7-20. Dead man valve. SSPC file photo



- A look-out (or "pot-man") should be on the alert.
- A "dead man valve" safety cut-out device should be fitted and used (Figure 7-20). (Despite frequent non-compliance, this is a mandatory requirement, and should always be checked by the inspector.)
- Required personal protective equipment must be used.

Other precautions include wiring the hose couplings together to prevent accidental disconnection and visually checking the general condition of the blast-hoses, looking for cuts and blisters. Blast hose is generally loaded with conductive carbon to dissipate static electricity whenever the hose contacts the ground. In particularly hazardous environments, the blast-pot should be connected to the structure by a conductive braid, copper or brass being commonly used.

2. Water Cleaning

The safety precautions for high-pressure water cleaning (see SSPC-SP 12/NACE No. 5) are essentially the same as those for blast cleaning (Figure 7-21):

- The pump unit should have an automatic safety device.
- A pressure control valve or other suitable design should be used that immediately interrupts the high- or ultrahigh-pressure water flow when the operator releases the trigger
- The work platform should be stabilized, and the operator should have firm footing
- The operators should be well-trained and experienced
- Ear plugs, face shield, rain suit, and gloves should be used. (Note: Some high-tech protective clothing has been developed, using Kynar cloth similar to that used for "bullet-proof" vests.)
- An attendant should be present while the water jet unit is in operation

3. Power Tool Cleaning

Power tools should be fitted with an appropriate guard, and workers should wear protective clothing such as gloves, eye-protectors and long-sleeve coveralls to limit their exposure should the equipment start to break up, or throw out steel particles (Figure 7-22). Inspectors in the vicinity of this type of equipment should also protect their ears and eyes, and should cover their skin.

FIGURE 7-21. Ultra high pressure (40,000 psi) diesel pumping system mounted in a truck equipped with repair facility. Note the safety signs on the truck. Courtesy of Valley Systems Inc.

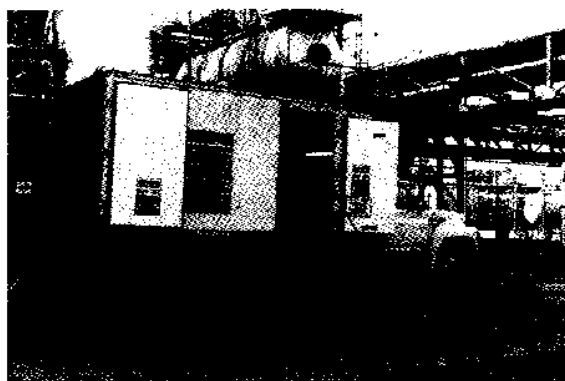


FIGURE 7-22. Use of a power tool. Courtesy of Unique Systems Corporation.



J. EXPLOSION AND FIRE PREVENTION

The inspector (and other workers) must be aware of the locations of fire extinguishers and alarm boxes, and must have received some training in the proper use of fire fighting equipment. Signs and warnings should also indicate the location of the nearest phone for emergency use.

1. Paint storage

Paints and coatings should be stored in an environment designed to minimize hazards. Good ventilation, careful stacking, and explosion-proof electrical circuits are all important. US regulations (29 CFR 1926.152) describe specific requirements for storing flammable or combustible materials. For example, no more than 60 gallons of flammable, or no more than 120 gallons of combustible material, may be stored in any one storage cabinet.

Wherever possible, it is advantageous to store and use solvent-containing paints, thinners and cleaning fluids below their flash points. Paints are best stored in a temperature-controlled environment, although it may not be practical in many cases. MEK, for example, one of the most widely used paint thinners, has a flash point of only 19°F (-7°C). Storage below this temperature is beyond the resources of most paint users.

2. Electrical Equipment

Electrical equipment used at the jobsite should be designed for use in aggressive conditions, with seals to provide resistance against water or mud entry. Circuit breakers should be used, and safety checks for continuity and effectiveness of the breaker system should be made. In hazardous environments which cannot be certified as "gas-free" the electrical equipment must be sealed to prevent exposure to gas. Such sealed equipment is specifically designed for hazardous environments, and is known as "intrinsically safe" equipment.

Generator's or main's electrical supply connectors are a particular source of hazard, and should be checked and certified by a qualified person prior to use.

3. Inspection Equipment

All electrically operated inspection equipment used in hazardous environments should be "intrinsically safe." Most battery operated inspection equipment is not intrinsically safe, and should not be used in a hazardous environment without an appropriate permit. This rule applies to all equipment with batteries, including electronic dry film thickness gauges, cameras, Tooke Gauges, electronic surface temperature gauges, and holiday detectors.

4. Classification of Work as "Hot" or "Cold"

Many work activities can be defined as "hot work" (e.g., welding) or "cold work" (e.g., painting by brush), the former usually having more restrictions applied. Many surface preparation or painting activities are considered to be controversial in this respect. Blast cleaning, for example, causes sparking when the abrasive hits steel, but some owners believe the spark is "cold" (i.e., unable to ignite gas) and the work activity should be called "cold work." Power wire brushing, or disc-grinding would most likely be classified as "hot work."

K. MEDICAL CHECK-UPS

When working with hazardous materials, blood or urine testing can determine the level of the material absorbed by the body. There are many OSHA standards that require medical surveillance if an action level is exceeded. Performance standards for specific chemicals such as lead (29 CFR 1926.62), cadmium (29 CFR 1926.1127), asbestos (29 CFR 1926.58), and inorganic arsenic (29 CFR 1926.1118) require medical surveillance if an exposure level is exceeded.

Besides blood or urine testing for hazardous materials, medical check-ups of workers may include fitness testing and drug/alcohol testing. For example, some companies require workers, including inspectors, to pass fitness tests at intervals, proving their ability to see, hear, maintain balance, or climb stairs and ladders. Also, many companies now have a written drugs policy and require employees and sub-contractors to be tested for alcohol and other substances at regular intervals. Throughout the world, it is generally accepted that safe working practice requires all workers to be free from the influence of alcohol and other drugs while working.

L. HANDLING HAZARDOUS WASTE

Many of the coatings which have been applied in the past contain hazardous materials, e.g., lead, cadmium, chromates, coal tars, and bitumens. The removal of these materials, particularly by blast cleaning, creates toxic wastes. When hazardous waste materials are generated by surface preparation operations, it is particularly important that protective clothing and respirators are worn.

One form of environmental monitoring that has developed as a result of hazardous waste concerns is the analysis of residual abrasives to determine levels of toxicity. For example, used abrasive should contain less than 5 mg/L (0.0007 oz/gal) of "leachable" lead if it is to be disposed of without special consideration. Some states (California in particular) also regulate disposal based on total lead content, and waste generators must comply with the more stringent regulation.

Testing for levels of toxic materials is a job for a certified laboratory. The coatings inspector becomes involved when he is made responsible for monitoring the collection of samples for testing purposes, or for supervising the collection of hazardous waste materials. Sampling methods are critical if accuracy is to be maintained, and an agreed upon and "approved" method should be used.

X. SUMMARY

The primary responsibility for safety on the job rests with the main contractor and its safety department or safety officer; however, the coatings inspector, as a worker, also has a responsibility to protect himself and those around him. The inspector must be knowledgeable of the general, personal, and legal risks he faces, and should be prepared to address all situations. Although the inspector is not usually responsible for safety monitoring, at times he may be required to assist in the safety monitoring process.

The hazards that the coatings inspector may be exposed to can be classified as hazardous materials, hazardous environments, and hazardous activities. Hazardous materials include solvents, coating components, acids/caustics, cleaning fluids, mercury in thermometers, and nuisance dusts. Hazardous environments include working at heights, in confined spaces, around fire and explosion hazards, and around high voltage equipment. Hazardous activities include being in the vicinity of surface preparation operations, such as blast cleaning, high-pressure water cleaning, or power tool cleaning.

The inspector should be familiar with all standards and regulations that impact his work, such as the HAZCOM regulations. He should also be familiar with the various safety practices that are used to protect him and other workers, and maintain his level of knowledge as regulations change.

XI. REFERENCES

Code of Federal Regulations (CFR)

- 29 CFR 1910 Occupational Safety and Health Standards
- 29 CFR 1910.95 Occupational Noise Exposure
- 29 CFR 1910.134 Respiratory Protection
- 29 CFR 1910.146 Permit Required Confined Spaces
- 29 CFR 1926 Safety and Health Regulations for Construction
- 29 CFR 1926.52 Occupational Noise Exposure
- 29 CFR 1926.58 Asbestos
- 29 CFR 1926.59 Hazard Communication
- 29 CFR 1926.62 Lead
- 29 CFR 1926.64 Process Safety Management of Highly Hazardous Chemicals
- 29 CFR 1926.152 Flammable and Combustible Liquids
- 29 CFR 1926.417 Lockout and Tagging of Circuits
- 29 CFR 1926.451 Scaffolding
- 29 CFR 1926.500 Guardrails, Handrails, and Covers
- 29 CFR 1926.501 Duty to Have Fall Protection
- 29 CFR 1926.502 Fall Protection Systems Criteria and Practices
- 29 CFR 1926.503 Training Requirements
- 29 CFR 1926.1118 Inorganic Arsenic
- 29 CFR 1926.1127 Cadmium

Compressed Gas Association, Inc. (CGA)

- CGA G-7.1 Commodity Specification for Air

SSPC: The Society for Protective Coatings (SSPC)

SSPC Guide 6I Guide for Containing Debris Generated During Paint Removal Operations.

SSPC-SP 12 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating (NACE No. 5)

U.S. Public Law

Public Law No. 91-596 Occupational Safety and Health Act

XII. FURTHER READING

Accident Prevention Manual for Business and Industry, 10th Edition, National Safety Council, 1992.

NIOSH/OSHA, *Pocket Guide to Chemical Hazards*, National Institute for Occupational Safety and Health, Washington, DC, 1994.

NIOSH, Recommendations for Control of Occupational Safety and Health Hazards: Manufacture of Paints and Allied Coating Products, National Institute for Occupational Safety and Health, Washington, DC, 1984.

29 CFR 1926, Subpart D, Occupational Health and Environmental Control

29 CFR 1926, Subpart Z, Toxic and Hazardous Substances

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BIOGRAPHICAL SKETCH

Tony Cunningham is the President and co-founder of Transocean Anti-Corrosion Inc., a company that provides inspection services, consultancy, and training in the coatings field. Mr. Cunningham began his career as a high school teacher, moving into engineering as a coatings inspector in 1972. He has worked as a teacher, consultant, or inspector in 29 different countries on four continents.

Mr. Cunningham is a member of various professional societies. He participates in NACE, SSPC, and AWS Committees. For his significant work in the development and presentation of SSPC, NACE, and other training programs, he received SSPC's 1995 Education Award. He is also an Associate Editor of the Journal of Protective Coatings and Linings and past-president of the London Branch of the Institute of Corrosion.

Mr. Cunningham was educated at school in England, and at University in Scotland. He is an SSPC Protective Coatings Specialist and a NACE qualified Inspector. He has also taught inspection for NACE since the inception of the Coating Inspector Program.

APPENDIX: MONITORING EQUIPMENT

A. DETECTOR TUBES

Colorimetric detector tubes (e.g., Draeger tubes) are used for rapid detection and semi-quantitative determinations of airborne contaminants (Figure 7-23). In this method, often referred to as "grab sampling," a calibrated amount of air is drawn (using a detector tube pump) through a tube that contains a solid, granular material. The granular material is impregnated with a chemical reagent that changes color specifically in the presence of the hazardous chemical in question. The amount (length) of color change in the tube is proportional to the airborne concentration of the hazardous chemical.

The major requirement of this method is that the user know what hazardous chemicals to test for. For coating materials, solvents, and other chemical products, this can be determined by consulting the manufacturer's material safety data sheets (MSDSs). There are a number of color indicating tubes available, including tubes for carbon monoxide, acetone, methylene chloride, oxygen, and methyl-ethyl ketone. Pumps and color indicator tubes are available from the various safety and industrial hygiene supply houses.

FIGURE 7-23. Detector tubes. Courtesy of Mine Safety Appliances Company.



The procedure for the colorimetric detector tube method is as follows:

- Determine the contaminant in question and procure the appropriate detector tube.
- Break off both ends of the tube.
- Insert the proper tube end into the pump.
- Draw air through the pump per the manufacturer's instructions.
- Determine the amount of airborne contaminant by comparing the color change to the graduations along the tube. The farther the stain along the tube the greater the concentration of contaminant.

B. OXYGEN MONITOR

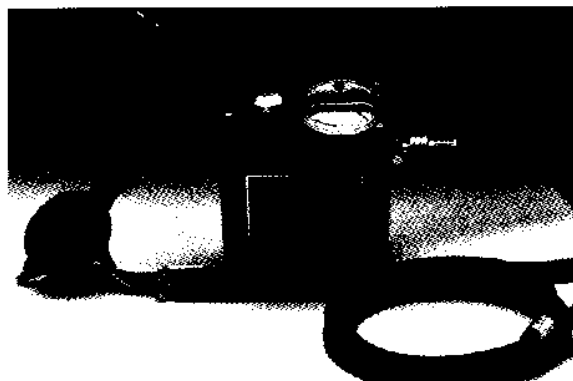
An oxygen monitor is a personal monitoring instrument worn by an individual when he is moving from one area to another within the workplace. The instrument is typically a small box worn on the belt, which sounds an alarm when the oxygen content of air drops below a pre-set level. The "normal" oxygen content of air is approximately 21%, and a monitor would sound the alarm when oxygen drops below 19.5%.

C. EXPLOSIMETER

The "explosimeter" is a sampling instrument used to test for concentrations of explosive gases (Figure 7-24). This instrument sucks air and gases in through a tube. On the inside of the instrument, the contained gas is tested to determine whether it will burn. It is important that this type of testing is performed from outside the environment concerned, and it is common to use an extended sampling tube to draw the gases to the instrument.

Since it is known what concentrations of specific gases are explosive, the explosimeter is set to give a warning when hazardous levels are present. The hazardous level is generally defined as a percentage of the lower explosive limit

FIGURE 7-24. Explosimeter. Courtesy of Mine Safety Appliances Company.



Many monitoring instruments have a built-in accuracy check, requiring the push of a button to gain a certain response—an instrument needle past a calibration mark, or a particular number on the digital display. The operator should know his instrument, and recognize when the behavior of the instrument seems to be erratic.

(LEL). The unsafe level for working is usually considered to be 10% of the LEL.

D. THREE-WAY MONITOR

A form of constant monitoring instrument is the "three-way monitor," which may be used to monitor three different aspects of the environment at the same time, on a continuous basis. It will monitor toxic gas, combustible gas, and oxygen level. In each case, the instrument is set for pre-determined levels of concentration, and for specific toxic gases, and will sound an alarm if the critical levels are exceeded.

The three-way monitor is complex and requires frequent calibration. The primary use of such a device is in a working environment where the situation may change unpredictably, for example, in a live gas producing wellhead station, or on an oil production platform. In these situations, any one of the three types of hazards is likely to occur.

E. CALIBRATION OF TESTING EQUIPMENT

Most of the instruments discussed here are used for decision making which can be, literally, a matter of life or death. It is essential that the accuracy of the instruments is known, and that the instruments are reliable. Calibration is therefore a frequent, sometimes daily, requirement.

Chapter 8

Field Test Methods and Instruments Used by Coatings Inspectors

by William D. Corbett

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B. Holiday Testing of Coatings on Metals - High-Voltage Method (ASTM D 5162 and NACE RP0188-90)

C. Holiday Testing of Coatings on Concrete (ASTM D 4787)

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- B. Pneumatic Adhesion Testing (ASTM D 4541)
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- B. Testing for Solvent-Resistance
- C. Determining Coating Hardness Using Durometer (ASTM D 2240)
- D. Determining Coating Hardness Using Barcol Impressor (ASTM D 2583)

XXI. Laboratory Test Methods

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I. SCOPE

This chapter describes field test methods and instruments that are commonly used during coatings inspection. The instruments are described generically as much as possible. Further information on the different commercial variations available should be obtained from the instrument suppliers (see Appendix G).

Test methods and operation of inspection instruments are summarized briefly for general information only. These are not intended to replace the full specifications or instrument instruction manuals. Calibration of the instruments is described, where appropriate. The latest issue, revision, or amendment of the reference standards should be used unless otherwise specified.

Procedures/tests such as SSPC-Vis 2, ASTM D 714, and ASTM D 1654 are not included since they are more applicable to aged rather than newly-applied coatings.

II. REFERENCES

American Society for Testing and Materials (ASTM)

- ASTM D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts
- ASTM D 522 Test Methods for Mandrel Bend Test of Attached Organic Coatings
- ASTM D 523 Test Method for Specular Gloss
- ASTM D 562 Test Method for Consistency of Paints Using the Stormer Viscometer
- ASTM D 658 Test Method for Abrasion Resistance of Organic Coatings by Air Blast Abrasive
- ASTM D 714 Test Method for Evaluating Degree of Blistering of Paints
- ASTM D 1005 Test Method for Dry Film Thickness of Organic Coatings Using Micrometers
- ASTM D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base
- ASTM D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems
- ASTM D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base
- ASTM D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products
- ASTM D 1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
- ASTM D 2240 Test Method for Rubber Property - Durometer Hardness
- ASTM D 2369 Test Methods for Volatile Content of Coatings
- ASTM D 2371 Test Method for Pigment Content of Solvent-Reducible Paints
- ASTM D 2372 Practice for Separation of Vehicle from Solvent-Reducible Paints
- ASTM D 2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
- ASTM D 2697 Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
- ASTM D 2794 Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
- ASTM D 3273 Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber
- ASTM D 3335 Test Method for Low Concentrations of Lead, Cadmium, and Cobalt in Paint by Atomic Absorption Spectroscopy
- ASTM D 3359 Test Methods for Measuring Adhesion by Tape Test
- ASTM D 3363 Test Method for Film Hardness by Pencil Test
- ASTM D 3450 Test Method for Washability Properties of Interior Architectural Coatings
- ASTM D 3723 Test Method for Pigment Content of Water Emulsion Paints by Low-Temperature Ashing
- ASTM D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
- ASTM D 4138 Test Method for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means
- ASTM D 4212 Test Method for Viscosity by Dip-Type Viscosity Cups

ASTM D 4263 Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method

ASTM D 4285 Method for Indicating Oil or Water in Compressed Air

ASTM D 4400 Test Methods for Sag Resistance of Paints Using a Multinotch Applicator

ASTM D 4414 Practice for Measurement of Wet Film Thickness of Organic Coatings by Notched Gages

ASTM D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

ASTM D 4541 Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D 4752 Test Method for Measuring MEK Resistance of Ethyl Silicate

ASTM D 4787 Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates

ASTM D 4796 Test Method for Bond Strength of Thermoplastic Traffic Marking Materials

ASTM D 4828 Test Method for Practical Washability of Organic Coatings

ASTM D 4940 Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives

ASTM D 5162 Practice for Discontinuity (Holiday) Testing of Non-Conductive Protective Coatings on Metallic Substrates

ASTM E 11 Specification for Wire Cloth and Sieves for Testing Purposes

ASTM E 337 Test Method for Measuring Humidity with a Psychrometer (The Measurement of Wet-Bulb and Dry-Bulb Temperatures)

Federal Test Methods

FTMS 141 Method 627.12 Mildew Resistance

International Concrete Repair Institute (ICRI)

Technical Guideline No. 03732 Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays

International Organization for Standardization (ISO)

ISO 1127-6 Determination of Water-Soluble Contaminants by Conductivity Measurement

ISO 1127-7 Determination of Water-Soluble Chlorides

ISO 8502-1 Field Tests for Soluble Iron Corrosion Products

ISO 8502-2 Laboratory Determination of Chloride on Cleaned Surfaces

ISO 8502-3 Assessment of Dust on Steel Surfaces Prepared for Painting (Pressure-Sensitive Tape Method)

ISO 8502-6 Extraction of Soluble Contaminants for Analysis - The Bresle Method

ISO 8502-9 Field Method for the Conductimetric Determination of Water-Soluble Salts

Paints and Varnishes, Volume 3, Preparation of Steel Substrates, International Organization for Standardization, Geneva, Switzerland

NACE International (NACE)

NACE RP0188-90 Discontinuity (Holiday) Testing of Protective Coatings

NACE RP0287-91 Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using Replica Tape.

SSPC: The Society for Protective Coatings (SSPC)

SSPC-AB 1 Mineral and Slag Abrasives

SSPC-AB 2 Specification for Cleanliness of Recycled Ferrous Metallic Abrasives

SSPC-PA 2 Measurement of Dry Coating Thickness with Magnetic Gages

SSPC-SP 1 Solvent Cleaning

SSPC-SP 2 Hand Tool Cleaning

SSPC-SP 3 Power Tool Cleaning

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

SSPC-SP 7 Brush-Off Blast Cleaning (NACE No. 4)

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

SSPC-SP 11 Power Tool Cleaning to Bare Metal

SSPC-SP 12 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating (NACE No. 5)

SSPC-Vis 1 Visual Standard for Abrasive Blast Cleaned Steel

SSPC-Vis 2 Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces (ASTM D 610)

SSPC-Vis 3 Visual Standard for Power- and Hand-Tool Cleaned Steel

SSPC Publication 91-07, Effects of Surface Contaminants on Coating Life, S.K. Boocock, R.L.F. Weaver, B.R. Appleman, and G.C. Soltz, SSPC: The Society for Protective Coatings, Pittsburgh, PA, 1992.

Other

F.E. Clarke, "Determination of Chloride Ion in Water," Analytical Chemistry, Vol. 22, April 1950, pp. 553-555.

III. MEASURING AMBIENT CONDITIONS

A. DETERMINING RELATIVE HUMIDITY AND DEW POINT (ASTM E 337)

1. Description

Sling and battery-operated psychrometers use wet and dry bulb thermometers in conjunction with psychrometric tables to obtain the relative humidity and dew point (Figure 8-1).

2. Procedure

a. Locate a test point in the area where the work is to be done, avoiding direct sunlight and proximity to structures. Face the air current.

b. Make sure that the sock for the wet bulb is clean or replace it. To avoid deposition of oil or dirt, never touch the sock with your fingers.

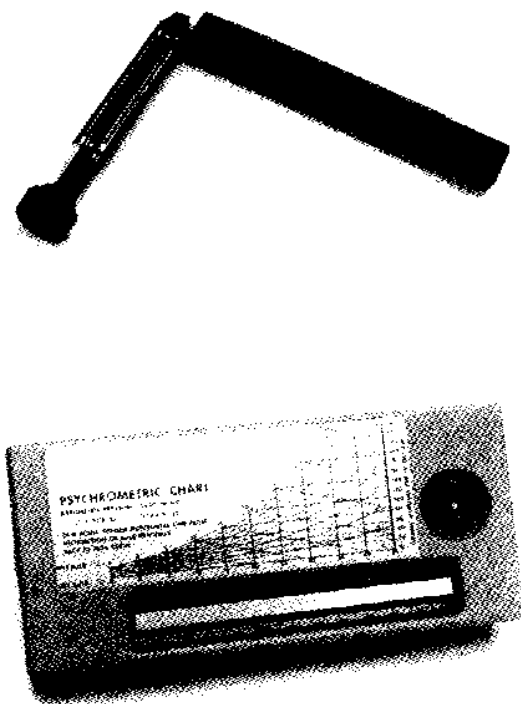
c. Thoroughly saturate the sock on the wet bulb with clean water (distilled or deionized water is preferred), using a small, clean wash bottle. Allow several minutes for wicks that are new or dry from lack of use to become thoroughly saturated. Remoisten the sock before each measurement. Do not allow the dry bulb to get wet.

d. When using the sling psychrometer, whirl the appendage with the attached thermometers through the air away from the body for 20 to 30 seconds. Then, read the thermometers (the wet bulb one first) quickly but accurately.

Without re-wetting the wick, whirl for an additional 20 to 30 seconds and read the thermometers again. Continue this procedure until the wet-bulb thermometer has a constant temperature for three consecutive readings (usually a few minutes). For battery-powered psychrometers, turn the fan switch to "ON" and wait for the thermometers to stabilize (usually about 2 minutes) before reading.

e. Subtract the wet bulb temperature from the dry bulb temperature to obtain the "wet bulb depression." Use the psychrometric tables provided with the psychrometer to relate wet bulb depression to relative humidity and dew point. Use the particular tables for the prevailing barometric pressure or the tables for 30 inches (760 mm) of mercury, if the barometric pressure is not known.

FIGURE 8-1. Top - Sling psychrometer. Bottom - Battery operated psychrometer. Both photos courtesy of Elcometer Inc.



3. Calibration

Sling and battery-powered psychrometers are factory-calibrated, but their thermometers should be compared periodically, preferably indoors, with NIST certified thermometers to verify their calibration.

B. SIMULTANEOUSLY MEASURING RELATIVE HUMIDITY AND TEMPERATURE

1. Description

Recorders are available for simultaneously measuring relative humidity and temperature. They consist of a metal case with a glass door, a dual pen recorder, and a battery-

powered or a spring-wound drive. Temperature measurements are made using bi-metallic expansion and relative humidity measurements using horse hairs that expand or contract with variations in humidity. Instruments are available to make simultaneous, continuous measurements for 24 hours or for 7 days.

2. Procedure

- Open the case by releasing the locking mechanism. For spring-wound models, remove the winding key and insert it into the winding sprocket; wind clockwise until the key stops turning freely.
- Release the pens from the chart surface by operating the pen lift bar.
- Place a clean chart on the chart hub and gently push it in place; be sure to slip the chart under the guide keys.
- Set the time by inserting a coin or flat-blade screwdriver into the chart hub and turning it clockwise until the correct time is beneath the blue recorder pen. Lower the pen.
- Close the recorder door and engage the locking mechanism.

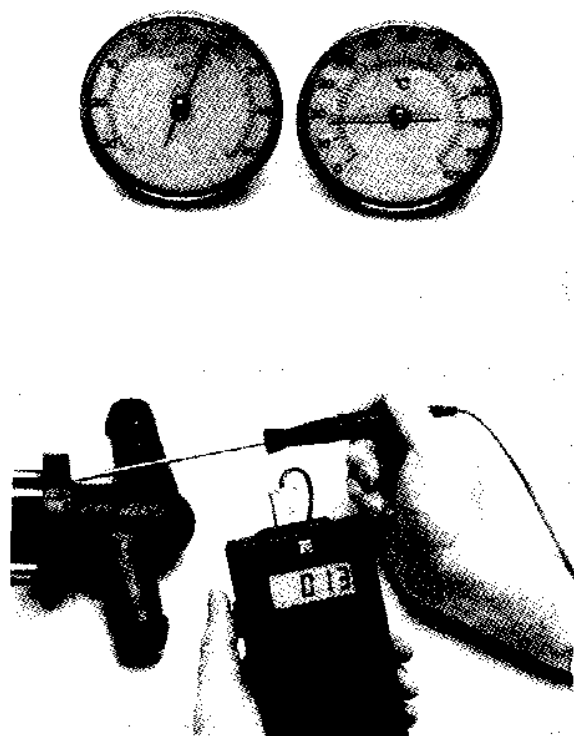
3. Calibration - Temperature

- Place a calibrated thermometer beside the recorder in a controlled environment and allow each to stabilize.
- Use a small screwdriver to turn the calibration adjustment until the pen position on the chart corresponds to the true temperature. Repeat the adjustment when each new chart is installed.

4. Calibration - Humidity

- Place the instrument in a controlled environment and allow it to stabilize.
- Use a calibrated sling or battery-powered psychrometer to establish the true relative humidity.
- Use a screwdriver to turn the calibration adjustment until the pen position on the chart corresponds to the correct relative humidity. Repeat the adjustment when each new chart is installed.

FIGURE 8-2. Top - Magnetic surface temperature thermometer. Bottom - Digital thermometer. Both photos courtesy of Elcometer Inc.



C. MEASURING AMBIENT AND SURFACE TEMPERATURES

1. Description

There are several types of thermometers available for determining temperatures (Figure 8-2). These include common glass thermometers, those containing bimetallic sensors (some with magnets to hold them onto steel surfaces), and those with thermocouples.

2. Procedure

- a. Allow at least three minutes for temperature stabilization before reading.

- b. For instruments containing meters with glass faces, tap the glass gently to ensure that needle is free and view directly face-on to avoid inaccurate readings due to parallax.

3. Calibration

Calibrate according to manufacturer's instructions at the start of each job and once weekly thereafter.

D. MEASURING WIND VELOCITY

Wind meters can be used to help determine when wind speeds exceed specification requirements during application of coatings. Excessive winds during coating application may result in dryspray, overspray, or damage to nearby property.

1. Description

A wind meter is positioned vertically in the wind stream and the wind speed (in miles per hour [MPH] or kilometers per hour) is read from the meter scale.

2. Procedures

- a. Always monitor wind speed where the coating operations are taking place. For example, wind speeds at ground level can be vastly different than wind speeds several feet in the air.
- b. For determining wind speeds in the 2-10 miles per hour (3-16 kilometers per hour) range, hold the wind meter vertically in the wind stream, allowing the wind to enter the back of the instrument. Do not block the holes located on the bottom back side of the meter. Hold the instrument steady until the white ball in the center column stabilizes. Read and record the corresponding wind speed from the left side vertical scale (low range) on the front of the meter.
- c. For determining wind speeds in the 4-66 miles per hour (6-100 kilometers per hour) range, hold the wind meter vertically in the wind stream, allowing the wind to enter the back of the instrument. Do not block the holes located on the bottom back side of the meter. Cover the hole on the extreme top of the meter with an index finger. Hold the instrument steady until the white ball in the center column stabilizes. Read and record the corresponding wind speed from the right

side vertical scale (high range) on the front of the meter.

3. Calibration

Wind meters are factory calibrated; no field calibration is necessary. Ensure that the white ball remains free-floating inside the center column. Clean the center column as necessary using pipe cleaners provided with the meter.

IV. TESTING OF ABRASIVES AND ABRASIVE BLAST CLEANING EQUIPMENT

A. SELECTING AND EVALUATING MINERAL AND SLAG ABRASIVES (SSPC-AB 1)

1. Description

SSPC-AB 1, Paragraph 4 defines the requirements for selecting and evaluating mineral and slag abrasives used in blast cleaning. Additionally, it describes sampling methods and qualification and conformance tests to conduct on non-recyclable abrasives.

B. DETECTING CONTAMINATION ON ABRASIVE (ASTM D 4940)

1. Description

A slurry of the abrasive is made with pure (distilled or deionized) water, allowed to settle, and then tested for various contaminants. A more precise laboratory procedure for determining the conductivity and chloride ion concentration can be found in ISO 1127-6 and ISO 1127-7, respectively.

2. Procedure

- a. Combine a sample of abrasive in pure water and stir into a slurry. Allow the slurry to settle and examine/test the surface and body of the liquid as follows:
- b. Observe the surface of the liquid for a sheen indicating oil contamination.
- c. Observe the opacity of the liquid to detect suspended mud or fines present in the abrasive.

d. Use pH paper to determine if the liquid is in the normally acceptable range of 5 to 8.

e. Filter off the solid materials and determine the conductivity of the filtrate following the procedure of ASTM D 4940.

C. TESTING FOR CLEANLINESS OF RECYCLED FERROUS METALLIC ABRASIVES (SSPC-AB 2)

Testing for lead content and water soluble content is done as described in ASTM D 3335 and 4940, respectively. Testing for oil content is accomplished by visual inspection of the solution used in ASTM D 4940 before filtering. Testing for non-abrasive residue is described below.

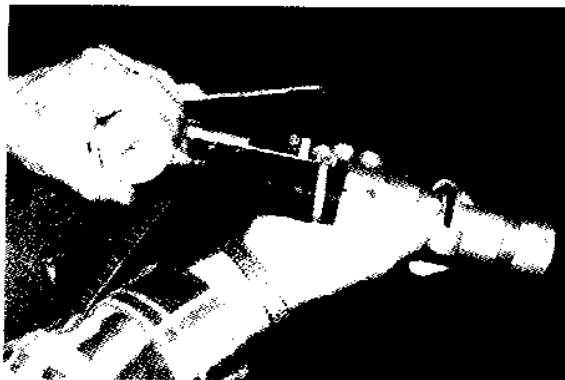
1. Description

Ferrous abrasive particles are removed from a sample of recycled abrasive using a sheathed magnet. The sheath is then removed to allow the adhering ferrous abrasive to fall into a pre-weighed collection vessel. The remaining non-magnetic residue is also weighed.

2. Procedure (for a minimum of three replicates)

- a. Screen about 115 g (1/4 lb.) of recycled abrasive through a 203 mm (8-inch) diameter #100 sieve, per ASTM E 11, for one minute.
- b. Spread the screened portion (<#100 sieve) over a clean surface approximately 0.1 m² (1 ft²).
- c. Place a magnet in a plastic sheath or cylinder in contact with the screened material so that ferrous particles cling to it.
- d. Locate the sheathed magnet directly over a pre-weighed collection vessel and remove the magnet from the sheath so that the attached particles fall into the vessel.
- e. Repeat steps c. and d. until no more ferrous particles are removed and weigh the total amount of ferrous material collected.
- f. Collect the remaining non-ferrous residue into another pre-weighed vessel and weigh it. If it weighs more than 1% of the total abrasive tested, further cleaning is necessary.

FIGURE 8-3. Needle pressure gage. SSPC file photo.



D. DETECTING OIL OR WATER IN COMPRESSED AIR (ASTM D 4285)

1. Description

A white, absorbent material, such as filter paper or a blotter, is used to collect oil and water from an air stream. These contaminants are detected visually.

2. Procedure

- a. Secure in place a white blotter or other absorbent material on a rigid backing within 24 inches (610 mm) of the air-discharge point centered in the air stream of the blast equipment.
- b. Allow the air-stream to impact onto the collector for a minimum of 1 minute.
- c. Visually examine the collector for the presence of oil or moisture. Any indication of either is sufficient cause for rejection of the compressed air stream. To avoid false indications:
 - Allow compressed air to reach operating conditions before testing.
 - Fasten the collector material to a rigid backing and avoid personal contact with the air stream.
 - Locate the collector as close to the use point of the air stream as possible and downstream of the in-line oil and water separators.

E. DETERMINING BLAST CLEANING AIR PRESSURE

1. Description

The hypodermic needle on a pressure gage is inserted through the blast hose just below the nozzle and the pressure read from the dial (Figure 8-3). The gage can also be used to determine pressure drop in air hoses.

2. Procedure

- a. Start up the blast cleaning equipment, so that all blast nozzles are operational.
- b. Insert the gage needle through the blast hose as close to the nozzle as possible and slanted toward it at a 45 degree angle to minimize needle damage or clogging.
- c. Read the blast cleaning air pressure directly from the gage dial.
- d. Repeat the test periodically, as required by the specification or when events occur that could vary the pressure.

V. TESTING FOR SURFACE CLEANLINESS- STEEL

A. DETERMINING LEVEL OF CLEANLINESS OF BLAST CLEANED STEEL BY VISUAL STANDARD (SSPC-Vis 1)

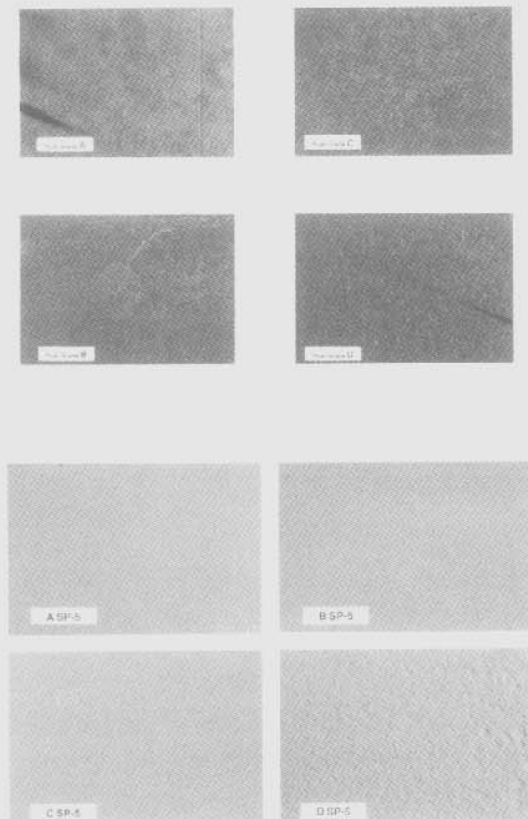
1. Description

SSPC Vis 1 (sets of standard photographs illustrating the four levels of blast cleaned steel) is used to assist in determining if blast cleaned steel surfaces meet the written cleanliness standards (SSPC-SP 5, 10, 6, 7) (Figure 8-4).

2. Procedure

- a. Determine the initial condition or grade of the steel to be cleaned (it may contain more than one grade) by comparing it to the four photographs representing different conditions:
 - Rust Grade A: Steel surface completely covered with adherent mill scale; little or no visible rust

FIGURE 8-4. Reference photos from SSPC Vis-1. Top - Initial conditions. Bottom - Cleaned appearances (SSPC-SP 5, White Metal Blast Cleaning). All SSPC file photos.



- Rust Grade B: Steel surface covered with both mill scale and rust
 - Rust Grade C: Steel surface completely covered with rust; little or no pitting visible
 - Rust Grade D: Steel surface completely covered with rust; pitting visible
- b. Immediately prior to painting, turn to the section of SSPC-Vis 1 representing the rust grade level determined in Step 1 and select the photograph that represents the specified level of cleaning:
- SSPC-SP 7 Brush-Off Blast Cleaning
 - SSPC-SP 6 Commercial Blast Cleaning
 - SSPC-SP 10 Near-White Blast Cleaning
 - SSPC-SP 5 White Metal Blast Cleaning

Thus, if a Rust Grade B steel is to be cleaned to SSPC-SP 10, use the photograph designated "B-SP 10", and visually compare it to the cleaned steel to help determine whether it meets the written standard. Note that variations from the photograph may occur in texture, shade, color, tone, the amount of mill scale or pitting, or the abrasive used.

B. DETERMINING LEVEL OF CLEANLINESS OF POWER- AND HAND-TOOL CLEANED STEEL BY VISUAL STANDARD (SSPC-Vis 3)

1. Description

SSPC-Vis 3 (sets of standard photographs illustrating the various levels of power- and hand-tool cleaned steel) is used to assist in determining if power- and hand-tool cleaned steel surfaces meet written standards (Figure 8-5).

2. Procedure

- a. Determine the initial condition of the steel to be cleaned (it may contain more than one condition) by comparing it to the seven photographs representing the different conditions:

- Condition A: Steel surface completely covered with adherent mill scale; little or no visible rust
- Condition B: Steel surface covered with both mill scale and rust
- Condition C: Steel surface completely covered with rust; little or no pitting visible
- Condition D: Steel surface completely covered with rust; pitting visible
- Condition E: Previously painted steel surface; light-colored paint applied over blast-cleaned surface, paint mostly intact
- Condition F: Previously painted steel surface; zinc-rich paint applied over blast-cleaned steel, paint mostly intact
- Condition G: Paint system applied over mill scale bearing steel; system thoroughly weathered, thoroughly blistered, or thoroughly stained

- b. Immediately prior to painting, turn to the section of SSPC-Vis 3 for the condition determined in Step 1 and select the photograph that represents the specified level of cleaning. For SSPC-SP 3 and SSPC-SP 11, it is also

FIGURE 8-5A. Reference photos from SSPC-Vis 3. Top - Initial conditions. Bottom - Cleaned appearances (SSPC-SP 11, Power Tool Cleaning to Bare Metal). All SSPC file photos.

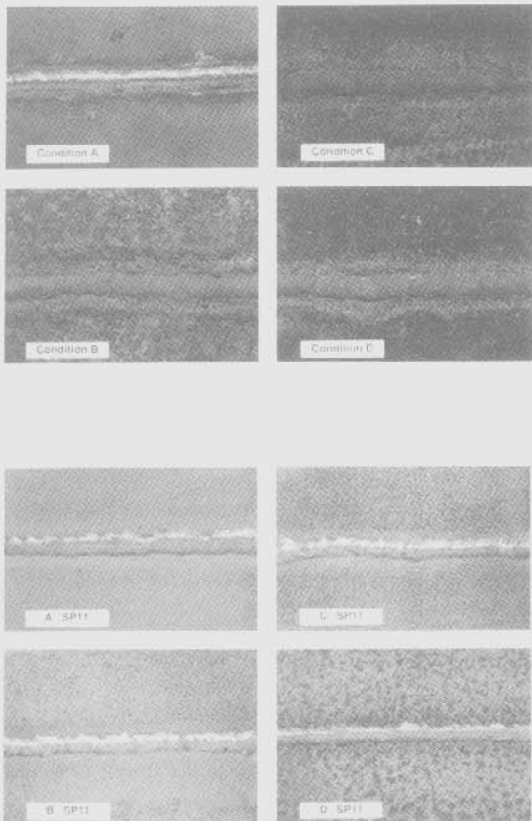


FIGURE 8-5B. Reference photos from SSPC-Vis 3. Top - Initial conditions. Bottom - Cleaned appearances (SSPC-SP 11, Power Tool Cleaning to Bare Metal). All SSPC file photos.



necessary to identify the specific power tool used to clean the steel.

- SSPC-SP 3 Power Tool Cleaning (Power Wire Brush)
- SSPC-SP 3 Power Tool Cleaning (Sanding Disc)
- SSPC-SP 3 Power Tool Cleaning (Needle Gun)
- SSPC-SP 11 Power Tool Cleaning to Bare Metal (Needle Gun or Rotary Flap Peen)
- SSPC-SP 11 Power Tool Cleaning to Bare Metal (Non-Woven Disk)

Thus, if a Rust Grade B steel is to be cleaned to SSPC-SP 3 by a sanding disc, use the photograph designated "B

SP3/SD" and compare it to the cleaned steel to help determine whether it meets the written standard. Note that variations from the photograph may occur in texture, shade, color, tone, or amount of mill scale or pitting.

C. DETERMINING LEVEL OF CLEANLINESS OF WATER JET-CLEANED STEEL FROM VISUAL REFERENCE PHOTOGRAPHS

1. Description

Visual standards for steel surfaces cleaned by water jetting have not been issued as of this writing. Thus, written specifications currently serve this purpose. In addition, reference photographs depicting the appearance of steel surfaces after cleaning by water jetting may be agreed upon between the purchaser and supplier. Note: The SSPC/NACE Joint Task Group 1 is developing a set of standard reference photographs suitable for use on steel surfaces cleaned by water jetting (see Appendix G).

2. Procedure

- Visually determine the condition of the steel (Condition C or Condition D) by selecting the rust grade reference photograph that most closely matches.
- Immediately after water-jetting, visually determine the condition of the cleaned steel by selecting the degree-of-cleaning of a reference photograph (agreed upon between purchaser and supplier) corresponding to the initial condition that most closely matches. Note: The forthcoming SSPC/NACE Visual Reference Photographs for Steel Surfaces Cleaned by Water Jetting are suitable for this purpose (see Appendix G).
- Immediately prior to painting, visually determine the degree of flash rusting by selecting the photograph that most closely resembles the flash-rusted surface.

VI. MEASURING SURFACE PROFILE - STEEL

A. DETERMINING SURFACE PROFILE OF BLAST CLEANED STEEL USING REPLICA TAPE (ASTM D 4417, METHOD C; NACE RP0287-91)

1. Description

Specially prepared replica tape, after being rubbed onto the blast cleaned surface, provides a mirror image of the

FIGURE 8-6. Use of replica tape. Copyright Brendan Fitzsimons, 1996. This illustration is taken from the Painting Inspectors Manual (now called the Protective Coatings Inspection Manual) published by Elcometer Instruments Ltd.



profile. The replica tape is inserted between the anvils of a spring micrometer, and a measurement of the surface profile or roughness is obtained (Figure 8-6). The tape consists of a 2.0 mil (51 micrometer) thick film of non-compressible Mylar, which serves as a backing for an emulsion containing microscopic bubbles.

2. Procedure

- Select a piece of tape representing the desired profile range: coarse, 0.8 to 2 mils (20-50 micrometers); or x-coarse, 1.5 to 4.5 mils (38 to 110 micrometers). Note: It may be possible to measure up to 6.0 mils (150 micrometers) using the x-coarse tape. Remove its paper backing, and place it on the blast cleaned steel surface, adhesive side down.
- Holding the tape firmly in place, rub the circular portion with a burnishing tool until the non-deformable Mylar backing on the tape turns uniformly gray.
- Remove the tape and measure its thickness within the circle using a spring micrometer. Then, subtract the thickness (2 mils; 50 micrometers) of the Mylar backing to obtain the profile.
- Measure the profile at sufficient locations, as indicated in the specification, or as agreed upon by the interested parties, to characterize the surface profile.

B. DETERMINING SURFACE PROFILE OF BLAST CLEANED STEEL USING COMPARATORS (ASTM D 4417, METHOD A)

1. Description

The surface profile of a blast cleaned steel surface is visually compared to a set of standard profiles on a rigid, corrosion-resistant metal disc (Figure 8-7).

2. Procedure

- Select the comparator disc prepared for the type of abrasive used (grit/slag, shot, or sand) and place it directly on the blast cleaned steel.
- Compare the test area visually using a 5X magnifier to best match one of the standard profiles. The magnifier should be in focus with both the blasted steel and the disc. Matching may also be done visually without magnification. (Note: It is not advisable to do the matching by touch. Touching blast cleaned steel with bare hands could contaminate the surface.) If the profile falls between two standard profiles, indicate a profile range between these two profiles (e.g., 2.0 to 3.0 mils; 50 to 76 micrometers).
- Determine the profile at sufficient locations, as indicated in the specification or as agreed upon by interested parties, to characterize the surface, making three evaluations at each location.

FIGURE 8-7. Surface profile comparator. Courtesy of Elcometer Inc.

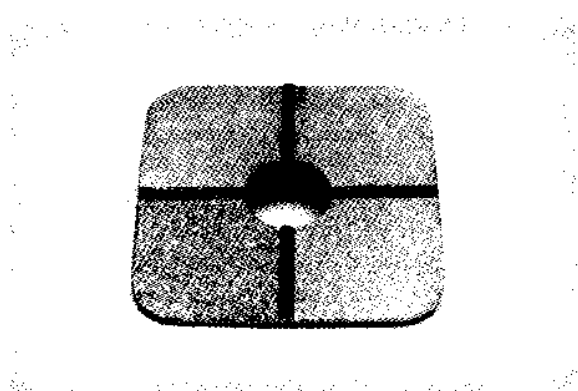
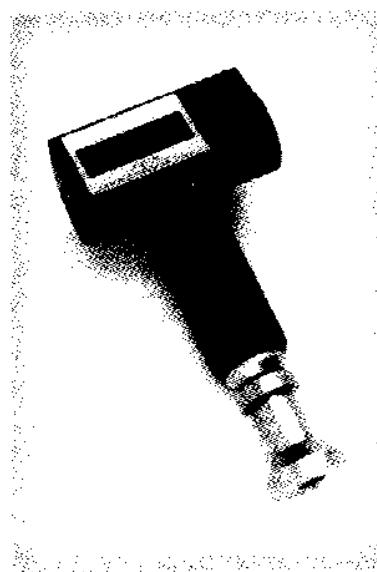


FIGURE 8-8. Profile depth gage. Courtesy of Elcometer Inc.



C. DETERMINING SURFACE PROFILE OF BLAST CLEANED STEEL USING PROFILE DEPTH GAGE (ASTM D 4417, METHOD B)

1. Description

The profile depth gage consists of a dial gage and a stylus (pointer) which protrudes from the base of the gage. The base of the gage rests on profile peaks, while the stylus protrudes into valleys of a blast cleaned steel surface (Figure 8-8). Several readings must be taken to ensure that the stylus is not resting on the tops or sides of peaks rather than fully penetrating the valleys.

2. Procedure

- Hold the gage by the base and press down onto the blasted steel surface until a reading appears on the dial.
- Make several measurements at several locations and average those taken at each location. Do not slide the gage along the surface, as this will damage the tip of the stylus.

3. Calibration

Place the gage on a smooth glass plate and adjust the outer ring of the dial, if necessary, to read zero.

VII. TESTING OF SURFACE TENSILE STRENGTH - CONCRETE

A. TESTING OF SURFACE TENSILE STRENGTH (SOUNDNESS) OF SURFACE (ASTM D 4541)

Before concrete surfaces are painted, they should be tested for soundness. Unsound surface concrete may erode after painting, causing loss of protection.

1. Description

The test method used to determine the pull-off strength of coatings (ASTM D 4541) can also be used to determine tensile strength of a concrete surface. It is performed by securing a loading fixture (pull stub) to the clean surface with adhesive and pulling off the stub with a calibrated instrument after the adhesive has cured (Figure 8-10). Several different adhesion testers are commercially available, so only general instructions are presented. The manufacturer's instructions should be carefully followed. It is important that the pull stub has a large enough test area to be reasonably representative of the total surface area of concern, and that the adhesive is thick enough to compensate for surface irregularities (roughness).

2. Procedure

- a. Select a test area of concern that is clean, relatively flat, and large enough to accommodate as many replicate tests as desired. Ensure that surfaces are free of form release agents or other interfering materials. Then score or core drill the coating in the test area prior to attachment of a loading fixture.
- b. Mix and apply the adhesive (generally a two component epoxy adhesive) to the clean loading fixture according to the adhesive manufacturer's instructions and secure the fixture to the concrete surface. Gently remove any excess adhesive and maintain a constant pressure on the fixture during curing of the adhesive.
- c. After curing of the adhesive, place a bearing ring or comparable device (if it is to be used) concentrically around the loading device and increase the load to the

FIGURE 8-9. Top - Surface tensile strength testing of concrete, as described in ASTM D 4541. Bottom - Surface tensile strength testing of concrete, as described in ACI 503R, Appendix A. Both photos courtesy of Stonhard, Inc.



fixture as smoothly and continuously as possible at a rate less than 150 psi/second (1 MPa/second) until failure occurs.

- d. Record the force applied at failure and the type of failure (adhesive or concrete). Convert this force into the tensile strength using the instrument calibration factors.

B. TESTING OF SURFACE TENSILE STRENGTH (SOUNDNESS) OF SURFACE (ACI 503R, Appendix A)

1. Description

The ACI 503R, Appendix A test method for determining the surface soundness of concrete is quite similar to that described above for the ASTM D 4541 method, except on a larger scale.

2. Procedure

- a. Machine and cut the base of a standard steel 1.5 in. (38 mm) pipe cap to provide a flat surface 2 in. (51 mm) in diameter.
- b. Bond the pipe cap to the clean concrete surface using a commercially-available, quick-setting epoxy adhesive, carefully following the manufacturer's instructions.
- c. After curing of the epoxy, the tensile strength of the concrete should be determined using a loading device with hooks secured to a Dillon dynamometer (see ASTM D 4796). Its loading arm should be screwed into the pipe cap.

VIII. DETERMINING CONCRETE SURFACE PROFILE (ICRI Guideline No. 03732)

1. Description

International Concrete Repair Institute (ICRI) molded replicates are used to determine if the concrete surface profile (CSP) meets the specification requirements.

2. Procedure

Visually compare the CSP with the set of nine molded replicates and select the nearest match.

IX. TESTING FOR SURFACE pH - STEEL AND CONCRETE

Chemical cleaning with acidic or alkaline products may be used on steel or concrete surfaces. Concrete may also be etched with acid. If residual acidic or alkaline chemicals are not completely removed from the surfaces, they may

adversely affect the adhesion and other performance characteristics of coatings applied to them.

A. DETERMINING pH USING TEST STRIP (ASTM D 4262)

1. Description

The test method for determining pH of a chemically cleaned or etched concrete surface is described fully in ASTM D 4262. It is also appropriate for steel surfaces, because it tests rinse water, not the surfaces themselves. The pH test paper that tests the rinse water should have a range from 1 to 11 pH units with a capability to measure increments of 0.5 pH units.

2. Procedure

- a. After wetting the surface with potable water, place a strip of the test pH paper in the residual rinse water.
- b. After color develops on the test strip, select the closest match with the standards on the color chart provided by the manufacturer of the pH paper.

X. LEVELS OF SOLUBLE SALT CONTAMINANTS ON STEEL SURFACES (SSPC-SP 12/NACE No. 5)

Contamination of otherwise visually clean steel surfaces can have very serious effects on coatings applied over them. These adverse effects include:

- Osmotic blistering of coatings
- Acceleration of corrosion
- Interference with the action of chemical corrosion inhibitors such as chromates (particularly with chloride contamination)

There are numerous sources of soluble salt contamination, including the following:

- Atmospheric contamination from ocean spray, combustion of fuel (sulfates), and chemical processes
- Direct contact with sea water
- De-icing salts on highways and bridges
- Contaminated abrasive

Chlorides and sulfates, being the most frequently occurring soluble salt contaminants, comprise the most prob-

adversely affects coating performance varies with the following:

- Service environment
- Nature and amount of contamination
- Generic type and design of coating system
- Thickness of coating

ISO/TC at the time of this writing is preparing a series of tables listing high and low risk amounts of chloride and sulfate contamination for different generic coating systems in different types of service. SSPC-SP 12/NACE No. 5 defines three levels of soluble salt contamination as shown in Table 1.

XI. EXTRACTING SOLUBLE SALT CONTAMINANTS FROM STEEL SURFACES

SSPC 91-07 describes several extraction procedures. The swabbing method is described below. Alternative extraction methods include:

- The limpet (Soltz) cell. This consists of a machined Plexiglas cell plate with four adjustable magnets to hold the cell onto a steel surface, and a rubber seal to retain the aqueous extracts. A syringe is used to pump extraction water in and out of the cell and into a sample container. The cell contains a built-in conductivity meter.
- The Bresle cell. This is a small adhesive patch which forms a pocket when attached to a steel surface. A syringe is used to apply water to the surface to be tested, and to transfer the extract into a sample container. (See B, below.)

A. EXTRACTING SOLUBLE SALTS USING SWABBING TECHNIQUES

1. Description

The extraction is conducted using a measured amount of distilled water (from a graduated cylinder), cotton swabs, gloves (to prevent contamination by hand perspiration), and a collection container. Note: The extraction process is not very efficient (e.g., only half of a contaminant may be recovered).

TABLE 1. Levels of soluble salt contamination, from SSPC-SP 12/NACE No. 5.

Condition	Description of Surface
SC-1	An SC-1 surface shall be free of all detectable levels of contaminants as determined using available field test equipment with sensitivity approximating laboratory test equipment. For purposes of this standard, contaminants are water-soluble chlorides, iron-soluble salts, and sulfates.
SC-2	An SC-2 surface shall have less than 7mg/cm ² chloride contaminants, less than 10 mg/cm ² of soluble ferrous ion levels, and less than 17 mg/cm ² of sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test equipment.
SC-3	An SC-3 surface shall have less than 50 mg/cm ² chloride and sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test equipment.

2. Procedure

- Use a ruler and pencil to outline an area of specific size (e.g., 6 in. by 6 in. (36 in²); or 15 cm by 15 cm (225 cm²).
- Using distilled or deionized water, or a portable demineralizer, pour a measured volume (e.g., 15 ml; 0.51 oz) of pure water into a small (e.g., 50 ml; 1.7 oz) clean plastic beaker.
- Using forceps or latex gloves, dampen a cotton ball with water in the beaker and thoroughly swab the area measured in Step 1. Then, swirl the cotton ball within the beaker of water. Next, squeeze the cotton ball against the interior wall of the beaker to release most of the water.
- Repeat the swabbing operation described in Step 3 above three more times, then leave the cotton ball in the beaker.
- Use a fresh cotton ball to dry the outlined area just swabbed and place it in the beaker also.
- Swirl the water and cotton balls for two minutes to achieve thorough mixing. The water is now ready for testing.

g. Use the water from Step f to determine its soluble salt concentration by one of the methods described below (Section XII). Note: While several field tests are described below for analysis of specific ions of interest, it should be noted that laboratory tests are much more accurate and should be used where accuracy is critical.

B. EXTRACTING SOLUBLE SALTS USING THE BRESLE SAMPLER (ISO 8502-6)

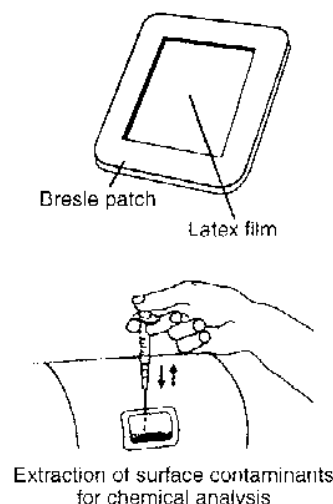
1. Description

This method uses a latex rubber cell (Bresle Sampler) to aid in the extraction of surface contaminants (Figure 8-10).

2. Procedure

- Remove the backing (with Bresle logo) and the foam circle from the test cell and apply the cell firmly and tightly to a dry test surface, either vertical or horizontal.
- Insert the 5 ml (0.2 oz) syringe needle into the cell through its spongy perimeter, taking care not to inject beneath the cell or into the semi-transparent test area. Then, evacuate the air from the test area by pulling back on the syringe plunger.
- Inject 3 ml (0.1 oz) of distilled or deionized water into the above cell taking care to keep air bubbles out of the syringe. Hold the cell perimeter firmly during this operation to help prevent water leakage.
- Withdraw the syringe slightly from the center of the cell and gently rub the top of the cell for 10 to 15 seconds to encourage dissolution of soluble salts.
- Withdraw and reinject the water a minimum of three times, each time gently rubbing the top of the cell for 10 to 15 seconds. Then, remove as much of the water as possible and place it in a clean vial or other container.
- Use the water from Step e to determine its chloride ion concentration, ferrous ion concentration, or pH, soluble salt concentration by one of the methods described below (Section XII). Note: While several field tests are described below for analysis of specific ions of interest, it should be noted that laboratory tests are much more accurate and should be used where accuracy is critical.

FIGURE 8-10.
Schematic of
Bresle sampler.



XII. ANALYZING SOLUBLE SALT CONTAMINANTS EXTRACTED FROM STEEL SURFACES

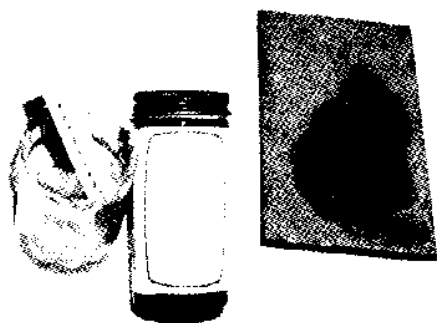
A. ANALYZING CHLORIDE ION USING TITRATION TEST STRIPS

1. Description

A commercial titration test strip (Quantab) for measuring amounts of chloride ion contamination of cleaned surfaces is available. The laminated test strip is impregnated with silver dichromate. When immersed in the test extract, water rises in the column by capillary action. Reaction with chloride ion produces a white precipitate (silver chloride) on the normally tan column. When all the chloride ion is consumed, the water continues to rise until it changes the color of the yellow band near the top of the test strip to blue, indicating completion of the test. The length of the white column is proportional to the chloride ion concentration (Figure 8-11).

This test method is sometimes referred to as titration. It is, however, distinctly different from the usual titration by continuously adding small amounts of reagent to a test solution until a chemical reaction is completed, as indicated by a color change.

FIGURE 8-11. Test strips for chloride determination.
Illustration by Russell Davison, SSPC.



2. Procedure

- Immerse the lower end of the test strip for chloride ion in the water extract described in XI.A. or XI.B. above.
- Allow the water to rise and saturate the test strip, until the yellow band across the top of the strip turns blue (about 5 minutes).
- Record the scale number at the top edge of the white column and compare it with the calibration chart provided by the manufacturer of the test strip.
- Since the test strip measures chloride in parts per million (ppm), and since 1 ppm is equivalent to $1 \mu\text{g/mL}$, the amount of chloride extracted is equal to the volume of water used (15 mL in the example in XI.A.) times the ppm. Calculate the concentration of chloride ion by multiplying the ppm from the conversion chart by the quantity of water used, then dividing this weight by the size of the test area. For example, if the test strip reads 50 ppm, the amount of chloride is $15 \times 50 = 750 \mu\text{g}$. To express this in $\mu\text{g/cm}^2$, divide the micrograms (750 μg) by the area (225 cm^2 in the example in XI.A.), which equals $3 \mu\text{g/cm}^2$. The detection limit of the test strip (the lowest level of chloride that can be detected) is approximately 30 ppm.

B. ANALYZING FERROUS ION USING TEST STRIPS

1. Description

Test strips can be used for a rapid, semi-quantitative determination of ferrous ion. These strips are impregnated with a chemical reagent (2, 2'-bipyridine) that forms a dark red complex with ferrous ion. The intensity of this red color is proportional to the concentration of ferrous ion.

To determine the total soluble iron concentration (ferrous plus ferric ions), ascorbic acid is added to the solution before testing. The ferric ion concentration can then be determined by subtracting the ferrous ion concentration from the total iron ion concentration.

2. Procedure

- Briefly immerse a ferrous ion test strip in the extract water described in XI.A. or XI.B. above.
- Shake off the excess water and, after 10 seconds, select the best match of the red color developed on the test zone of the strip with the standards on the color chart provided by the test strip manufacturer. The detection limit of the test strip is approximately 3 ppm.
- To determine total iron ion concentration, add a spatula tip of ascorbic acid to the test extract for every 10 mL (0.34 oz) of water and conduct Steps a and b above.

C. ANALYZING CHLORIDE ION USING FIELD TITRATION

There are a number of test methods for determining the concentration of chloride ion in aqueous extracts of cleaned surfaces. Since toxic products are used, they must be handled with care, and mailing and shipping restrictions may prevail.

In each case, the chemical reagents and support equipment are obtained from a particular supplier. All the methods are based upon:

- The chemical reaction of mercuric ion with an indicator dye (diphenylcarbazone-bromophenol blue) to form a purple complex; and

- The reaction of chloride ion to preferentially combine with the mercury in this complex releasing the indicator in its initial colorless form.

1. Description

Vacuum Ampule Test Method - The vacuum ampule test method is marketed by Chemetrics Company (see Appendix G). A special device and procedure are used to conduct the titration in the absence of air. Small amounts of the sample containing chloride ion are slowly introduced into a blue solution of mercuric nitrate and indicator complex until it becomes colorless. At this point, the reaction is complete, and the volume of chloride solution required to replace the indicator from the complex is recorded.

Direct Titration Method - Chemicals necessary for the direct titration procedure are available from Hatch, Inc. In this procedure, the indicator is added to a measured amount of the chloride-containing solution, and small amounts of mercuric salt reagent are continuously added until the purple color of the complex develops and remains upon stirring. The amount of chloride ion is calculated from the sample size and the amount of mercuric reagent added.

Small samples (e.g., 5 mL; 0.2 oz) can be titrated using the Hana Instruments Chloride Test Kit and the Hach Digital Titrator (see Appendix G).

ISO 8502-2 describes a similar laboratory test method for determining the amount of chloride on cleaned surfaces. Again, the diphenylcarbazone/bromophenol blue mixed-indicator titration method of Clarke (see References) is used.

2. Procedures

In all cases, the procedure provided by the manufacturer should be followed carefully. They explain in fine detail how to use the special equipment. The manufacturer should also be contacted about the practical use of equipment/chemicals in the desired concentration range and the precision of the procedure in that range.

D. TESTING FOR SULFATE

1. Description

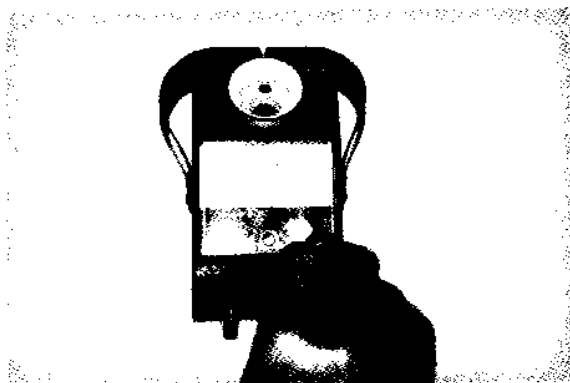
The simplest way to test for soluble sulfate (sulfate ion) is to add a solution of barium chloride to produce a turbidity (fine precipitate of barium sulfate) and then determine the sulfate concentration from the intensity of the turbidity. The amount of turbidity is best determined with a laboratory spectrophotometer, but field test kits are available. Panes of plastic of different cloudiness can also be used for field comparisons. In all cases, instructions from the suppliers should be followed carefully.

Field test kits are available from Hach Co. and LaMotte Co. (see Appendix G). The basics of the Hach test method for measuring the amount of sulfate present in a sample are described below.

2. Procedure

- a. Add to the mixing bottle the extract described in XI.A. or XI.B. above, and dilute it with water to the 25 mL mark.
- b. To this solution, add the solid contents of one packet of chemical reagent. Cap the mixing bottle, shake it for fifteen minutes, and then pour the turbid solution into the 25 mL graduated cylinder.
- c. While holding the cylinder in a vertical position and looking into it from above, slowly and continuously immerse the plastic dipstick into the turbid solution until the black dot projecting from its side is no longer visible.
- d. While holding the dipstick in this position and viewing from the non-graduated side of the cylinder, see where the meniscus of the solution crosses the scale on the dipstick. Read the concentration of sulfate from the scale on the dipstick.
- e. If the black dot disappears before the start of the scale (200 mg/mL mark), the concentration of sulfate is greater than 200 g/mL. If the black dot does not disappear, the concentration of sulfate is less than 50 mg/mL.

FIGURE 8-12. Conductivity meter. Illustration by Russell Davison, SSPC.



E. ANALYZING SOLUBLE SALTS USING CONDUCTIVITY METER (ISO 8502-9)

1. Description

Extract water obtained as described in XI.A. and XI.B. can be tested for conductivity to determine the soluble salt content (Figure 8-12). There are many different conductivity meters available for this purpose. The limpet cell has a built-in conductivity meter.

The conductivity is converted into parts per million of sodium chloride, assuming that it is the only salt present.

2. Procedure

The operating instructions of the conductivity meter manufacturer should be followed carefully. Use just enough sample of water extract to cover the electrode probes sufficiently for operation of the meter.

To account for any contamination on the equipment used (i.e., beaker, syringe, and electrode probes), run a blank test using the equipment with the distilled or deionized water used for extraction and subtract this conductivity reading from the readings of the extracts.

XIII. DETECTING NON-VISIBLE GREASE OR OIL ("HYDROCARBON") CONTAMINATION

Visually clean painted or unpainted surfaces may be contaminated with a thin film of grease, oil, or other water-insoluble material. Unless detected and removed before coating, this contamination may reduce coating adhesion. The most common sources of grease or oil contamination in painting operations are natural oils from the hands of workers and from lubricants used in compressors or power tools used in mechanical cleaning.

A. DETECTING NON-VISIBLE GREASE OR OIL USING WATER BREAK TEST

1. Description

The water break test is used to detect films of grease, oil, or other water insoluble contaminants on painted or unpainted surfaces that visually appear to be clean. This test visually distinguishes differences in water-spreading characteristics (surface energies) between clean and contaminated surfaces.

2. Procedure

- a. Spray a mist of atomized distilled water onto the surface to be tested.
- b. Observe what happens to the film of water as follows:
 - If the water gathers in lenses that last about 25 seconds before flowing out, the surface is clean.
 - If the water gathers into droplets (forms a "water break") within 25 seconds, the surface is likely contaminated with grease, oil, or other water-insoluble material.

B. DETECTING NON-VISIBLE GREASE OR OIL USING ULTRAVIOLET (BLACK) LIGHT

The use of ultraviolet light to detect grease or oil contamination may be required in specifications. However, observations are subject to interpretation.

Testing for grease or oil is most commonly done on cleaned surfaces. Occasionally, however, it is required for use on surfaces immediately prior to cleaning, since solvent washing to remove grease and oil is required before cleaning in all SSPC surface preparation specifications. This procedure is most commonly used in crude oil tanks.

1. Description

Greases and oils will usually fluoresce when exposed to ultraviolet light. These products will absorb the ultraviolet light and then emit this energy as visible light. Some synthetic oils, however, do not exhibit fluorescence.

Fluorescence cannot normally be detected in sunlight, so that a shield must be used during daylight hours. A hood of black cloth is normally used as a shield. Lint on the cloth may produce a slight fluorescence, so care must be taken not to confuse it with fluorescence from contaminated surfaces.

2. Procedure

- a. Shine an ultraviolet lamp (either short or long wavelength) onto the surface. In daylight conduct the test using a shield (e.g., black cloth) to avoid sunlight.
- b. Observe the surface for fluorescence as follows:
 - A bright yellow or lime green fluorescence indicates contamination by grease or oil.
 - An absence of fluorescence indicates that the surface is not likely contaminated by grease or oil.

XIV. DETECTING DUST

The presence of dust from blast cleaning or other operations on a cleaned surface to be painted may result in reduced adhesion or otherwise adversely affect performance characteristics of the coating.

A. DETECTING DUST USING PRESSURE SENSITIVE TAPE METHOD (ISO 8502-3)

1. Description

Dust on a cleaned surface can be readily detected by pressing a clear, adhesive, cellophane tape onto the surface, removing it, and examining for any dust collected. The

tape is best examined by placing it on a display board of contrasting color and comparing it to pictorial references.

2. Procedure

- a. Press a piece of clear, adhesive, cellophane tape against the cleaned surface leaving one end up for easy removal of the tape. Take care not to contaminate the surface with oils from fingers.
- b. Remove the cellophane tape using the exposed end and visually compare it to pictorial references.

B. DETECTING DUST USING CLEAN CLOTH METHOD

1. Description

The presence of dust on a steel surface prepared for coating can be detected by rubbing the surface with a clean cloth. However, this method is less precise than the Pressure Sensitive Tape Method (see above) and may deposit lint on the surface. Also, the amount of debris on the cloth must be subjectively evaluated. It is very impractical to expect a surface to pass a "white glove test." In determining the presence of excessive dust, it is perhaps more practical to examine the surface for streaks or marks left from the cloth.

2. Procedure

- a. Wrap a piece of clean cloth around the index fingertip and make a 6 in. (150 mm) stroke with medium pressure across the surface.
- b. Remove the cloth and inspect it and the surface visually for dust.

XV. TESTING FOR MOISTURE IN CONCRETE

A. TESTING FOR MOISTURE IN CONCRETE USING PLASTIC SHEET TEST (ASTM D 4263)

1. Description

This procedure is used to detect the presence of moisture prior to painting. A plastic sheet is bonded (e.g., taped) along its edges to a concrete surface to condense any mois-

ture present. The test is qualitative, that is, it will determine whether moisture is present, but not how much.

2. Procedure

- a. Duct tape a clear plastic sheet approximately 18 by 18 inches (460 by 460 mm) tightly to the concrete surface by sealing all its edges.
- b. Allow the sealed sheet to remain in place for at least 16 hours. Remove the sheet and visually inspect both the underside of the sheet and the concrete for the presence of moisture.

B. MEASURING MOISTURE EMISSION FROM CONCRETE USING DOME TEST

1. Description

The dome method for measuring moisture emission from concrete is currently being prepared as a standard by ASTM. It is intended for use on concrete floors and other horizontal surfaces. The equipment consists of a plastic dish filled with anhydrous calcium chloride and a plastic dome that covers a known surface area, usually 70 - 100 in² (450 - 650 cm²). The dish is weighed before and after exposure to the concrete surface covered by the dome for a recorded period of time. From the area of the exposed concrete, the amount of water absorbed, and the period of exposure, the rate of moisture transmission is calculated as pounds of water per 1,000 ft² (93 m²) per 24 hours.

2. Procedure

- a. Weigh the sealed plastic dish of calcium chloride to the nearest 0.1 g (0.004 oz).
- b. Remove the tape and cover from the dish and place it on a coin on the test concrete surface to minimize the contact area. Store the tape and cover for later use in reweighing the dish and its contents.
- c. Place the plastic dome over the dish and seal it to the concrete surface with new sealant tape. Allow the dome to remain in place about 60 to 72 hours.
- d. Record the exposure time and remove the dome. Carefully place the original cover on the plastic dish of desiccant and seal it with the original tape that was stored in Step b for this purpose.

- e. Reweigh the resealed dish to determine how much water was picked up and perform the necessary calculations to obtain the rate of transmission (weight of water per unit area).

C. TESTING FOR MOISTURE USING A MOISTURE METER

Commercial moisture meters are available for measuring the moisture content of concrete. They work on the same general principle, measuring the electrical conductivity of the concrete, which is directly related to the moisture content. They are perhaps more appropriate for plaster or wood than for concrete.

1. Description

Moisture meters use needles or probes (e.g., for use on insulation) extending outward from the meter itself. These have to be placed on the surface of the concrete to detect surface moisture. However, to measure interior moisture, the substrate must be penetrated. This can be accomplished by drilling holes in the concrete, so that long needles can penetrate in, or by driving nails into the concrete and placing instrument probes on the nail heads. In any case, the instructions of the instrument manufacturer should be followed carefully. A general description of the test method is presented below.

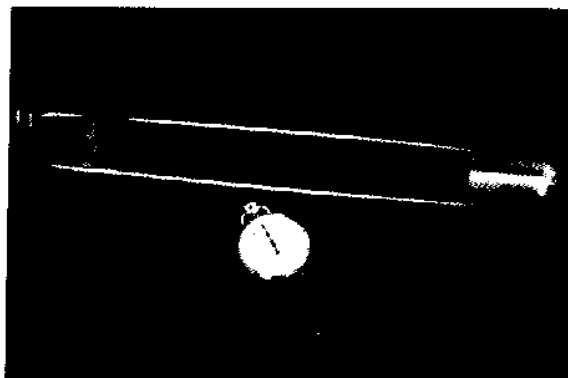
2. Procedure - Surface Moisture

To test for surface moisture, place the instrument (or instrument probes) directly on the surface and record the gage reading of percent moisture by weight.

3. Procedure - Interior Moisture

To test for interior moisture, drill two holes into the substrate, insert the instrument needles, and record the gage reading. Alternatively, drive two appropriately spaced 0.25 to 0.5 in. (6 to 13 mm) nails into the concrete, place the instrument probes on the nail heads, and record the instrument reading of percent moisture by weight.

FIGURE 8-13. Viscometer and stopwatch, SSPC file photo.



XVI. TESTING FOR VISCOSITY AND PAINT TEMPERATURE

A. FIELD TESTING FOR PAINT VISCOSITY (ASTM D 4212)

1. Description

One method for determining paint viscosity in the field is with a viscosity cup. This is a corrosion-resistant metal cup of known volume containing an orifice of known size in its bottom (Figure 8-13). The time of draining a full cup of paint (until the first break of the stream) through the orifice is a measure of its viscosity. Viscosity is temperature-dependent.

2. Procedure

- a. A cup with an appropriately sized orifice--one that drains between 20 and 80 seconds--is immersed in the homogeneous paint and lifted between 2 and 6 inches (50 - 150 mm) above the liquid level in the can.
- b. Using a stopwatch, measure the time from when the lifted cup first breaks the surface of the paint until the first definite break in the stream of paint flowing through the orifice. The time in seconds represents the viscosity. Clean cup thoroughly after each measurement. (Note: Viscosity is temperature-dependent. Measure and record the air and liquid paint temperature during viscosity measurements.)

B. MEASURING PAINT TEMPERATURE

1. Description

Paint thermometers consist of a small (e.g., 2 inch diameter; 50 mm) circular dial mounted on a long pointed stem. A bimetallic sensor on the stem measures the temperature of the paint or other liquid in which it is immersed. These thermometers are often equipped with a can clip to hold them in place and are available in various temperature ranges.

2. Procedure

- a. Immerse the stem of the thermometer into the paint or other liquid.
- b. Attach the clip (if present) to the top of the can and allow at least 3 minutes for the temperature to become constant.
- c. Lightly tap the face glass of the dial to ensure that the needle is free.
- d. Read the dial face-on to avoid inaccurate readings due to parallax.

3. Calibration

Confirm the accuracy of the factory-calibrated thermometer at the start of each job and weekly thereafter. Do this by comparing it to a calibrated thermometer after laying them side-by-side in a sheltered area and allowing 5 minutes for temperature stabilization.

XVII. MEASURING FILM THICKNESS

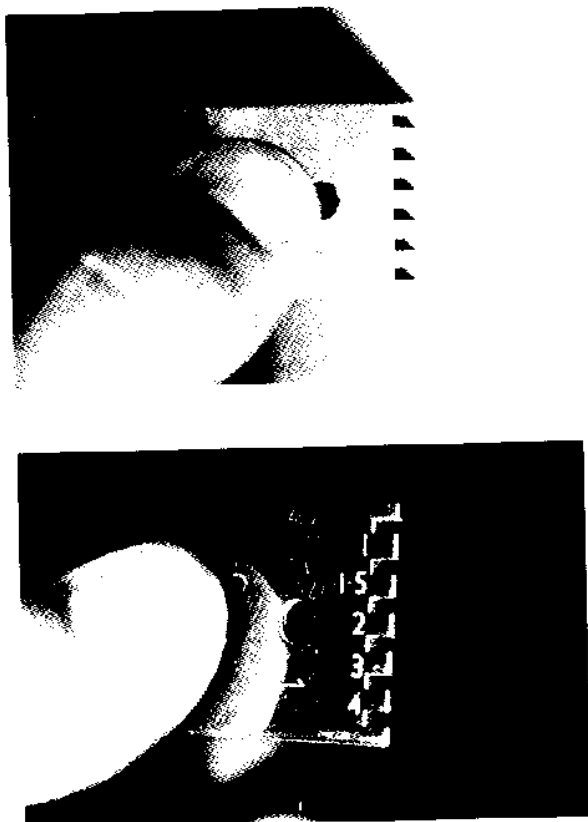
A. MEASURING WET FILM THICKNESS USING NOTCH TYPE GAGE (ASTM D 4414)

1. Description

The notch type coating wet film thickness gage typically has four faces, each for a different range of wet film thickness. Each face has two outer projections of equal length and a series of gradually decreasing steps between them.

A selected face is thrust into a film of wet paint immediately after its application, and the shallowest step that

FIGURE 8-14. Wet film thickness measurement. Top - Pressing the gage into the wet film. Bottom - Examining the gage to determine WFT.



becomes wetted by the wet film thickness of the paint noted (Figure 8-14).

2. Procedure

- Select the face of the wet film gage that includes the desired thickness and press it firmly and squarely into the paint immediately after its application.
- Remove the gage from the painted surface and note the shortest coated step. The wet film thickness lies between this and the adjacent uncoated step. Immediately clean the wet paint from the gage, so that it is ready for the next measurement.

B. MEASURING DRY FILM THICKNESS USING TYPE 1 MAGNETIC PULL-OFF GAGES (SSPC-PA 2)

1. Description

Magnetic pull-off gages measure the thickness of a non-ferrous coating over a ferrous substrate. They have an exposed magnet that is attached to a spring. The amount of tension that must be placed on the spring to lift the magnet from a coated steel surface is directly proportional to the distance of the magnet from the ferrous surface. This relationship is a measure of coating thickness.

This section will only address the preferred "banana" Type 1 gages, not "pencil" type pull-off gages described in ASTM D 1186 (Figure 8-15).

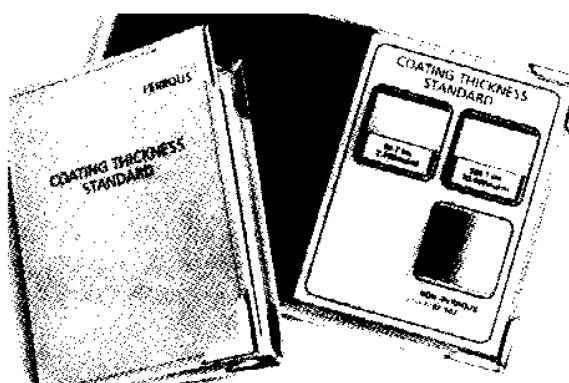
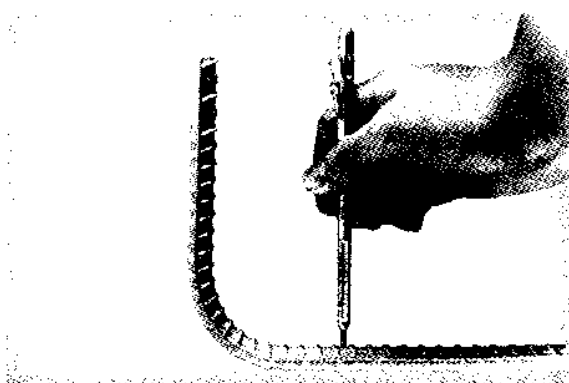
2. Procedure

- Hold the clean and calibrated gage firmly to the coated steel surface and turn the dial forward until the magnet is in direct contact with the coated surface.
- Retract the dial slowly and evenly until the magnet breaks contact with the surface.
- Read the coating thickness on the dial scale that lines up with the hairline on the instrument. Note that vibrations may cause premature lifting of the magnet, and soft or tacky coatings may inhibit its lifting. Five separate spot measurements (average of three readings) should be evenly spaced over each 100 ft² (9 m²). This is fully explained in Section 3 of SSPC-PA 2.

3. Calibration

- Use only the chrome-plated National Institute of Standards and Technology (NIST) standard thickness plates to calibrate the gage, selecting a standard that is close to the expected dry film thickness. Do not use plastic shims of known thickness, since they are non-adherent and may cause the magnet to lift prematurely.
- Place the instrument on the selected NIST plate and rotate the dial forward until the magnet contacts the plate.
- Retract the dial slowly and evenly until the magnet breaks contact with the surface.
- If the reading of the thickness is not within the tolerance of the instrument (normally 5 to 10%), record the

FIGURE 8-15. Type 1 dry film thickness gages. Top - Banana gage. Courtesy of Elcometer Inc. Center - Pencil type. Courtesy of DeFelsko Corporation. Bottom - NIST calibration plates. Courtesy of KTA-Tator, Inc.



necessary correction factor (if small) or use the calibration adjustment to make the necessary correction.

e. Measure the bare, cleaned substrate at several places to obtain an average base value. This value must be subtracted from coating thickness readings to get a measurement of paint thickness without substrate interference.

Note that the gage should be calibrated before each use, and verified for accuracy during and after each period of use.

C. MEASURING DRY FILM THICKNESS USING TYPE 2 MAGNETIC FIXED (CONSTANT PRESSURE) PROBE GAGES (SSPC-PA 2)

1. Description

Magnetic fixed or constant pressure probe gages measure the magnetic flux associated with non-magnetic coatings applied to ferrous (usually steel) surfaces. The gages must remain in direct contact with the surface until the reading is obtained (Figure 8-16). They are typically faster and more accurate than Type 1 magnetic pull-off gages.

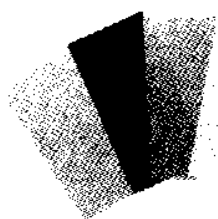
2. Procedure

a. Place the clean and calibrated gage probe (or gage body, depending upon the model) firmly onto the coated surface. A thickness reading in mils (or micrometers) will appear on the digital display.

3. Calibration

- a. Plastic or non-magnetic metal shims of known thickness are often provided by the supplier for the calibration of these gages. These should be certified as calibrated to NIST plates. NIST plates may also be used, if the supplier states that they are acceptable. Select the shim or plate that is closest to the expected dry film thickness and place it on the clean metal base.
- b. Place the gage firmly against the standard shim or plate and obtain a reading.
- c. If the reading is not within the tolerance of the instrument and calibration shims (see supplier's data sheet), use the calibration adjustment to make the necessary correction.

FIGURE 8-16. Top - Use of a Type 2 magnetic fixed probe dry film thickness gage. Courtesy of Elcometer, Inc. Bottom - Plastic calibration shims. SSPC file photo.



THE FOLLOWING TABLE IS FOR INFORMATION ONLY.

Shim Thickness (in.)	Shim Thickness (mm)
0.001	0.025
0.002	0.051
0.003	0.076
0.004	0.102
0.005	0.127
0.006	0.152
0.007	0.178
0.008	0.203
0.009	0.229
0.010	0.254

d. If the NIST plates are used, determine the magnetic base effect, as described for calibration of Type 1 gages (XVI.B.3), and subtract it from readings. This is not done when shims are used in the calibration.

Note that the gage should be calibrated before each use, and verified for accuracy during and after each period of use.

D. MEASURING DRY FILM THICKNESS USING EDDY CURRENT GAGES (ASTM D 1400)

1. Description

Eddy current gages are used to measure the dry film thickness of non-conductive coatings applied to non-ferrous metal surfaces (e.g., aluminum and copper). The instrument probe coil is energized by alternating current which induces eddy currents in the metal substrate. These eddy currents in turn create opposing alternating magnetic fields in the substrate that modify the electrical characteristics of the probe coil. The extent of these changes is a measure of the coating thickness. If this type gage is used over ferrous metal surfaces, a reading will be obtained; however, the measurement will be inaccurate.

2. Procedure

- Place the clean, dry calibrated gage (or gage probe) firmly onto the coated surface. A reading in mils (or micrometers) will appear on the digital display.
- Take at least five measurements, spaced evenly over every 100 sq ft (9 sq. meters). Note that, while SSPC-PA 2 does not address eddy current gages, the frequency of measurements outlined in PA 2 can be readily adopted.

3. Calibration

- Non-metallic shims of known thickness are typically provided by the supplier for the calibration of these gages. NIST plates cannot be used. Select the shim that is closest to the expected dry film thickness and place it on the clean metal base (same substrate that readings will be taken on).
- Place the gage firmly against the standard shim and read the digital scale.
- If the reading is not within the tolerance of the instrument and shims (see supplier's data sheet), use the calibration adjustment to make the necessary correction.

Note that the gage should be calibrated before each use, and verified for accuracy during and after each period of use.

E. MEASURING DRY FILM THICKNESS ON CONCRETE AND OTHER SURFACES USING ULTRASONIC GAGES

1. Description

The ultrasonic gage for measuring coating thickness operates on the same principle as other ultrasonic instruments. An ultrasonic pulse is transmitted from the probe through the coating and then reflected back from the substrate. The time required for this travel is directly proportional to the coating thickness. Unless the coating is soft, a couplant must be used between the probe and the coating (Figure 8-17). Water is excellent on smooth, thin coatings, and a glycol gel is excellent on rough coatings. The instrument manufacturer provides more specific information on the use of couplants. In addition, ASTM is currently developing a standard for the use of this type of instrument (expected to be issued in 1997).

2. Procedure

- a. Activate the instrument and apply its probe with constant pressure to the coating area wetted with the couplant. Record the thickness reading shown on the digital display.

- b. Repeat this operation to characterize the thickness of the total coated area as described in SSPC-PA 2.

3. Calibration

- a. Non-metallic shims of known thickness are typically provided by the supplier for the calibration of these gages. NIST plates cannot be used. Select the shim that is closest to the expected dry film thickness and place it on the clean metal base (same substrate that readings will be taken on).
- b. Apply couplant and place the gage probe firmly against the standard shim and read the digital scale.
- c. If the reading is not within the tolerance of the instrument and shims (see supplier's data sheet), use the calibration adjustment to make the necessary correction.

Note that the gage should be calibrated before each use, and verified for accuracy during and after each period of use.

F. MEASURING DRY FILM THICKNESS BY DESTRUCTIVE MEANS (ASTM D 4138)

1. Description

Destructive dry film thickness (Tooke) gages are used to visually (using a 50X calibrated microscope) determine the width of an incision made through the paint film at a specific angle. The width of the incision is then related to the coating thickness (Figure 8-18). The incision should be made on a relatively flat area, and several measurements should be recorded and averaged for each incision because substrate roughness may affect coating thickness measurements. Different coats should be colored differently, and the primer color should be easily distinguished from that of the substrate, so that thickness measurements of each coat can be made easier.

FIGURE 8-17. Ultrasonic dry film thickness gage. Courtesy of KTA-Tator Inc.

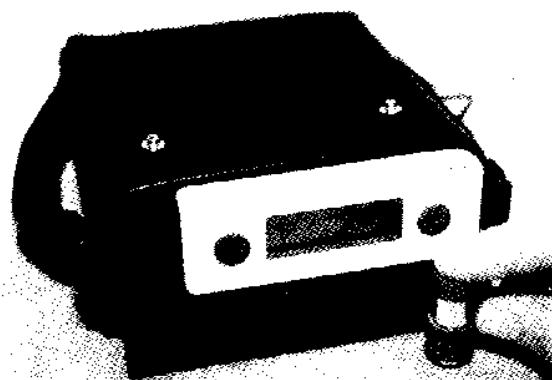
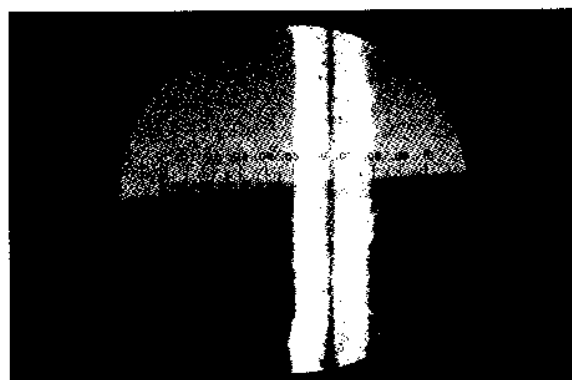
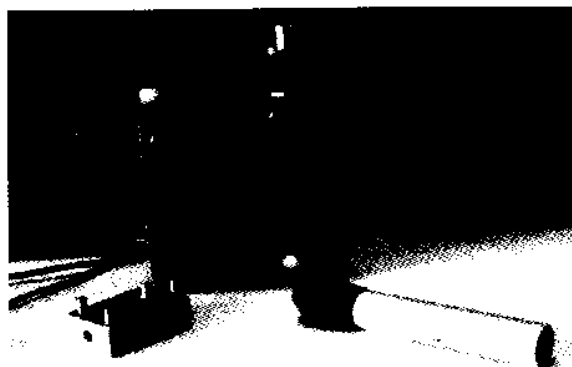


FIGURE 8-18. Destructive dry film thickness gage. Top - Gage. Bottom - View through microscope. Both photos courtesy of KTA-Tator Inc.



2. Procedure

- Make a reference benchmark on the coated surface with the marker supplied with the instrument.
- Select a cutting tip appropriate for the coating thickness and carefully make an incision completely through the coating system, perpendicular to the benchmark. Mark the incision with the cutting tip used.
 - 10X tip - 0 to 3 mils (0-76 micrometers) coating thickness
 - 2X tip - 3 to 20 mils (75-510 micrometers) coating thickness
 - 1X tip - 20 to 50 mils (510 -1270 micrometers) coating thickness

- View the incision through the lighted 50X microscope showing both sides of the cut through the coating and line up the reticule of the microscope perpendicular to and across the incision. Use the adjustment near the light bulb to focus the image.

- Using the smoother side of the cut, count the number of scale units for each coat or for the total system, as desired. Then, divide the number of scale units by 10, 2, or 1, depending upon the tip used, to obtain the thickness in mils.

- Obtain readings at several locations along the incision and average the measurements to provide a representative film thickness value.

G. MEASURING FILM THICKNESS OF PREFABRICATED COATINGS AND LININGS (ASTM D 1005)

1. Description

The film thickness of prefabricated coatings and linings can be measured by one of four procedures described in ASTM D 1005. Procedures A and B utilize stationary micrometers (mounted on a rigid base), and Procedures C and D utilize hand-held micrometers. Procedures A and C are not recommended for film thicknesses less than 0.5 mils (13 micrometers). At least three replicate determinations should be made.

2. Procedure - Stationary Micrometers

- Secure the test specimen to the base.
- Close the gage slowly until contact is made without visible distortion of the specimen.
- Read the gage and record the measurement.

3. Procedure - Hand-Held Micrometers

- Place the test specimen between the micrometer anvil contacts perpendicular to the contact points.
- Carefully bring the anvil in contact with the specimen.
- Read and record the thickness.

XVIII. DISCONTINUITY (HOLIDAY) TESTING

A. HOLIDAY TESTING OF COATINGS ON METALS - LOW-VOLTAGE WET-SPONGE METHOD (ASTM D 5162 and NACE RP0188-90)

1. Description

A low-voltage battery-powered wet-sponge probe is dragged across the coated surface. If there is a coating discontinuity, a electric circuit through the coating to the metal substrate is completed to set off the instrument alarm (Figure 8-19). This instrument is used on coatings with thicknesses up to 20 mils (510 micrometers).

2. Procedure

- a. Secure the ground wire of the instrument to a bare section of the coated metal substrate.
- b. Add to a container of water the type and amount of wetting agent recommended by the supplier. Saturate the sponge with water. This will help to break the surface tension of the water.
- c. Check the instrument for operational readiness by touching the wetted sponge to the grounding clamp or a section of bare metal (the alarm will sound).

FIGURE 8-19. A low-voltage wet sponge holiday detector. Courtesy of Elcometer, Inc.

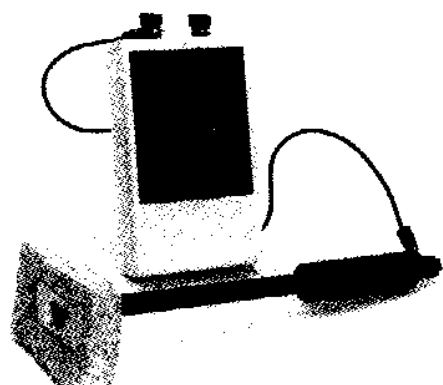


FIGURE 8-20. A high-voltage holiday detector. Courtesy of Elcometer, Inc.



- d. Drag the wetted sponge across the entire surface using systematic overlapping passes, at a rate of approximately one foot per second (0.3 meters per second), double pass.
- e. If the alarm (signaling device) sounds, indicating a holiday, turn the sponge on-end to locate and mark it more precisely for repair.

B. HOLIDAY TESTING OF COATINGS ON METALS - HIGH-VOLTAGE METHOD (ASTM D 5162 and NACE RP0188-90)

1. Description

The high-voltage instrument is grounded to a section of bare metal, and an exploring probe is passed over the coating. A spark passing through the air gap at discontinuities energizes the signaling device (Figure 8-20). The instrument is used for coatings with film thicknesses greater than 20 mils (510 micrometers). Although a voltage of 100 to 125 volts per mil (4 to 5 volts per micrometer) is used as a rule of thumb, it is best to consult the coatings supplier or the specification for appropriate voltage levels.

2. Procedure

- a. Secure the ground wire to the instrument and to a section of bare metal substrate.
- b. Energize the instrument and set it at the proper voltage.

c. Check the instrument for operational readiness by passing the electrode probe across a bare area or one with a coating defect. If a spark is visible but the alarm does not sound, a less resistant connection to the substrate may be necessary.

d. Move the electrode probe systematically and continuously across the coated surface at a rate of approximately one foot per second (0.3 meters per second), single pass. (Stopping may cause coating damage.) A spark or alarm signals a holiday.

C. HOLIDAY TESTING OF COATINGS ON CONCRETE (ASTM D 4787)

1. Description

The methods for holiday testing of coatings on concrete are the same as those for coated metal surfaces. However, if simple testing shows that the concrete is insufficiently conductive, it is necessary to apply a conductive underlay ment.

2. Procedure

See XVIII A for the low-voltage holiday testing procedure and XVIII B for the high-voltage holiday testing procedure. If high-voltage instruments are to be used, an output terminal must be used to permit the ground wire to have a good electrical connection to the substrate.

XIX. ADHESION TESTING

A. MECHANICAL ADHESION TESTING (ASTM D 4541; Annex A.1)

1. Description

The adhesion tester mechanically measures the relative adhesion of protective coatings and linings. An aluminum pull stub (loading fixture) is bonded onto a coated surface. After curing of the adhesive, a pulling force on the pull stub is continuously increased and monitored by the pull-off instrument until the pull stub becomes detached or until a specific force is attained (Figure 8-21).

FIGURE 8-21.
Mechanical
adhesion testing.
Courtesy of KTA-
Tator Inc.



2. Procedure

a. Lightly sand both a clean, smooth test area of coating and the base (contact area) of a pull stub. Then, wipe both sanded areas clean. When testing for adhesion of coatings to concrete, score or core drill the test site prior to attachment of the loading fixture.

b. Thoroughly mix the provided adhesive (usually an epoxy) according to its instructions. Apply it smoothly and evenly to the entire base of the pull stub, and press this surface against the coating test area. Wipe away the excess adhesive around the pull stub. Do not twist the pull stub. Push straight downward.

c. After the adhesive has cured, lower the jaws of the pull-off instrument's grip until they slip under the head of the pull stub. Connect the grip to the pull stub, align the device according to the manufacturer's instructions, and set the force indicator at zero.

d. Increase the load on the pull stub smoothly and continuously until failure occurs or until a specific load is attained.

e. Record the failure load from the bottom of the drag indicator, and the type of failure by percentage as follows:

- Adhesion - Failure between two coats or the substrate and the first coat
- Cohesive - Failure or break in any one coat

- Glue - Cohesive failure of the glue or adhesion failure of glue to pull stub or first coat

B. PNEUMATIC ADHESION TESTING (ASTM D 4541; Annex A.2)

1. Description

The Pneumatic Adhesion Tensile Testing Instrument (PATTI) is a self-aligning instrument consisting of detachable loading fixtures having a flat, cylindrical base, a central grip for engaging the loading fixture, and a pressurized gas system for applying a continuous pull to the loading fixture (Figure 8-22).

2. Procedure

- Lightly sand a clean, smooth test area of coating, then wipe clean.
- Thoroughly mix the provided epoxy adhesive according to its instructions, apply it smoothly and evenly to the entire base of the loading fixture, and press this surface against the coating test area. Do not twist the loading fixture. Push downward. Place a cut-off ring, knife edge down around the fixture to eliminate the need for manual removal of the excess adhesive.
- After the adhesive has cured, carefully remove the cut-off ring and place one of the instrument pistons

FIGURE 8-22. Pneumatic adhesion tester. Courtesy of KTA-Tator Inc.

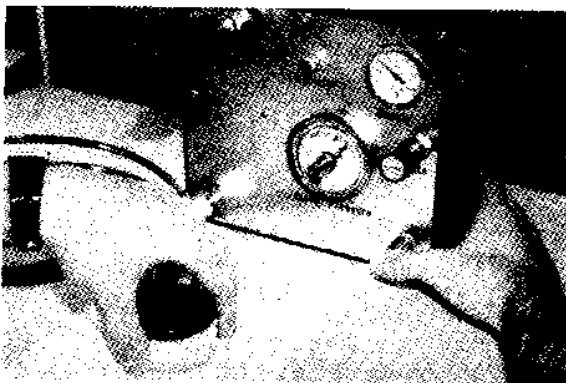
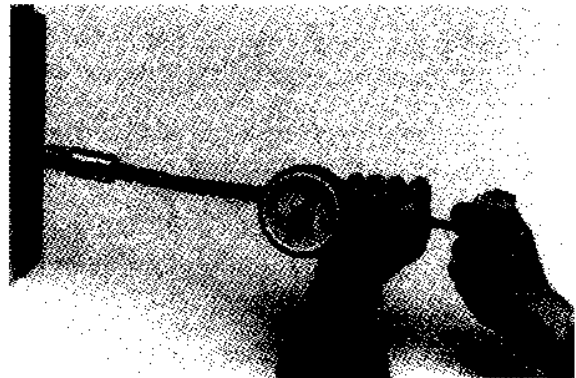


FIGURE 8-23. Hydraulic adhesion tester. Courtesy of Elcometer, Inc.



over the loading fixture and thread the bearing plate onto it until it makes contact with the piston. Reverse the bearing plate 1/4 to 1/2 turn and set the red pointer on the instrument to 0 (analog dial only).

d. Attach the hose to the piston and activate the system until the loading fixture is detached or the specific load is attained. Convert the gas pressure in psi to pull pressure using the conversion chart supplied with the piston. Also, record the type of break, defined by percentage as cohesive, adhesive, or glue break (see XIX.A.2.e).

C. HYDRAULIC ADHESION TESTING (ASTM D 4541)

1. Description

The Hydraulic Adhesion Test Equipment (HATE) instrument uses a hydraulic system secured through a centered hole in the load fixture to measure loading tensile adhesion (Figure 8-23).

2. Procedure

- Solvent clean the bonding surface of the load fixture, the Teflon plug, and the coating area to be tested. Then, lightly sand the test area until smooth and wipe clean.
- Insert the Teflon plug into the loading fixture until its tip protrudes from the surface of the fixture. Apply a thin coat of epoxy adhesive to the bonding surface of the fixture taking care not to get it on the plug.

- c. Press the loading fixture onto the coating and wipe off the excess adhesive around it.
- d. Remove the Teflon plug and allow the adhesive to cure according to the manufacturer's instructions.
- e. Connect the instrument to the load fixture and increase the pressure slowly until the fixture disbonds or until a specified pressure is attained. Record the pressure and the type of break by percentage, defined as cohesive, adhesive, or glue break (see XIX.A.2.e).

D. ADHESION TESTING USING TAPE TEST (ASTM D 3359)

1. Description

ASTM D 3359 has two test methods. Both methods involve applying and removing pressure-sensitive tape to a pattern cut into the coating and comparing the effect on the coating to written or pictorial standards (Figure 8-24).

Method A is intended primarily for field use. An "X"-cut is made in the film, pressure-sensitive tape is applied over it and then pulled off, and the coating adhesion is assessed by comparison to a scale of 0A to 5A of written definitions.

Method B is more suitable for laboratory use, but is often used in the field. A lattice pattern of six or eleven cuts is made in each direction, pressure sensitive tape is applied over it and pulled off, and the coating adhesion is assessed on a scale from 0B to 5B by comparison with figures depicting these levels. This method is not considered suitable for films thicker than 5 mils (125 micrometers). However, if all parties agree, wider spaced cuts can be used for coatings in excess of 5 mils (125 micrometers).

2. Procedure - Method A

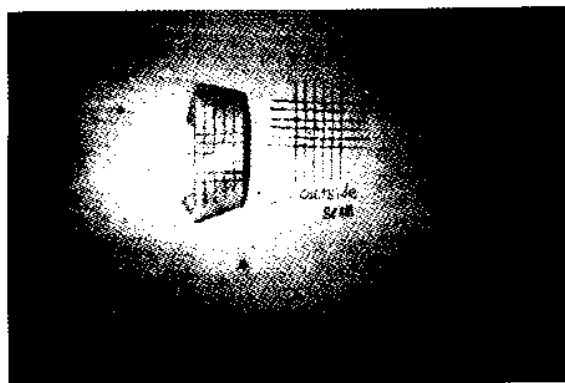
- a. Use a utility knife or razor blade and a straightedge to make two cuts in the coating (to the substrate) each about 1.5 inches (38 mm) long to form an "X". A sack knife with a dull blade may destroy the coating. The angle of the X should be 30 degrees to 45 degrees, in order to be fully covered by the tape.
- b. Remove two layers of tape from the roll, then place a strip of pressure sensitive tape over the cut and press it firmly in place with an eraser on the end of a pencil.

- c. Within 2 minutes, remove the tape by pulling it rapidly and smoothly back upon itself.
- d. Inspect the cut area and make the best match for the following scale:
 - 5A No peeling or removal
 - 4A Trace peeling or removal along incisions
 - 3A Up to 0.0625 inch (1.6 mm) jagged removal along most of either incision
 - 2A Up to 0.125 inch (3.2 mm) jagged removal along most of either incision
 - 1A Removal of most of area of "X" under the tape
 - 0A Removal beyond area of "X"

3. Procedure - Method B

- a. Use a knife or razor blade and the template provided to cut a lattice pattern into the coating:
 - For coatings up to 2 mils (50 micrometers) thick - Use 11 lines, spaced 1 mm (0.4 in.) apart
 - For coatings 2 to 5 mils (50-125 micrometers) thick - Use 6 lines, spaced 2 mm (0.08 in.) apart
 - For coatings in excess of 5 mils (125 micrometers) - Use Method A.
- b. Place a piece of pressure-sensitive tape over this pattern and press it firmly in place using an eraser at the end of a pencil.
- c. Remove the tape by pulling it rapidly and smoothly back upon itself.

FIGURE 8-24. Tape test for adhesion, Method A. SSPC file photo.



- d. Inspect the cut pattern for damage and make the best match for the scale of 0B to 5B described narratively and shown pictorially in ASTM D 3359.

XX. TESTING FOR HARDNESS AND SOLVENT RESISTANCE

A. DETERMINING COATING HARDNESS BY PENCIL TESTING (ASTM D 3363)

1. Description

The hardest of a series of pencils (actually leads) of different hardness is pressed downward and forward about 0.25 inch (6.4 mm). The process is repeated until pencils are found that will not cut through the coating and that will not scratch the coating (they may be the same pencil). The hardest pencil that will leave the film uncut defines the gouge hardness; the hardest pencil that will not scratch the film defines the scratch hardness.

2. Procedure

- a. Sharpen slightly, then flatten the point of all hardness pencils with fine sand paper or emery cloth, and, while holding the hardest one at a 45 degree angle, push it downward into the coating and forward about 0.25 inch (6.4 mm) away from the operator.
- b. Repeat this test with the next softer pencil until pencils are found that will not gouge and will not scratch the coating.

B. TESTING FOR SOLVENT-RESISTANCE

1. Description

A solvent-resistant coating is rubbed for 50 up-and-down strokes (called "double rubs") with a solvent-soaked cloth, and the cloth is visually inspected to determine if any coating is removed. Fully-cured thermosetting coatings are not affected by this test, but thermoplastic and uncured thermosetting coatings will be dissolved. This test is similar to ASTM D 4752 for measuring the methyl ethyl ketone (MEK)-resistance of ethyl silicate zinc-rich coatings.

2. Procedure

- a. Dip a clean cloth in methyl ethyl ketone (MEK) or other solvent.

- b. Rub the soaked (not dripping) cloth on the coating using medium pressure for 50 up-and-down strokes.
- c. Visually inspect the cloth for transfer of coating.
- d. Report the number of up-and-down strokes performed.

C. DETERMINING COATING HARDNESS USING DUROMETER (ASTM D 2240)

1. Description

The completeness of curing of coating films can be determined by testing for durometer hardness according to ASTM D 2240. It is more commonly used to determine hardness of rubber, cellular materials, elastomeric materials, thermoplastic elastomers, and some plastics. The ASTM standard test method describes seven types of durometers (A, B, C, D, DO, O, and OO) and their uses. Each type has a different scale of hardness. The apparatus has the following components:

- Presser foot with hole in center for indenter to pass through
- Indenter of hardened steel to displace surface of material tested
- Indenter extension indicating device with a scale from 0 to 100
- Calibrated spring for applying force to the indenter
- Timing device (optional) for indicating when a desired time has elapsed

2. Procedure

- a. Calibrate the durometer spring, as described in the manufacturer's instructions and specification.
- b. Place the conditioned specimen on a hard, smooth, horizontal surface.
- c. Hold the durometer in a vertical position at least 0.5 in. (13 mm) from any edge and apply the presser foot to the specimen as rapidly as possible, without shock, keeping the presser foot parallel to the surface of the specimen. Apply just enough pressure to maintain firm contact between the presser foot and specimen.
- d. After the presser foot is in firm contact, record the scale reading. Make five measurements at different specimen positions and determine the arithmetic mean.

D. DETERMINING COATING HARDNESS USING BARCOL IMPRESSOR (ASTM D 2583)

1. Description

A Barcol impressor can be used, as described in ASTM D 2583, to determine the indentation hardness of both reinforced and non-reinforced plastic materials. This instrument has the following components:

- Indenter consisting of a hardened steel truncated cone having an angle of 26 degrees with a flat tip of 0.0062 in. (0.157 mm), which it fits into a hollow spindle and is held down by a spring-loaded plunger.
- Indicating device with a dial of 100 divisions, each representing a depth of 0.0003 in. (0.0076 mm).
- Calibration standards consisting of both "hard" and "soft" aluminum alloy disks supplied by the manufacturer of the impressor. Use the standard closest to the anticipated reading.

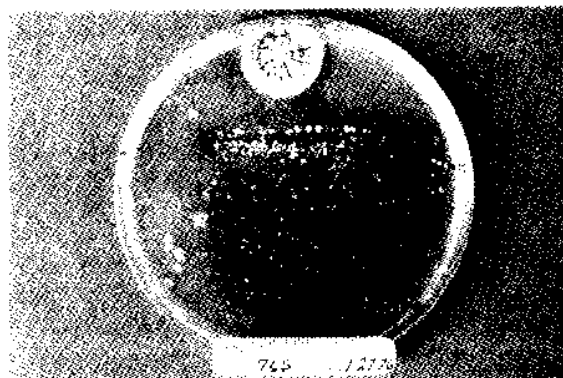
2. Procedure

- a. Condition the test specimen at $73\pm4^{\circ}\text{F}$ ($23\pm2^{\circ}\text{C}$) and $50\pm5\%$ relative humidity for at least 40 hours.
 - b. Place the impressor, the material to be tested, and the aluminum calibration disk on a solidly-supported hard, flat surface.
 - c. Calibrate the instrument by starting with the plunger upper guide backed out until it just touches the spring. Then, place the impressor on a glass surface and press down until the point is forced all the way back to the lower guide. If the indicator does not read "100," adjust the plunger until it does. Repeat this operation with both the hard and soft disks.
 - d. Make measurements of test specimens, using the general procedure described above for calibration.
- Average the replicate readings to obtain representative results.

XXI. LABORATORY TEST METHODS

While this chapter will not attempt to describe laboratory test methods, the inspector should be aware that such tests exist and should be considered when deficiencies are suspected in coating composition, liquid paint or dry film

FIGURE 8-25. Determining mildew resistance (agar plate test). SSPC file photo.



properties. For this reason, a list of the more common laboratory tests is presented below:

A. MEASURING PROPERTIES OF LIQUID COATING

- Viscosity (Stormer viscometer): ASTM D 562
- Sag Resistance: ASTM D 4400
- Nonvolatile Content (% Total Weight Solids): ASTM D 2369
- Nonvolatile Content (% Total Volume Solids): ASTM D 2697
- Pigment Content of Latex Paints: ASTM D 3723
- Pigment Content of Solvent-Based Coatings: ASTM D 2371 and 2372
- Density: ASTM D 1475
- Fineness of Pigment Grind: ASTM D 1210

B. DETERMINING FILM PROPERTIES

- Washability: ASTM D 3450
- Scrub Resistance: ASTM D 4828
- Hiding Power (Opacity): ASTM D 344
- Flexibility (Elongation): ASTM D 522
- Abrasion Resistance (Taber): ASTM D 4060
- Abrasion Resistance (Blast Abrasive): ASTM D 658
- Gloss/Reflectivity: ASTM D 523

- Mildew Resistance (Chamber Test): ASTM D 3273
- Mildew Resistance (Agar Plate Test): FTMS 141 Method 6271.2 (Figure 8-25)
- Impact Resistance: ASTM D 2794

inspection capability in accordance with ANSI N45.2.6. He is also an SSPC Protective Coatings Specialist, an SSPC Certified Supervisor/Competent Person for Industrial Deredging Projects, and has taken the OSHA Construction Hazard Awareness Training.

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BIOGRAPHICAL SKETCH

William D. Corbett is the Director of Training Services for KTA-TATOR, Inc. and KTA/SET Environmental. In this position, which he has held since 1993, he is responsible for direction and supervision of all client training programs. Prior to this, he was Training Manager for KTA, and a laboratory technician working directly under the supervision of the laboratory director. Mr. Corbett has been employed by KTA-Tator, Inc. since 1979. His experience includes all aspects of laboratory analytical and physical testing of coatings, field instrumentation for coatings inspection, and worker and environmental monitoring using all types of personal and area ambient monitoring equipment.

Mr. Corbett is an active member of SSPC. He is a frequent lecturer at SSPC tutorials on coatings inspection/instrumentation and occupational and environmental monitoring instrumentation. He was also an annual lecturer at the NACE Liberty Bell Corrosion course on inspection/instrumentation and surface preparation. Mr. Corbett is a frequent author of articles in the American Painting Contractor, Journal of Protective Coatings and Linings, and PWC Magazine. He received the SSPC Outstanding Publication Award in 1992.

Mr. Corbett has an A.D. in Business Administration from Robert Morris College. He is certified at a Level I coatings

Appendix A

Abbreviations and Acronyms

°C: degrees Celsius	CCD: charged coupled device
°F: degrees Fahrenheit	CCTV: closed circuit television
µg: microgram	CEN: European Committee for Standardization
ACGIH: American Conference of Governmental Industrial Hygienists	CFM: cubic feet per minute
ACI: American Concrete Institute	CFR: Code of Federal Regulations
ALARA: as low as reasonably achievable	CGA: Compressed Gas Association
ANSI: American National Standards Institute	CGSB: Canadian General Standards Board
API: American Petroleum Institute	cm: centimeter
ASME: American Society of Mechanical Engineers	cm ² : square centimeter
ASTM: American Society for Testing and Materials	COSHH: Control of Substances Hazardous to Health (UK)
AWS: American Welding Society	CSA: Canadian Standards Association
AWWA: American Water Works Association	CSI: Construction Specifications Institute
BSI: British Standards Institution	dB: decibels
BTU: British thermal units	DBA: design basis accident
BWR: boiling water reactor	DC: direct current
CAA: Clean Air Act	DFT: dry film thickness

Abbreviations and Acronyms

DIN: Deutsches Institut für Normung, e.V.	hr.: hour
DOD: Department of Defense	i.e.: that is
e.g.: for example	ICCD: intensified charged coupled device
ECTFE: ethylene chlorotrifluoroethylene	IDLH: immediately dangerous to life or health
EPA: Environmental Protection Agency	in.: inch
ESD: emergency shutdown device	in ² : square inch
ESS: engineered safety system	IR: infrared
ETFE: ethylene tetrafluoroethylene	ISO: International Organization for Standardization
FAA: Federal Aviation Administration	JPCL: Journal of Protective Coatings and Linings
FBE: fusion bonded epoxy	kg: kilogram
FDA: Food and Drug Administration	km: kilometer
FGD: flue gas desulfurization	L: liter
FHWA: Federal Highway Administration	lbs.: pound
FRP: fiberglass-reinforced plastic or fiberglass-reinforced polyester	LCD: liquid crystal display
FSAR: final safety analysis report	LDSTA: Locks, dams, spillways, and their appurtenances
FSCT: Federation of Societies for Coatings Technology	LED: light-emitting diode
ft.: foot	LEL: lower explosive limit
ft ² : square foot	LFL: lower flammable limit
ft ³ : cubic foot	LOCA: loss of coolant accident
g: gram	LPG: liquefied petroleum gas
gal.: gallon	m: meter
GPO: US Government Printing Office	m ² : square meter
HATE: Hydraulic Adhesion Test Equipment	m ³ : cubic meter
HAZCOM: Hazard Communication Standard (OSHA)	Max.: maximum
	MBR: magnetic base reading

MEK: methylethyl ketone	OSHA: Occupational Safety and Health Administration
mg: milligram	oz.: ounce
Mg: megagram	Pa: Pascal
MIBK: methylisobutyl ketone	PATTI: Pneumatic Adhesion Tensile Testing Instrument
MIC: microbiologically induced corrosion	PEL: permissible exposure limit
MILSPEC: military specification	pH: $-\log [H^+]$
Min.: minimum	pli: pounds per lineal inch
mm: millimeter	PPE: personal protective equipment
MPa: megaPascal	ppm: parts per million
mph: miles per hour	psi: pounds per square inch
MPI: Meat and Poultry Inspection Program	PVC: polyvinyl chloride (also pigment volume concentration)
MSDS: material safety data sheet	PVDF: polyvinylidene fluoride
MSHA: Mine Safety and Health Administration	PWR: pressurized water reactor
NACE: NACE International (formerly National Association of Corrosion Engineers)	RHR: residual heat removal
NDT: non-destructive testing	ROV: remote operated vehicle
NECH: National Electrical Code Handbook	rpm: revolutions per minute
NFPA: National Fire Protection Association	RTP: reinforced thermosetting plastics
NIOSH: National Institute for Occupational Safety and Health	s: second
NIST: National Institute of Standards and Technology	SCUBA: self contained breathing apparatus
NRC: Nuclear Regulatory Commission	SI: Système Internationale d'unités (International System of Units)
NSF: NSF International (formerly National Sanitation Foundation)	SIS: Swedish Standards Institution
NVM: non-volatile matter	SIT: silicon intensified target
OSH: Occupational Safety and Health	SLR: single lens reflex

Abbreviations and Acronyms

SNAME: Society of Naval Architects and Marine Engineers

SSPC: SSPC: The Society for Protective Coatings (formerly the Steel Structures Painting Council)

STEL: short-term exposure limit

TLV: threshold limit value

TSC: thermal spray coating

TWA: time-weighted average

UEL: upper explosive limit

UL: Underwriters Laboratories

UN: United Nations

USDA: United States Department of Agriculture

UV: ultraviolet

VOC: volatile organic compound

W/C: water to cement ratio

WFT: wet film thickness

WHO: World Health Organization

X: times (e.g., in magnification)

XRF: X-ray Fluorescence

Appendix B

Glossary

ABRADING: (1) Erosion by mechanical or particulate impact. (2) Surface preparation of concrete that is intended to roughen the surface profile of the concrete and remove foreign materials. Methods classified as abrading include mechanical abrasion, water blast cleaning, and abrasive blast cleaning. Abrading methods are defined in ASTM D 4259.

ABRASION RESISTANCE: The ability of a coating to resist being worn away and to maintain its original appearance and structure when subjected to rubbing, scraping, or wear. [ASTM]

ABRASIVE: (1) A material used for wearing away a surface by rubbing. (2) A fine, granulated material used for blast cleaning. Abrasive particles of controlled mesh sizes are propelled by compressed air, water, or centrifugal force to clean and roughen a surface. Blast cleaning abrasives often are simply referred to as metallic or non-metallic and as shot- or grit-like. [IM]

ABRASIVE AIR BLAST CLEANING: See AIR ABRASIVE BLAST CLEANING.

ABRASIVE BLAST CLEANING: Also called abrasive blasting, a surface preparation method that uses an abrasive propelled by air pressure, centrifugal force, or water pressure to clean and usually to profile a surface. Stand-off distance, angle of attack, and dwell time are the three most important variables under the control of an operator that can affect the quality and effectiveness of the blast cleaning. [IM]

ABRASIVE BLASTING: See ABRASIVE BLAST CLEANING.

ABRASIVE MIX: Also called work mix or operating mix, the mixture of metallic or recyclable non-metallic abrasive sizes that results from the periodic addition of new abrasive to recycled abrasive during a blasting operation to maintain cleaning rate and surface profile.

ABRASIVE PAD: See NON-WOVEN ABRASIVE PAD.

ABRASIVE WHEELS: Metallic wheels mounted on a rotary power tool, commonly used to grind welds, and remove weld spatter. They are also commonly used to remove rust and mill scale from localized areas. See POWER TOOL CLEANING.

ABUTMENT: A substructure composed of stone, concrete, brick, or timber supporting the end of a single span or the extreme end of a multispan superstructure and, in general, retaining or supporting the approach embankment. [B]

ACCELERATOR: See CATALYST.

ACID ETCHING: A method of preparing concrete floors for painting. An acid etching solution may be made of diluted hydrochloric acid (5 to 10 percent), diluted phosphoric acid (20 to 25 percent), or, often for environmental reasons, citric acid. These solutions can clean and remove dirt and other impurities from the concrete as well as provide a surface texture to improve the adhesion of the coating. [IM]

ACIDITY: The extent to which a solution is acid, normally expressed as its pH value. [L]

ACID-RESISTANT BRICK: A specially processed or vitrified brick suitable for use in contact with mineral acids, usually in conjunction with acid-resistant mortars.

ACTIVATOR: See CATALYST.

ADHESION: The degree of attraction between a coating and a substrate or between two coats of paint that are held together by chemical or mechanical forces or both. Adhesion often is called the "bonding strength" of a coating. Adhesion should not be confused with "cohesion," which is the force holding a single coating layer together. [IM]

ADHESION FAILURE: A failure between two distinct coating layers or between the substrate and the first layer of coating. See ADHESION TEST, TENSILE (PULL-OFF).

ADHESION TEST, CROSSCUT: Also called crosshatch test, a coatings adhesion test in which a crosshatch pattern is scribed onto the coated surface, then tape is applied and pulled off. Adhesion is assessed according to surface area from which flaking has occurred (ASTM D 3359). Adhesion measured by the crosscut test is referred to as the shear (or knife) adhesion.

ADHESION TEST, TENSILE (PULL-OFF): A method for testing the greatest perpendicular force which an area of coating can withstand before: (1) detaching from the surface (adhesion) or (2) fracturing within a layer of coating or substrate (cohesion). The method can also be used to determine whether a coating will remain intact at a particular applied tensile force. This standard test method is defined in ASTM D 4541.

ADMIXTURE: A material other than water, aggregates, hydraulic cement, and fiber reinforcement used as an ingredient of concrete or mortar and added to the batch immediately before or during its mixing (e.g., accelerating admixture, air-entraining admixture, retarding admixture, water-reducing admixture). [ACI]

AERATION POND: Pond supplied with oxygen to promote digestion of sewage by aerobic (oxygen utilizing) microorganisms.

AGAR PLATE TEST: Accelerated laboratory test for determining resistance of coatings to growth of specific mildew organisms; conducted in petri dishes containing nutrient media.

AGGREGATE: (1) A group of dry pigment particles held together by their surface forces; the spaces between the particles are filled with air. [CED] (2) Granular material, such as sand, gravel, crushed stone, crushed hydraulic-cement concrete, or iron blast-furnace slag, used with a hydraulic cementing medium to produce either concrete or mortar. [ACI]

AIR ABRASIVE BLAST CLEANING: Also called abrasive air blast cleaning, a surface preparation method in which compressed air is used to propel abrasive particles against a surface to be cleaned. "Open blast cleaning" indicates that a localized containment does not surround the blast stream. "Closed blast cleaning" means that a localized containment does surround the blast stream. [IM]

AIRLESS SPRAYING: A coating application method that uses hydraulic pressure instead of air to atomize paint by forcing it through a spray nozzle with a small orifice at a pressure of 2,000 to 3,000 psi (14-21 MPa). The spray pattern and flow of paint are controlled by the size and shape of the orifice. The size of the orifice must be matched with the viscosity of the paint and the size of the material pump. This process is aided if the material is previously heated. [IM]

ALIPHATIC: A class of organic hydrocarbon compounds composed of open chains. These include paraffins, olefins, etc.

ALKALINITY: The extent to which a solution is alkaline (basic). [L]

ALLIGATORING: A type of crazing or surface cracking of a definite pattern that looks like alligator hide. The effect is often the result of weather aging of a coating. See also CRACKING.

ALUMINUM POTASSIUM SILICATE: Generically known as mica, a complex hydrous aluminum silicate, based on several mineralogically related groups. $3\text{Al}_2\text{O}_3 \cdot \text{K}_2\text{O} \cdot 6\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. Synonyms: ground muscovite,

graphitic mica, sericite. Mica is a laminar pigment which can increase the barrier properties of a coating. [CED]

AMBIENT CONDITIONS: The weather conditions including: air temperature, relative humidity, dew point, wind velocity, and air temperature, which are monitored on the jobsite.

AMINE: An organic compound derived from ammonia by replacement of one or more hydrogen atoms with hydrocarbon radicals. It is used as a curing agent for epoxy resins.

AMINE BLUSH: Surface opalescence (blush) on epoxy films caused by reaction of amine co-reactant with carbon dioxide and water to form an amine carbamate.

ANAEROBIC: Free of oxygen and/or air. [CED]

ANAEROBIC DIGESTER: The vessel for digesting the organic matter in the waste treatment process. Digestion is accomplished by organisms that do not use oxygen in their metabolism.

ANCHOR PATTERN: See SURFACE PROFILE.

ANCHORAGE: (1) The portion of the abutment where the main cable stays of a suspension bridge are anchored into the abutment. [B] (2) A mooring for a ship.

ANCHORING SYSTEM: The method of securing a gunited material to a steel substrate. The two major methods are wire mesh attached to anchoring posts and T-type anchors.

ANHYDROUS: Moisture-free; a compound without water of crystallization. [IM]

ANODE: The electrode of an electrolytic cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. It is usually at the anode that corrosion occurs and metal ions enter solution. Contrast with CATHODE. [ASM]

ANODIZED: Provided electrochemically with a protective or decorative oxide film.

ANTI-FOULING PAINT: A paint formulated to release noxious or poisonous substances at a controlled rate to

prevent the growth of barnacles, algae, and other organisms on the underwater part of a ship hull. [IM]

ANTIMONY: Metallic element. Antimony oxide is used as a white hiding pigment. Experimental data indicate that antimony is a suspected carcinogen.

APPURTENANCE: A secondary attachment or appendage to a stationary structure.

ARCH: A structure with a curved undersurface that supports a highway over an opening. Structurally, an arch carries vertical loads by the resistance of the abutments to horizontal thrusts. [B]

ARCING: Spraying a coating with the gun moving in an arc, rather than at a constant distance from the substrate surface, so that a film of varying thickness results. Arcing may also occur with abrasive blasting to produce a variable level of surface cleaning.

ARC SPRAYING: Metal spraying in which an electric arc is used to melt the metal.

AROMATIC: Hydrocarbon containing an unsaturated ring of carbon atoms, typified by the benzene ring structure. Xylene (xylol), toluene (toluol), and high-flash naphtha are aromatic solvents used in coatings.

ARSENIC: An element that occurs free and combined in many minerals. Arsenic is a well-known poison whose compounds were formerly used in antifouling paints.

ASBESTOS: A group of fibrous minerals which occur as small veins in the massive body of natural hydrous silicates of serpentine or amphibole and have heat-, fire-, and solvent-resistant properties. [CED] It was once used to reinforce coatings.

ASPHALT: Black to dark-brown solid or semisolid cementitious material which gradually liquefies when heated. The predominating constituents are bitumens, all of which occur in the solid or semi-solid form in nature or are obtained by refining petroleum, or which are combinations of the bitumens mentioned with each other or with petroleum or derivatives thereof. [CED]

AUGER: (1) The screw-like part of a predampening machine (e.g., for guniting) that feeds material into the

conveyor mechanism. (2) A tool used for boring holes in wood.

BACKSCATTER: Diffuse reflection (scattering) of radiation in a direction opposite to that of the incident radiation.

BAG HOUSE: The final portion of a dust collection system, which removes the smallest particles from the air. A cyclone or other separator, which is ahead of the bag house, removes the larger particles. This type of equipment is used in blasting and paint operations to purify the exhaust air.

BALLAST: Water stored in tanks on board ships to contribute to the trim and stability of the vessel. Ballast is pumped in and out from the sea to adjust the draft and distribute weight to control sag, hog, center of gravity, etc. This ballast can cause sweating on the exterior surface, which can contribute to coating failure

BANANA GAGE: An elongated type of magnetic dry film thickness gage with a handle at one end and the probe at the other end. Between the handle and the probe is a positioning base and a thickness display dial. See **MAGNETIC GAGE**.

BARCOL HARDNESS: Hardness value obtained by measuring the resistance to penetration of a sharp steel point under a spring load. The instrument, called the Barcol Impressor, gives a direct reading on a 0-100 scale. The hardness value is often used as a measure of the degree of cure of plastics; not suitable for paints. This standard test method is defined in ASTM D 2583. [CED]

BARCOL IMPRESSOR: See **BARCOL HARDNESS**.

BARIUM: A toxic heavy metal. Barium pigments are used for corrosion and mildew control. In general, the barium compounds used in paint have extremely low solubility and reactivity.

BARNACLES: Any of certain crustaceans of the group cirripedia, as the goose barnacles, the stalked species which cling to ship bottoms and floating timber; and the rock barnacles, the species which attach themselves to marine rocks. See **BIOFOULING**. [CED]

BAROMETRIC PRESSURE: Atmospheric pressure, referenced in the US Weather Bureau Psychrometric

Tables. Used to aid in the determination of relative humidity and dew point, based on the dry and wet bulb readings from the psychrometer.

BARRIER COAT: (1) A coating or coating system that protects an underlying substrate by minimizing or eliminating the penetration of moisture or vapors. (2) A coating used to separate a layer of paint from a surface to prevent chemical or physical interaction. [TM]

BARRIER PROTECTION: See **BARRIER COAT**.

BASCULE BRIDGE: A bridge having a superstructure designed to swing vertically about a fixed or a moving horizontal axis. The axis may be the center of a hinge pin or trunnion, or it may be only a line fixing the center of a circular rotation combined with translation (rolling lift bridge). [B]

BASE: (1) A chemical species which when dissolved in water generates hydroxide (OH^-) ions or is capable of reacting with an acid to form a salt. (2) The major component of a multicomponent coating system. In two-component systems, the other component is usually called an "accelerator," an "activator," a "hardener," or a "curing agent." (3) A subfloor slab or "working mat," either previously placed and hardened or freshly placed, on which floor topping is placed in a later operation; also the underlying stratum on which a concrete slab, such as a pavement, is placed. [ACI]

BEARING: A general term applied to a device or assemblage designed to transmit a reaction from one member or part of a structure to another and to permit the longitudinal movements resulting from temperature changes and superimposed loads without transmitting a horizontal force to the substructure. Bearings can be further described as rocker, roller, or shoe types. [B]

BEND TEST: See **FLEXIBILITY TEST**.

BINDER: (1) Nonvolatile portion of the liquid vehicle of a coating. It binds or cements the pigment particles together and the paint film as a whole to the material to which it is applied. See **NONVOLATILE VEHICLE**. [CED] (2) Cementing material, either hydrated cements or products of cement or lime and reactive siliceous materials; the kinds of cement and curing conditions govern the general kind of binder formed; also materials such as

asphalt, resins, and other materials forming the matrix of concretes, mortars, and sanded grouts.

BIOFOULING: Biological encrustation of surfaces in sea water by flora and fauna, e.g., barnacles.

BISPHENOL A: Dihydroxydiphenyldimethylmethane, mol. wt. 224.1. Insoluble in water. Used in the manufacture of phenolic and epoxy resins. Condensation product formed by reaction of two (bis) molecules of phenol with acetone. This polyhydric phenol is a standard resin intermediate, along with epichlorhydrin, in the production of epoxy resins. [CED]

BISPHENOL A EPICHLOROHYDRIN: Chemical name of epoxy resin which is reacted with amines and other curing agents to form epoxy based coatings.

BISPHENOL F: Dihydroxydiphenyldimethylmethane. Used in the manufacture of phenolic and epoxy resins. Condensation product of the reaction of two molecules of phenol with formaldehyde.

BLACK LIGHT: Popular term for ultraviolet (UV) radiation without any visible radiation. Syn: ultraviolet (UV) radiation. [CED]

BLAST POT: A container that holds abrasive material until it is mixed with compressed air in air abrasive blast cleaning systems. [IM]

BLASTING PRESSURE: The pressure, usually expressed in pounds per square inch (PSI) or kiloPascals (kPa), of an air and abrasive mixture as it passes through the nozzle of an abrasive blasting system.

BLEACH ROOM: In pulp and papermaking, the area or building where the pulp is exposed to different oxidizing chemicals to change the pulp color from the brown of wet cardboard to the bright white common on writing and publishing papers. This is accomplished in a series of successive stages, with each stage having a given chemical and pulp color associated.

BLEACH SOLUTION: A water solution of sodium hypochlorite, often called household bleach. It is a disinfectant and mildewcide used as a surface treatment for removing mildew and bacteria before painting. [IM]

BLEACHMAKING AREA: In pulp and papermaking, a chemical manufacturing facility typically within the pulp mill area where raw chemical materials are converted to bleaches and oxidizing chemicals for the bleach room. This area often includes a generator to produce chlorine dioxide from the reaction of commercially available raw materials.

BLISTERING: (1) Formation of dome-shaped projections in paints or varnish films resulting from local loss of adhesion and lifting of the film from an underlying paint film (intercoat blistering) or the base substrate. The standard test method for evaluating the degree of blistering of paints is described in ASTM D 714. [IM, V1] (2) The irregular raising of a thin layer at the surface of placed mortar or concrete during or soon after completion of the finishing operation, or in the case of pipe after spinning; also bulging of the finish plaster coat as it separates and draws away from the base coat. [ACI]

BLOCK FILLER: An emulsion that is heavily pigmented, usually with a finely divided silica flour. Block filler is sprayed or rolled onto a surface with a medium- to long-nap roller to work it into the pores of cinder or concrete block. [IM]

BLOTTER PAPER: Soft, spongy, absorbent paper.

BLOTTER TEST: The test for checking the cleanliness of compressed air supply as it reaches the blasting nozzle (described in ASTM D 4285).

BLOW HOLE: See BUG HOLE.

BLOWDOWN: The removal of dust from a surface by using a stream of clean compressed air.

BLUSHING: Film defect which appears as a milky opalescence as the film dries; can be a temporary or permanent condition. It is generally caused by rapid evaporation, moisture, or incompatibility. [CED]

BOLTED CONNECTION: A mechanical fastening (connection) consisting of a threaded metal rod or pin (bolt) joined to a metal nut.

BOOTTOP: The area on the exterior hull of a ship between the light load line and the deep load line. The boottop will be fully immersed when the cargo is fully

loaded and above water when the vessel is lightly loaded. This area is exposed to sun, wind, and water when light and to immersion when fully loaded.

BOSUN'S CHAIR: A rigging device suspended from a single cable or rope and designed for use by a single individual, who is limited to working in a sitting position. It allows access to high work areas and provides good maneuverability and accessibility to areas not easily reached by larger scaffolding systems. [IM, V1]

BOXING: Pouring paint from one container into another several times to assure that no unmixed material remains on the bottom and that the paint is uniformly mixed. [IM, V1]

BRACKISH: (1) Contaminated with salt water. (2) Partly fresh and partly salt water.

BREATHING-TYPE COATING: A coating that is sufficiently permeable to permit transmission of water vapor without detrimental effect to itself. [CED]

BRESLE SAMPLER: A latex rubber cell which adheres to a surface, used to aid in the extraction of water-soluble surface contaminants.

BRIDGE: A structure providing a means of transit for pedestrians and/or vehicles above the land and/or water. In general, the essential parts of a bridge are: 1) the substructure consisting of its abutments and pier or piers supporting the superstructure, 2) the superstructure slab, girder, truss, arch or other span or spans supporting the roadway loads and transferring them to the substructure, and 3) the roadway and its incidental parts functioning to receive and transmit traffic loads. [B]

BRIDGE DECK: The portion of a bridge that provides direct support for vehicular and pedestrian traffic. The deck may be either a reinforced concrete slab, timber flooring, a steel plate or grating, or the top surface of abutting concrete members or units. While normally distributing load to a system of beams and stringers, a deck may also be the main supporting element of a bridge, as with a reinforced concrete slab structure or a laminated timber bridge. [B]

BROOKFIELD VISCOMETER: A viscometer in which a cylinder or disk is rotated in a test liquid, and the torque

necessary to overcome viscous resistance is measured. ASTM D 2196 covers the determination of the apparent viscosity and the shear thinning and thixotropic properties of non-Newtonian materials in the shear range of 0.1 to 50 s⁻¹. [CED]

BRUSH BLASTING: See BRUSH-OFF BLAST CLEANING.

BRUSH DOWN: To remove dust from a surface by using a clean, soft brush.

BRUSH-OFF BLAST CLEANING: Blast cleaning standard with the lowest quality requirements. According to SSPC-SP 7, "Brush-Off Blast Cleaning," a brush-off blast cleaned surface is free of all visible oil, grease, dirt, dust, loose mill scale, loose rust, and loose paint. Tightly adherent mill scale, rust, and paint may remain on the surface. Brush-off blast cleaning is also defined in NACE No. 4. [IM]

BRUSHOUT: The application of paint on a small surface for testing. [DAC, CED; reproduced with permission from the McGraw-Hill Companies, from the Dictionary of Architecture and Construction, C.M. Harris, Ed., 1975.]

BUG HOLE: Small regular or irregular cavity (also called blow hole), usually not exceeding 15 mm in diameter, resulting from entrapment of air bubbles in the surface of formed concrete during placement and consolidation. [ACI].

BULKHEAD: (1) An upright partition or wall separating compartments, as in a ship's hold. (2) Wall retaining soil along waterfront.

BURNISH: To polish or rub to a smoother or glossier surface. [CED]

BUTTER: To spread mortar on bricks or tile.

BWR: See BOILING WATER REACTOR.

CABLE-STAYED BRIDGE: A bridge type for medium spans in which the decking is suspended by diagonal cables attached directly to the supporting tower.

CADMIUM: Toxic heavy metal. Cadmium compounds have been used as color pigments (e.g., orange, red, yel-

low) often mixed with other heavy metal compounds. Their use in coatings is restricted by some governmental agencies because of toxicity concerns.

CALCIUM CARBONATE: A white crystalline substance used as an extender pigment. Also known as calcite, marble dust, carbonate of lime, English whiting, limestone, and cliffstone whiting. [PDC, IM]

CALCIUM HYPOCHLORITE: A white powder used especially as a bleaching agent and disinfectant; also called bleaching powder.

CALCIUM OXIDE: CaO. Chemical name for lime or quicklime.

CALIBRATE: To check, adjust, or determine by comparison with a standard. [CED]

CALIBRATION PLATES: Precision plates used for calibrating magnetic dry film thickness gages. Most commonly used standard plates are from NIST.

CALIBRATION SHIMS: Small color coded shims, usually of plastic, of various thicknesses that are used for calibrating Type II (fixed probe) magnetic dry film thickness gages.

CANAL: An artificial channel or waterway constructed to contain and/or transport water for the purposes of navigation, irrigation, etc.

CANTILEVER BRIDGE: A general term applying to a bridge having a superstructure of the cantilever type, which has a girder or truss having its members or parts so arranged that one or both of its end portions extend beyond the point or points of support. [B]

CARBON BLACK: Finely divided carbon formed by any one of several processes. Synonym: gas black. These carbon blacks vary in particle size and some of them may be surface treated. [CED]

CARCINOGEN: A material that either causes cancer in humans, or, because it causes cancer in animals, is considered capable of causing cancer in humans. [CED]

CATALYST: A reaction promoter. A substance that induces, alters, or accelerates a chemical reaction. A true

catalyst is unchanged by the reaction it creates. In the paint industry, catalysts (also called activators, accelerators, and promoters) are used to speed the curing or crosslinking of certain coatings. Curing agents and hardeners (which enter into chemical reactions) are also sometimes (incorrectly) referred to as catalysts. [IM, V1]

CATHODE: The electrode of an electrolytic cell at which reduction is the principal reaction. (Electrons flow toward the cathode in the external circuit.) Typical cathodic processes are cations taking up electrons and being discharged, oxygen being reduced, and the reduction of an element or group of elements from a higher to a lower valence state. Contrast with ANODE. [ASM]

CATHODIC DISBONDING: Mechanical lifting of a coating caused by hydrogen bubbles formed when cathodic protection is excessive.

CATHODIC PROTECTION: (1) Reduction of corrosion rate by shifting the corrosion potential of the electrode toward a less oxidizing potential by applying an external electromotive force. (2) Partial or complete protection of a metal from corrosion by making it a cathode, using either a galvanic or an impressed current. [ASM]

CATWALK: A narrow walkway for access to some part of a structure. [B]

CAULK: See CAULKING COMPOUND.

CAULKING COMPOUND: A soft, plastic, putty-like material, consisting of pigment and vehicle, used for sealing joints in buildings and other structures where normal structural movement may occur, or for preventing leakage.

CAUSTIC: A strong chemical base. [CED]

CAUSTICIZING AREA: A chemical manufacturing and reprocessing area within a pulp and papermaking facility where the green liquor from the recovery boiler smelt dissolving tanks and clarifier is converted back to the white cooking liquor.

CEMENTITIOUS: Having cementing properties. [ACI]

CENTRIFUGAL WHEELS: Finned wheels on abrasive blasting equipment that pick up and hurl abrasive at high

speeds onto the steel plates or shapes in a centrifugal blasting machine. See **ABRASIVE BLAST CLEANING**.

CERAMIC: Producing fired clay and porcelain articles, their glazes, pigments, and modifiers. Relating to a product of clay fired at high temperatures. [CED]

CHALKING: (1) Formation of a friable powder on the surface of a paint film caused by the disintegration of the binding medium due to ultraviolet light breaking chemical bonds in the binder. The chalking of a paint film is dependent upon the binder and pigmentation, as well as the intensity of the ultraviolet light. The standard test method for evaluating degree of chalking is described in ASTM D 4214. (2) Formation of a loose powder resulting from the disintegration of the surface of concrete or of applied coating, such as cement paint. [ACI]

CHECKING: (1) The development of breaks in the surface of a coating film that do not penetrate to an underlying coating or the substrate. If an underlying coating or the substrate is visible, the breaks are called "cracks." Checking can be visible or microscopic. See also **CRACKING**. The standard test method for evaluating degree of checking is described in ASTM D 660. [IM, V1] (2) Development of shallow cracks at closely spaced but irregular intervals on the surface of plaster, cement paste, mortar, or concrete. [ACI]

CHEMICAL RESISTANCE: The ability of a material to resist degradation by reaction with, dissolution by, or reduction of physical continuity from contact with a chemical agent or agents, thereby retaining its capacity to perform as a structural or aesthetic entity. The standard test method for chemical resistance of coatings is described in ASTM D 3912.

CHEMICAL TREATMENT TANKS: Tanks used for the storage of the various chemicals in either the water treatment or waste water treatment process. They may also be part of the process system as to where the chemicals are injected into the tanks as the water passes through them.

CHILLED IRON: A metallic abrasive prepared by channeling molten metal into streams, which then drop onto jets of water under pressure, atomizing the molten metal into random sizes of shot that fall into a water-filled quenching pit.

CHIPPING: (1) Cleaning steel by removing paint or rust and scale, using a special "chipping" hammer. (2) Flaking deterioration of dried paint film, usually as a result of damage, impact, or wear. The ability of a coating or layers of coatings to resist total or partial removal, usually in small pieces, resulting from impact by hard objects or from wear during service. [IM, V1] (3) Treatment of a hardened concrete surface by chiseling. [ACI]

CHLORIDE ION: Negatively charged ion (Cl^-) derived from the element chlorine.

CHLORINATION: In wastewater treatment plants, chlorination is used as a pretreatment to keep wastewater fresh or from turning "septic" before it gets to the treatment plant. Chlorination is then used in the post treatment for disinfecting the water and for oxidation, which enhances the sedimentation process. In water treatment facilities and swimming pools, chlorination it is used primarily for disinfecting the water.

CHORD: In a truss, the upper and the lower longitudinal members, extending the full length of the bridge. [B]

CHROMATE: One of a class of chemical compounds of chromium. Chromate pigments have been used as colored hiding pigments and/or inhibitive pigments. They are suspected to be carcinogens, so their use is being greatly reduced.

CHROMIUM: Metal whose salts (chromates) are sometimes used as pigments in primers for corrosion control.

CHUTE: (1) In pulp and papermaking, a bulk solids transfer device for moving material from one location to another. For example, a chute may transfer woodchips from the discharge of a belt into a vessel or storage bin. (2) A sloping trough or tube for conducting concrete, cement, aggregate, or other free flowing materials from a higher to a lower point. [ACI]

CIGARETTE WRAP: A coating application technique in which a rectangular sheet is applied to a pipe so that the edges are parallel and at right angles to the pipe axis, much like rolling a homemade cigarette. The edges that are parallel to the pipe axis form a longitudinal seam with a specific amount of overlap. If additional sheets are applied to cover more area, they are overlapped at circumferential joints.

CLARIFIER: In pulp and papermaking, the clarifier is an active process tank which allows solids to settle out of solution while clean or clarified liquid is tapped off the top at an overflow weir. The solids or underflow is pumped from the bottom and returned further back in the process flow. The clarified liquid is pumped to the next processing step. Clarifiers resemble atmospheric storage tanks but have an active process step occurring within the vessel. In water and wastewater treatment, there are several clarifiers. In the primary clarifier, floating solids are removed from the top of influent water, and the heavy sediment is removed from the bottom of the clarifier. In the secondary clarifier, sometimes referred to as the flocculation basin, flocculation takes place.

CLEAN AIR ACT: US Congress legislation designed to protect ambient air from pollution. The Clean Air Act, as amended, provides the foundation for EPA's efforts to improve air quality. The CAA, building on earlier legislation, was passed in 1970, and was amended in 1977 and again in 1990. The Clean Air Act is found in 40 CFR Subchapter C, "Air Programs," encompassing Parts 50 through 99. [V1]

CLOSED BLAST CLEANING: See AIR ABRASIVE BLAST CLEANING.

COALESCENCE: The formation of a film of resinous or polymeric material when water evaporates from an emulsion or latex system, permitting contact and fusion of adjacent latex particles. Action of the joining of particles into a film as the volatile evaporates. [DAC, CED; reproduced with permission from the McGraw-Hill Companies, from the Dictionary of Architecture and Construction, C.M. Harris, Ed., 1975.]

COAL TAR: A dark brown to black cementitious material produced by the destructive distillation of bituminous coal. [ASTM]

COEFFICIENT OF THERMAL EXPANSION: Change in unit of length (or volume) accompanying a unit change of temperature, at a specified temperature. [ASTM]

COHESION: Propensity of a single substance to adhere to itself; the internal attraction of molecular particles toward each other; the ability to resist partition from the

mass; internal adhesion; the force holding a single substance together. [CED]

COHESION FAILURE: A failure or break within a given coat or material (the coating breaks within itself). See ADHESION TEST, TENSILE (PULL-OFF).

COIN RUB TEST: A method of testing the cure of inorganic zinc-rich coatings.

COKE OVEN TARS: Tars distilled from coal during the production of coke.

COLD ROOM: A room or area where perishables are stored, usually between 32 and 45°F (0 and 7°F).

COMBUSTIBLE: Capable of burning. Combustible liquids are those having a flash point at or above 140°F (60°C).

COMMERCIAL BLAST CLEANING: Moderate grade of blast cleaning. According to SSPC-SP 6/NACE No. 3, Commercial Blast Cleaning, a commercial blast cleaned surface is free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter; staining is limited to no more than 33 percent of each unit area of surface. [IM]

COMPARATOR: See SURFACE PROFILE COMPARATOR.

COMPRESSIVE STRENGTH: (1) Maximum compressive stress which a material is capable of developing. [CED] (2) The measured maximum resistance of a concrete or mortar specimen to axial compressive loading; expressed as force per unit cross-sectional area; or the specified resistance used in design calculations. [ACI]

CONCRETE: A composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate, usually a combination of fine aggregate and coarse aggregate; in portland-cement concrete, the binder is a mixture of portland cement and water. [ACI]

CONCRETE MIX: A mixture of cement, aggregate, water, and possibly admixtures.

CONCRETE SPATTER: Solid particles of concrete formed on a surface by curing of liquid concrete mix splashed onto it.

CONDUCTIMETRIC ANALYSIS: Chemical analysis made by determining the electrical conductivity of a solution.

CONDUCTIVE: Able to conduct electricity or heat.

CONDUCTIVITY: See ELECTRICAL CONDUCTIVITY.

CONDUCTIVITY METER: Field or laboratory instrument for measuring total electrical conductivity of an aqueous solution.

CONFINED SPACE: An area that may be hazardous because a limited number of openings could make escape difficult in an emergency, and because ventilation may be inadequate to support life. The space may also present unknown hazards such as toxic or caustic chemicals. [V] The legal definition of a confined space (29 CFR 1910.146) is one that is large enough and so configured that an employee can bodily enter and perform assigned work; has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits); and is not designed for continuous employee occupancy.

CONSTANT PRESSURE PROBE GAGE: See MAGNETIC FIXED PROBE GAGE, TYPE 2.

CONTACT THERMOMETER: A magnetic thermometer which is placed directly onto the steel surface to determine surface temperature. See also NON-CONTACT THERMOMETER.

CONTAINMENT: (1) A method to limit dust, debris, paint chips, paint dust, spent abrasives, and overspray from contaminating the environment. The type, concentration, and toxicity of the contamination determines the extent of containment required. Typical types of containment systems include free-hanging enclosures, partial structure enclosures, and total structure enclosures with or without negative pressure. [IM] (2) Hermetically sealed portion within the reactor building of a nuclear power plant which contains the nuclear reactor.

CONTROL GATE: On a lock, a gate that moves in either a vertical or horizontal direction (depending on its type) and controls the passage of water, thereby maintaining a desired water level either upstream or downstream. If valves are used for this purpose, they are referred to as control valves. Relatively small control gates in a lock are referred to as wickets.

CONTROL OF SUBSTANCES HAZARDOUS TO HEALTH (COSHH): British law, established in 1988 as an addition to the Health and Safety at Work Act, 1974.

CONVERSION COATING: A treatment, either chemical or electrochemical, of the metal surface to convert it to another chemical form which provides an insulating barrier of exceedingly low solubility between the metal and its environment, but which is an integral part of the metallic substrate. [CED]

CONVERTIBLE COATING: Irreversible transformation of a coating after its film formation to a film insoluble in the solvent from which it was deposited. This should not be confused with chemical conversion coating. See THERMOSETTING. [CED]

CONVEYOR EQUIPMENT: In pulp and papermaking, conveyor equipment typically includes the belts, rollers, bearings, motors, chutes, and bridge structure for moving solid materials around the mill.

CO-REACTANT: One of two or more chemical materials formulated to react with each other to produce a desired end product.

COSHH: See CONTROL OF SUBSTANCES HAZARDOUS TO HEALTH

COSOLVENT: A solvent, sometimes called a coupling agent, that allows the mixing of two immiscible liquids. [IM, VI]

COUPLANT: A substance used between the probe and test surface to permit or improve transmission of ultrasonic energy of an ultrasonic thickness gage.

COUPLING AGENT: See COSOLVENT.

CRACKING: (1) The splitting of a dry paint film, usually the result of continuing curing or aging that causes the film

to become hard and brittle. Different types of cracking include hair-cracking or hairlines, checking, cracking, crazing, crocodiling or alligatoring, and mud cracking. The standard test method for evaluating degree of cracking is described in ASTM D 661. (2) To break up into simpler chemical components, as with cracking of petroleum

CREVICE: A narrow opening; fissure.

CROSSCUT ADHESION TEST: See ADHESION TEST, CROSSCUT

CROSSHATCH TEST: See ADHESION TEST, CROSSCUT.

CROSSLINKING: Applied to polymer molecules, the setting up of chemical links between the molecular chains to form a three-dimensional or network polymer generally by covalent bonding. [CED]

CURB INLET: See SCUPPER.

CURING: (1) The process by which a coating changes from a liquid state into a dry, stable, solid protective film. Curing of a coating may involve chemical reaction with oxygen, moisture, or chemical additives, or the application of heat or radiation. [IM, V1] (2) The maintenance of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties may develop. [ACI]

CURING AGENT: An additive component, sometimes called a hardener or (incorrectly) a catalyst, that helps a coating film or concrete cure by chemical reaction. Compare CATALYST.

CURING COMPOUND: A liquid that can be applied as a coating to the surface of newly placed concrete to retard the loss of water or, in the case of pigmented compounds, also to reflect heat so as to provide an opportunity for the concrete to develop its properties in a favorable temperature and moisture environment. [ACI]

CUT BACK: A solution of a coating binder material (e.g., coal tar or asphalt) in an organic solvent to provide easy application of a film.

dB: See DECIBEL.

DBA: See DESIGN BASIS ACCIDENT.

DEAD MAN'S CONTROL: Safety cut-out device at blast nozzle connected to pressure relief valve on blast-pot (blast-kettle). May be air operated or electrical. Pressure of blasting operative's hand maintains pressure and allows blast equipment to operate.

DECHLORINATION: In wastewater treatment plants, treatment to reduce the chlorine level of the effluent water before it is discharged. This can be done by injecting the effluent with sulfur dioxide gas (at a 1:1 ratio to the amount of chlorine injected previously) as it leaves the chlorine contact basins. Dechlorination is then completed by aerating the water either through a cascade system or air injection.

DECIBEL: Abbreviated dB, unit of measurement for sound intensity.

DECK: On a ship, the main deck is the horizontal surface exposed to the weather. There are other exterior decks, such as forecastle decks, poop decks, boat decks, bridge decks, and other levels of decks, depending on the type of vessel. Interior decks are the floors to the inside spaces, which are exposed to different environments, such as engine rooms, store rooms, workshop rooms, laundry, kitchen, etc. Interior decks of ships are not discussed in this book, because their coating is outside of its scope.

DE-ICING SALTS: Salts added to roads or other surfaces to melt ice by lowering its freezing point; they are very corrosive to steel in bridge structures.

DELAMINATION: (1) The separation of a coat or coats of paint from the previous coat or from the substrate. Failure of a coating to adhere to the previous coating. [IM, V1] (2) In the case of a concrete slab, a horizontal splitting, cracking, or separation of a slab in a plane roughly parallel to, and generally near, the upper surface; found most frequently in bridge decks and caused by the corrosion of reinforcing steel or freezing and thawing; similar to spalling, scaling, or peeling except that delamination affects large areas and can often only be detected by tapping. [ACI]

DENSITY: A measure of mass per unit volume. The density of paint usually is expressed as pounds per gallon or kilograms per liter. [IM]

DEPTH GAGE: Instrument for measuring depth of a pit or crevice.

DEPTH MICROMETER: See DEPTH GAGE.

DESIGN BASIS ACCIDENT (DBA): In nuclear power plants, the worst potential accident that could occur in a given system or component. The design basis accident for the containment, since it is a pressure vessel, is the circumstance that creates the worst pressure, the Loss of Coolant Accident (LOCA).

DESTRUCTIVE DRY FILM THICKNESS GAGE:
See DRY FILM THICKNESS GAGE, DESTRUCTIVE.

DETACHMENT: Disbondment of one coat or a number of coats from the undercoat or the substrate; also called delamination.

DETECTOR TUBE: Glass tube (e.g. Draeger tube) with indicator chemicals, set to react at specific levels of gaseous content when air drawn through it. There are a number of detector tubes available, e.g., for carbon monoxide, acetone, methylene chloride, oxygen, and methylethyl ketone.

DETERGENT CLEANING: Removing contamination from a surface using an aqueous solution of a surface-active agent.

DE-WATERING: (1) Term describing a type of accident in a nuclear power plant in which water spills from the system to the extent that the fuel in the reactor is no longer immersed. (2) The removal of water from drydocks, locks, or other containments.

DEW POINT: That temperature at which water pressure present in the atmosphere is just sufficient to saturate it. When air is cooled below the dew point, the excess of water vapor appears as tiny water droplets or crystals of ice depending on the temperature of the air mass. [IUPAC, CED]

DFT: See DRY FILM THICKNESS.

DIAGONAL: A structural member of the bridge transversing from one side of the structure to the other at an angle near 45 degrees. Angular cross braces (struts) are often smaller angular or rod structural members, often in

an "X" or cross pattern, used to provide structural strength between parallel girders. [B]

DIAPHRAGM: Transverse structural members that furnish lateral support to beams. [B]

DIGESTER: In pulp and papermaking, the digester is a large, cylindrical, vertical pressure vessel where the wood chips are steamed with the caustic cooking solutions to remove the lignin. In wastewater treatment, the digester is where organic matter in the sludge is decomposed by anaerobic bacteria, releasing a mixture of burnable gases.

DIRECT FOOD CONTACT SURFACE: Any surface which is designed to be in direct contact with food for human consumption during any part of processing.

DISBONDING: Failure of a coating to adhere to a substrate to which it is applied. Intercoat disbonding is the failure of a coating to adhere to a previous coating layer or to the substrate to which it has been applied. Intracoat disbonding is the failure of a coating layer to cohere or hold itself together. See ADHESION, COHESION and DETACHMENT. [IM, V1]

DISCONTINUITY: See HOLIDAY.

DISSIMILAR METAL CORROSION: See GALVANIC CORROSION.

DOLLY: See PULL STUB.

DOMESTIC TEST: Method of measuring moisture content of concrete area enclosed in a glass or plastic dome.

DOUBLE RUB: The act of rubbing a solvent saturated cloth in one complete forward and backward motion over the coated surface. [CED]

DRAWBRIDGE: A general term applied to a bridge over a navigable stream, river, lake, canal, tidal inlet, or strait having a movable superstructure span of any type permitting the channel to be freed of its obstruction to navigation. [B]

DRY BULB TEMPERATURE: The temperature recorded by the dry bulb thermometer of a psychrometer. [IM]

DRY BULB THERMOMETER: The thermometer on a sling or other psychrometer whose bulb is directly exposed to the air (i.e., not covered with a wet sock). See PSYCHROMETER.

DRY DOCK: A containment in which ships are lifted above water or from which water is removed to permit for construction or repair of areas normally immersed. A graving dock is a particular type of dry-dock that is enclosed by means of gates or caissons.

DRY FILM THICKNESS (DFT): Depth of cured film, usually expressed in mils (0.001 inch) or micrometers (millionths of a meter). Standard methods for measuring dry film thickness are defined in SSPC-PA 2, ASTM D 1005, ASTM D 1186, and ASTM D 1400.

DRY FILM THICKNESS GAGE: An instrument used to measure the dry film thickness of a coating.

DRY FILM THICKNESS GAGE, DESTRUCTIVE: Instrument used to destructively determine the dry film thickness as described in ASTM D 4138. It is capable of measuring the thickness of individual layers of paint.

DRY FILM THICKNESS GAGE, EDDY CURRENT: A type of dry film thickness gage that can be used to measure the thickness of non-conductive coatings on non-ferrous metal substrates.

DRY FILM THICKNESS GAGE, MAGNETIC: One of the different types of gages designed to determine the dry film thickness of coatings on a steel substrate. See BANANA GAGE; MAGNETIC FIXED PROBE GAGE, TYPE 2; MAGNETIC PULL-OFF GAGE, TYPE 1; and PENCIL-TYPE PULL-OFF GAGE.

DRYING OIL: An oil that possesses to a marked degree the property of readily taking up oxygen from the air and changing to a relatively hard, tough, elastic substance when exposed in a thin film to the air. [ASTM]

DRY SPRAY: (1) A rough, powdery, non-coherent, discontinuous film produced when an atomized coating partially dries before reaching the surface. (2) Overspray or bounce back falling dry on unintended surfaces and producing an adherent, sand-like covering. [IM]

DRY WALL: Prefabricated cementitious construction material for walls of buildings or housing.

DUCTILITY: Tendency of a material to undergo deformation and extension without cracking or splitting. [CED]

DURABILITY: A term indicating degree of permanency, used to describe individual properties, such as the durability of gloss, or general characteristics, such as the durability of a paint. [IM]

DUROMETER HARDNESS: An arbitrary numerical value which measures the resistance to indentation of the blunt indenter point of the durometer. The value may be taken immediately or after a very short specified time. [ASTM]

DUROMETER: Instrument for measuring the surface hardness of rubber, plastic, or protective coatings. See DUROMETER HARDNESS. [CED]

EDDY CURRENT GAGE: See DRY FILM THICKNESS GAGE, EDDY CURRENT.

EDDY CURRENT TESTING: Determining a coating dry film thickness on certain metals by measuring opposing electrical (eddy) currents produced by the gage.

EDGE FAILURE: A type of coating adhesion failure in which undercutting (penetration of corrosion underneath the coating) occurs at an unprotected or incompletely protected edge.

EFFLORESCENCE: A deposit of salts, usually white, formed on a surface, the substance having emerged in solution from within either concrete or masonry and subsequently been precipitated by evaporation. [ACI]

EFFLUENT: Any spent liquors or other waste material which are emitted by a source (waste from plating shops, pickling tanks, sewage treatment plants, chemical manufacturing plants, etc.). [IUPAC, CED]

ELASTOMERIC: Rubberlike; relating to or having the properties of elastomers. [CED]

ELECTRICAL CONDUCTIVITY: The property of a fluid or solid that permits the passage of an electrical current as a result of an impressed emf. It is measured by the

quantity of electricity transferred across unit area per unit potential gradient per unit time. (In sampling and analysis, changes in this property are utilized to measure the presence of certain ions and compounds such as sulfur dioxide.) [ASTM]

ELECTRIC ARC GUN: A type of thermal spraying equipment in which a metal wire is melted continuously by electric arc and then atomized by an air jet. An electric arc gun is less maneuverable than an oxy-fuel gas gun, but the deposit rate of the metal is two to three times greater. See THERMAL SPRAYING. [IM]

ELECTROSTATIC PRECIPITATOR: An electrical device used to attract and separate suspended particles from an exhaust system

ELECTROSTATIC SPRAYING: A method of applying a spray coating in which charged particles of paint are attracted to a grounded, conductive substrate. The mist travels around corners of the substrate with the result that the article is coated more uniformly on all sides and edges with very little overspray and bounce back. [IM, V1]

ELONGATION: A method of measuring coating flexibility; the increase in specimen length from the point of initial load application to the point of film rupture in a tension test. ASTM D 2370 covers the measurement of elongation as well as tensile strength and stiffness (modulus of elasticity) of organic coatings when tested as free films. [ASTM, CED]

EMULSION: Two-phase liquid system in which small droplets of one liquid (the internal phase) are immiscible in, and are dispersed uniformly throughout, a second continuous liquid phase (the external phase). [CED]

EMULSION PAINT: Paint, the vehicle of which is an emulsion of binder in water. The binder may be oil, alkyd, resinous varnish, resin, or other emulsifiable binder. Not to be confused with a latex paint in which the vehicle is a latex. [CED]

ENAMEL: A finish coat of paint that dries to a smooth, gloss surface. [IM]

ENCAPSULATION: The process of enclosing a surface, especially of one containing hazardous materials, on all

sides. Encapsulants include drywall, fiber-filled coatings, wood, or other materials. [IM]

ENGINEERING STANDARD: A type of document that provides options for construction work such as coating different types of structures.

EPICHLORHYDRIN: A chemical used in the production of epoxy resins

ETCHING: Making a physical impression on a surface, usually roughening, with a chemical agent such as acid; often done to increase coating adhesion. See ACID ETCHING.

EXOTHERMIC REACTION: Chemical reaction that produces heat.

EXPANSION DAM: The part of an expansion joint serving as an end form for the placing of concrete at a joint. Also applied to the expansion joint device itself. [B]

EXPANSION JOINT: (1) A separation provided between adjoining parts of a structure to allow movement where expansion is likely to exceed contraction; (2) A separation between pavement slabs on grade, filled with a compressible filler material; (3) An isolation joint intended to allow independent movement between adjoining parts. [ACI]

EXPOSURE: Placement of a specimen in test conditions. [IM]

EXTRUSION: The process of forcing a material (extruding) through a die; also the finished product itself. See RING EXTRUSION PROCESS and SIDE EXTRUSION PROCESS.

FABRICATED STRUCTURAL STEEL: Steel members made by fastening steel shapes such as plates and angles, together by riveting, bolting, or welding. [B]

FASCIA GIRDER: An exposed outermost girder of a span sometimes treated architecturally or otherwise to provide an attractive appearance. [B]

FATHOMETER: Sonic instrument for determining depth under water; depth finder.

FBE: See FUSION BONDED EPOXY.

FEATHER EDGING: (1) Reducing the thickness of the edge of a dry paint film, such as the edge of a damaged area, by sanding or rubbing down prior to repainting. (2) Tapering the edges of a coat of wet paint by laying off with a comparatively dry brush. [MPDA, IM]

FERROUS: (1) A chemical compound that contains iron in the bivalent (2^+) state. (2) Any metal alloy based primarily on iron. [IM]

FGD: See FLUE GAS DESULFURIZATION.

FIBERGLASS: Glass in fibrous form used to provide reinforcement or other desirable properties to a variety of products such as coatings and linings.

FIBERGLASS-REINFORCED PLASTIC (FRP): Resin linings, usually polyester, vinyl ester, or epoxy, into which layers of fiberglass are incorporated to optimize the lining's performance. The abbreviation "FRP" is also used for "fiber-reinforced plastic," a general term for a composite that is reinforced with cloth, mat, strands, or any other fiber form.

FIELD STANDARD: A quality control reference product (e.g., surface) used for comparison to construction work at the job site.

FILLER: (1) A thick, pigmented material used to fill holes, defects, or pores in a surface before coating. See also BLOCK FILLER. [IM] (2) Finely divided inert material such as pulverized limestone, silica, or colloidal substances sometimes added to portland-cement paint or other materials to reduce shrinkage, improve workability, or act as an extender. (3) Material used to fill an opening in a form. [ACI]

FILLET WELD: A weld, approximately triangular in cross section, joining two surfaces essentially at right angles to each other in a lap, tee, or corner joint. [ASM]

FIN: A narrow linear projection on a formed concrete surface, resulting from mortar flowing into spaces in the formwork; also a type of blade in a concrete mixer drum. [ACI]

FINENESS OF GRIND: A numerical assessment of the degree of dispersion of pigment in the vehicle of a coating, or of the presence of coarse particles in pigmented coat-

ings as determined by the protrusion of particles or agglomerates through the wet film at a given thickness. [CFD]

FINES: Finely crushed or powdered material, such as blasting abrasive residues.

FINISH: (1) Final coat in a paint system. (2) Sometimes refers to the entire coating system: the texture, color, and smoothness of a surface, and other properties affecting appearance. [CED] (3) The texture of a concrete surface after compaction and finishing operations have been performed.

FINISHING: Leveling, smoothing, consolidating, and otherwise treating surfaces of fresh or recently placed concrete or mortar to produce desired appearance and service. [ACI]

FIXED PROBE GAGE: See MAGNETIC FIXED PROBE GAGE, TYPE 2.

FIXED SPAN: A superstructure span having its position practically immovable, as compared to a movable span. [B]

FLAKE-FILLED: Filled with flake-like materials such as a coating filled with micaceous iron oxide pigment to increase its barrier protection properties.

FLAME SPRAYING: The spray application of a coating whereby metal wire, metallic powder, or thermoplastic powder is melted using a spray gun with a torch-like flame and then sprayed with compressed air. See also METALLIZING, PLASMA SPRAYING, and THERMAL SPRAYING. [IM, V1]

FLAMMABILITY: Those characteristics of a material that pertain to its relative ease of ignition and relative ability to sustain combustion. [ASTM]

FLANGE: The projecting portion of a beam, channel, or column. [B]

FLASH POINT: The lowest temperature of a liquid at which it gives off sufficient vapor to form an ignitable mixture with the air near the surface of the liquid or within the vessel used. [CED] Materials with flash points below 100°F (38°C), such as most solvents and solvent-borne

coatings are considered dangerous. The standard method for flash point is defined in ASTM D 3941. [IM]

FLASH RUSTING: Rusting that occurs on metal within minutes to a few hours after blast cleaning or other cleaning is complete. The speed with which flash rusting occurs may be indicative of salt contamination on the surface, high humidity, or both. [IM, V1]

FLEXIBILITY: Degree to which a coating after drying is able to conform to movement or deformation of its supporting surface, without cracking or flaking. [CED]

FLEXIBILITY TEST: Test applied to cured films to determine if they are able to elongate without fracture or disbondment. Syn: Bend test. [CED] See ELONGATION.

FLINT ABRASIVE: Not flint at all, but actually a natural quartz (silicon dioxide) which fractures into sharp-edged grains and is used on the common sandpaper for wood. [CED]

FLOCCULENT: Having a loose, fluffy organization resembling wool. Used to describe degree of association of pigment suspended in paint vehicle.

FLOORBEAM: A beam or girder located transversely to the general alignment of the bridge. A floor beam at the extreme end of a girder or truss span is commonly termed an end floor beam. [B]

FLUE GAS DESULFURIZATION (FGD): Removal of sulfur-containing products from a chimney or other channel (flue) used to convey combustion gases to the outside of a structure.

FLUID TIP: The removable end of an air-spray gun from which the atomized paint is sprayed and in which the needle is seated. The fluid tip works in conjunction with the needle to regulate the flow of fluids before they are atomized. [IM]

FLUIDIZED BED COATING: Method of applying a coating in which a heated or electrostatically charged article is immersed or passed over a fluidized bed of powdered coating (the coating material adhering to the hot metal), then heated in an oven to provide a smooth, continuous film. [CED]

FLUORESCENCE: Optical phenomenon characterized by the reemission of absorbed radiant energy by certain chemicals or materials. [CED]

FLYASH: Fine particles remaining after burning of combustible materials.

FOG COAT: See MIST COAT.

FOOT CANDLE: Unit of illumination equal to one lumen per square foot. [ASTM] The preferred unit of illumination is the SI unit lux (one lumen per square meter).

FORM RELEASE AGENT: Compound such as petroleum oil, wax, and silicone applied to concrete forms to allow easy removal from poured concrete after it has cured. [IM]

FREEZER ROOM: A room where food or food ingredients are kept frozen, usually between 32 and -15°F (0 and -8°C).

FRP: See FIBERGLASS-REINFORCED PLASTIC.

FUSION BONDED EPOXY (FBE): A type of epoxy powder coating commonly applied to pipelines, rebar, etc.

GALVANIC CORROSION: Accelerated corrosion of a metal because of an electrical contact with a more noble metal or nonmetallic conductor in a corrosive electrolyte. [ASM] The term "dissimilar metal corrosion" is sometimes used when appropriate.

GALVANIC PROTECTION: (1) The selective use of galvanic corrosion to protect one metal from deterioration by connecting it to another, more active (electrically negative), sacrificial metal. Both metals must be in contact with the same body of an electrolytic solution. Zinc, magnesium, or aluminum can be used as sacrificial metals for the galvanic protection of steel. (2) Protection of a metal in contact with an electrolytic solution from corrosion by the use of an impressed direct electrical current. (3) Protection of steel by zinc-rich coatings. [IM, V1] See CATHODIC PROTECTION.

GALVANIZING: Applying a zinc coating to steel by dipping it in molten zinc or by depositing zinc on the steel electrolytically or mechanically. [IM]

GATE: A door or other device used to control passage; used on locks and dams to control passage of water.

GEL TIME: The period of time from the initial mixing of the reactants of a liquid material to the time when gelation occurs, as defined by a specific test method. [ASTM]

GENERIC: (1) Belonging to an entire class or group. (2) Non-proprietary. [IM]

GIRDER: A flexural member that is the main or primary support for the structure, and that usually receives loads from floor beams and stringers. Any large beam, especially if built up. [B]

GIRDER BRIDGE: A bridge whose superstructure consists of two or more girders supporting a separate floor system of slab and floor beams, or any bridge utilizing large, built-up steel beams, prestressed concrete beams, or concrete box girders. [B]

GLOSS: The degree to which a surface reflects visual images. Gloss is a direct function of coating formulation and the amount and size of pigment particles in the coating, the more pigment particles and the larger the diameter, the lower is the gloss. [IM]

GLYCOL: Synonym for dihydric alcohols; ethylene glycol is the most simple of the glycols. $\text{CH}_2\text{OHCH}_2\text{OH}$. [CED]

GOUGE HARDNESS: In determining coating hardness by pencil testing (ASTM D 3363) the gouge hardness is defined by the hardest pencil that will leave the film uncut. See also SCRATCH HARDNESS.

GRAVING DOCK: A fixed basin for dry-docking of ships, usually composed of stone masonry, reinforced concrete, or steel sheet piling cells near a waterway; it can be closed off from the waterway by a movable gate, usually a floating caisson. The vessel is floated in, the gates closed, and the water pumped out. The vessel is set on blocks, and the basin during pumping leaves the hull exposed for exterior painting or repairs.

GRIT: (1) An angular material with sharp, irregular edges obtained from slag, steel, minerals, and various other materials for use as a blast cleaning abrasive. (2) Small,

hard foreign particles sometimes found in paint and coating materials. [IM]

GRIT BLASTING: Blast cleaning using grit. See also GRIT and ABRASIVE BLAST CLEANING. [IM]

GROUT: A mixture of cementitious material and water, with or without aggregate, proportioned to produce a pourable consistency without segregation of the constituents; also a mixture of other composition but of similar consistency. [ACI]

GUNITE: A proprietary term for shotcrete. [ACI]

GUSSET PLATE: A plate serving to connect or unite the elements of a member or the members of a structure and to hold them in correct alignment and/or position at a joint. [B]

HACKLE: Thin, needle-like or sliver-like protrusion, ranging from 3 to 6 mils (75 to 150 micrometers), found on steel plates that have been blast cleaned with steel shot or grit. [IM, V1]

HAND TOOL CLEANING: The use of manually operated impact, scraping, sanding, and brushing tools to remove loose paint, loose rust, and loose mill scale. Such tools include slag hammers, chipping hammers, scrapers, and wire brushes. The specification SSPC-SP 2, "Hand Tool Cleaning," is a consensus standard covering the procedures necessary for hand-tool cleaning of steel surfaces. [IM]

HARDENER: (1) Chemical agent used to promote or control the hardening or curing reaction in coating or resin systems. See CURING AGENT. (2) A chemical (including certain fluosilicates or sodium silicate) applied to concrete floors to reduce wear and dusting. [ACI]

HARDNESS: The property of a coating that allows it to resist damage or abrasion. [IM]

HARDNESS TESTING, PENCIL METHOD: A method of testing coating hardness that uses a series of pencils (actually leads) of different hardness. The object of pencil testing is to determine which pencil will not cut through the coating and which pencil will not scratch the coating (they may be the same pencil). The hardest pencil that will leave the film uncut defines the gouge hardness;

the hardest pencil that will not scratch the film defines the scratch hardness. This method is defined in ASTM D 3363.

HATE: See HYDRAULIC ADHESION TEST EQUIPMENT.

HAZARDOUS WASTE: A solid waste, including liquid waste, that exhibits any of the following hazardous characteristics: ignitability, corrosivity, reactivity, or toxicity, as defined in 40 CFR 261, "Identification and Listing of Hazardous Waste," or that is on a special list established by EPA. [ILPR, IM, V1]

HAZCOM: US regulations governing hazardous chemicals in the workplace, issued by OSHA in 1983; also known as the "Right-to-Know" regulations. The purpose of HAZCOM is to ensure that workers are informed about chemical hazards in the workplace, and that they are provided with information and training in how to safely handle the chemicals.

HEAT RESISTANCE: The ability of a coating to resist deterioration when exposed continuously or periodically to high temperatures at or below a given level, which depends on the binder type and other coating ingredients. [IM]

HEAT-SHRINK SLEEVE: Sleeve, usually plastic, that is placed around a structural component and shrunk in place by heating.

HEAVY METAL: Metallic element of high molecular weight, compounds of which are often toxic.

HIDING POWER: The ability of a coat of paint that has been properly applied to obscure (hide) a surface or a previous coating on the surface. [IM, V1]

HIGH SOLIDS COATING: A coating with a high non-volatile content. Sixty percent solids sometimes is used as a benchmark measurement, at or beyond which a coating is said to be high solids. Generally, a coating that contains at least 70% solids by volume. The term "higher solids," is more appropriate for coatings which have a higher percentage of solids than previous (conventional) formulations but still contain less than 70% solids by volume.

HOG: The upward curvature of a ship's bottom.

HOLD POINT: Critical point in an operation where it is stopped until the work to date has been approved.

HOLIDAY: Application defect whereby a small area is left uncoated. Synonyms: miss, skip, void, discontinuity, vacation. [CED]

HOLIDAY DETECTOR, HIGH VOLTAGE TYPE: Also called a spark tester, an instrument for detecting holidays in a nonconductive coating applied over a conductive substrate. A spark test instrument applies a voltage to the surface with a probe that creates a spark whenever a holiday, pinhole, or other defect is found. The spark triggers an alarm or light on the instrument. The voltage used depends on the coating type and thickness.

HOLIDAY DETECTOR, LOW VOLTAGE WET SPONGE TYPE: An instrument that uses 5 - 90 volts DC to detect holidays in coating. It is typically used for films of less than 20 mils (510 micrometers) dry film thickness.

HOLIDAY TEST: Test for detecting small areas of paint film that are incompletely coated (holidays). Standard methods for holiday testing are defined in ASTM D 5162, ASTM D 4787 and NACE RP0188-90. See HOLIDAY DETECTOR, HIGH VOLTAGE TYPE and HOLIDAY DETECTOR, LOW VOLTAGE WET SPONGE TYPE.

HONEYCOMB: Voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles. [ACI]

HOT DIP GALVANIZING: See GALVANIZING.

HOT FLOCKING METHOD: A method of powder coating application that relies on a non-electrostatic spray of powder onto parts which have been preheated above the softening point of the powder. In this method, powder melts and clings to the preheated parts. In some cases the coating is fused/cured by residual heat in the parts, while in others, a postheating step is required.

HOT SPRAYING: Spraying of hot lacquers or paints, the viscosities of which have been reduced to spraying consistency by means of heat instead of by the addition of volatile solvents. By such a process, it is possible to apply materials with higher-solid content and therefore better build. [CED]

HOT SPRAY METHOD (POWDER APPLICATION):
See HOT FLOCKING METHOD.

HULL: The frame or body of a ship exclusive of masts, deck houses, superstructure, and rigging.

HYDRAULIC ADHESION TEST EQUIPMENT (HATE): Commercial hydraulic instrument for determining coating adhesion to a substrate by the pull-off method. See ADHESION TEST, TENSILE (PULL-OFF).

HYDRAULIC CEMENT: A cement that sets and hardens by chemical interaction with water and is capable of doing so under water. [ACI]

HYDRAULIC STRUCTURE: A structure (dam, canal, lock, etc.) designed and constructed to impound, convey, and/or control the flow of water.

HYDROBLASTING: A cleaning process in which pressurized water is directed through a nozzle to impact a surface. The term hydroblasting is used generically to describe cleaning with water without abrasives from low pressure water cleaning to ultra-high pressure water jetting. See also HYDROJETTING and WATER JETTING.

HYDROCARBON SOLVENT: Aliphatic, aromatic, or cyclic (cycloparaffinic, naphthenic) solvent containing only carbon and hydrogen. [IM]

HYDROCHLORIC ACID: An aqueous solution of hydrogen chloride gas. Dissolves many metals, forming chlorides and liberating hydrogen. Used extensively in industry for numerous purposes including the surface preparation of concrete. See MURIATIC ACID. [L]

HYDROGEN SULFIDE: H_2S . Poisonous acidic gas, with a characteristic smell of rotten eggs. [L]

HYDROJETTING: A generic term describing the process in which pressurized water is directed through a nozzle to impact a surface. See also HYDROBLASTING and WATER JETTING.

HYDROLASING: A term commonly used for high or ultra-high pressure water blasting. See WATER JETTING and HYDROJETTING.

HYDROLYSIS: Chemical reaction consisting of splitting a compound into two parts, one of which combines with the H^+ ion of water, and the other combines with the OH^- ion of water. [CED]

HYDROXIDE ION: Negatively charged OH^- ion derived from water.

HYGROTHERMOGRAPH: An instrument for measuring and recording the air temperature and relative humidity.

HYPODERMIC PRESSURE GAGE: A gage with a hypodermic needle which is inserted into the hose at various locations (e.g., just before the nozzle used with abrasive blasting equipment) to determine air pressure at these locations.

IMMERSION-GRADE COATING: A coating suitable for use under immersion in water or other liquids.

IMMERSION SERVICE: Use of a coating under water or other liquid; in this service, the coating frequently is called a lining. [IM, V1]

IMPACT RESISTANCE: Ability of a coating to resist a sudden blow; ability to resist deformation from impact. [IM, V1]

IMPACT STRENGTH: Resistance to damage from collision with another body.

IMPRESSED CURRENT CATHODIC PROTECTION: Application of cathodic protection by means of an external DC power source. See CATHODIC PROTECTION. [ASTM]

INCIDENTAL FOOD CONTACT SURFACE: Any surface which is in such close proximity to food process areas as to at times be contacted by the food.

INDENTATION HARDNESS: Resistance to penetration by an indenter. [CED]

INDICATOR: Reagent used in chemical analysis that undergoes color changes with a change in chemical environment.

INDUCTION TIME: Sometimes called sweat-in time, the time interval that must elapse after mixing the components of multicomponent paint before application can begin. [IM]

INERT FILLERS: Filler materials for coatings or other products that are chemically unreactive (inert).

INFRARED (IR): Invisible part of the electromagnetic spectrum between radio waves and the red portion of visible light, with wavelengths between 0.78 and 1.0 micrometer (780 to 1,000 nanometers). It produces a heating effect on impact with an absorptive surface, and sometimes is used to cure coatings. Infrared radiation also is used to chemically characterize materials in infrared spectroscopy. [IM]

INGESTION: Entry of material (e.g., toxins) into the body through the mouth, or by inhalation through the respiratory system.

INHIBITIVE PIGMENT: A pigment that when formulated into a coating provides active corrosion inhibition to a metal substrate or inhibits some other undesirable effect. [IM, V1]

INHIBITIVE PRIMER: Primer containing inhibitive pigment or other material.

INHIBITOR: (1) General term for compounds or materials that slow down or stop an undesired chemical reaction, such as oxidation, corrosion, drying, skinning, mildew growth, etc. (2) In wet cleaning methods for steel, a material that can be added to the water or applied as a rinse to prevent flash rusting. [IM, V1]

INITIAL CONDITION: See RUST GRADE.

INITIATOR: See CATALYST.

INTERCOAT ADHESION: The ability of one coat of paint to adhere to the next. [IM]

INTRINSICALLY SAFE: Electrical equipment designed to separate sparking from external environment, which can thus be used in hazardous environments.

INTUMESCENT COATINGS: A fire-retardant coating that when heated forms a foam produced by non-flamma-

ble gases, such as carbon dioxide and ammonia. This results in a thick, highly insulating layer of carbon (about 50 times as thick as the original coating) that serves to protect the coated substrate from fire. [ASTM]

IONIC CONTAMINANTS: See SOLUBLE SALT CONTAMINANTS.

IR: See INFRARED.

IRON OXIDES: Pigments which are substantially oxides of iron. [CED]

ISOCYANATE: A compound containing one or more of the chemical group $-N=C=O$. Isocyanates comprise one major component of two-component polyurethane coatings. When the isocyanate groups are crosslinked with a hydroxyl-containing material (polyol), a polyurethane polymer is formed. [IM]

JOB SPECIFICATION: Written, legal document, usually part of a contract, that precisely describes an item of work that is to be accomplished. See also SPECIFICATION.

JOURNEYMAN PAINTER: A painter who successfully has completed an apprenticeship program and has acquired the training and experience to be skilled in the trade. [IM]

KEEL: Longitudinal timber or plate extending along the center of the bottom of a ship and often projecting from the bottom.

KNIFE ADHESION: See ADHESION TEST, CROSS-CUT.

LACQUER: Coating composition which is based on synthetic thermoplastic film-forming material dissolved in organic solvent and which dries primarily by solvent evaporation. Typical lacquers include those based on nitrocellulose, other cellulose derivatives, vinyl resins, acrylic resins, etc. They are re-soluble in their original solvent. [CED]

LAITANCE: A layer of weak and nondurable material containing cement and fines from aggregates, brought by bleeding water to the top of overwet concrete; the amount is generally increased by overworking or over-manipulat-

ing concrete at the surface by improper finishing or by job traffic. [ACI]

LAMINAR: Arranged in, consisting of, or resembling thin plates or scales.

LAMINATIONS: Relatively large surface flakes, scales, or layers that are formed on steel during the rolling process. [IM]

LATERAL BRACING: The bracing assemblage engaging the chords and inclined end posts of truss and the flanges of plate girder spans in the horizontal or inclined planes of these members to function in resisting the transverse forces resulting from wind, lateral vibration, and traffic movements tending to produce lateral movements and deformation. [B]

LATEX PAINT: A paint containing a stable aqueous dispersion of synthetic resin, produced by emulsion polymerization, as the principal constituent of the binder. Modifying resins may also be present. [ASTM]

LATTICE: A framework of crossed lines or members. Also, a framework of cut lines used in adhesion testing. See ADHESION TEST, CROSSCUT.

LATTICE TRUSS: In general, a truss having its web members inclined but more commonly the term is applied to a truss having two or more web systems composed entirely of diagonal members at any interval and crossing each other without reference to vertical members. [B]

LCD: See LIQUID CRYSTAL DISPLAY.

LEACHABLE: Capable of being removed by percolating water or other liquid.

LEAD: A heavy metal. Lead compounds have been used extensively in the past as hiding pigments and/or inhibitive pigments. Lead is hazardous to health if breathed or swallowed. It is especially hazardous to children, causing mental retardation as well as many other effects. It is also hazardous to workers generating lead-containing dust. Residential use of lead-containing paint pigments has been eliminated in the United States, and industrial use has been greatly reduced.

LEAD-CONTAINING PAINT: There is no consensus definition for lead-containing paint in industrial maintenance applications. The following definitions have been developed for related applications. (1) **CONSUMER PRODUCTS:** A paint or other, similar surface coating material in which the lead content (calculated as lead metal) exceeds 0.06 percent by weight of the total non-volatile content of the paint or the weight of the dried paint film. The 0.06 percent level is equivalent to 600 ppm. [ILPR] (2) **RESIDENTIAL USE:** A paint that contains at least 0.5 percent lead by weight of the dried paint film. The 0.5 percent level is equivalent to 5000 ppm. [IM]

LEAFING: The action of particles of certain metallic and other pigments in the form of thin flat flakes in aligning themselves with or floating on or near the surface of the vehicle. [CED]

LED: See LIGHT EMITTING DIODE.

LEL: See LOWER EXPLOSIVE LIMIT.

LEVELING: A coating's ability to flow out on a surface so that brush or roller marks or other irregularities produced during application are not apparent. [IM, VI]

LEVELING AGENT: Chemical added to coating to increase the ability of the wet film to settle to a uniform thickness.

LFL: See LOWER FLAMMABLE LIMIT.

LIFT SPAN: A superstructure span moved by revolution in a vertical plane or by lifting in a vertical direction to free a navigable waterway of the obstruction it presents to navigation. [B]

LIMPET (SOLTZ) CELL: A rigid cell used to collect soluble salt from a contaminated surface in order to determine its concentration.

LINE OF DEMARCATION: On ships, the line of demarcation is where the above-water paint system meets the underwater paint system. It is usually the deep load line or draft line on the vertical sides of the ship.

LINE TRAVEL MACHINE: A machine that performs one of the cleaning or coating processes and moves contin-

uously on wheels or other means along the length of the pipeline.

LINING: (1) A material used to protect a container against corrosion and/or to protect the contents of the container from contamination by the container shell material. Sprayable linings, sheet liners, and drop-in liners can be used to accomplish these purposes. [IM] (2) Any sheet, plate, or layer of material attached directly to the inside face of formwork to improve or alter the surface texture and quality of the finished concrete. [ACI]

LIQUOR STORAGE AREA: In pulp and papermaking, a chemical tank farm where the white, black, and green process liquors are stored in atmospheric storage tanks.

LITMUS TEST: The use of litmus paper or pH paper to measure the acidity or alkalinity (pH) of a water solution. [IM]

LIVE LOAD: Weight of vehicular traffic on a bridge. [B]

LOADING FIXTURE: A component of an instrument (e.g., an adhesion tester) to which a force (load) is applied to determine a physical property such as bonding strength.

LOCA: See LOSS OF COOLANT ACCIDENT.

LOCK: An enclosure with gates at each end to raise and lower boats from one elevation to another.

LOCKOUT: Lockout is a means of protecting workers from injury or death caused by the accidental start-up or release of stored energy from equipment. It involves blocking the flow of energy from the power source to the piece of equipment by using a device such as a padlock or chain, or by removing a component such as a fuse or circuit breaker. See also TAGGING.

LOSS OF COOLANT ACCIDENT (LOCA): An accident in a nuclear reactor in which water spills from the system to the extent that the fuel in the reactor is no longer immersed. A LOCA leads to rapid buildup of heat, since the core is deprived of the cooling influence of the water. The LOCA is the design basis accident for the containment. For further information on the LOCA, see the ASTM Manual of Coating Work for Light Water Nuclear Power Plant Primary Containment and Other Safety-related Facilities (listed in the Bibliography).

LOW VOLTAGE WET SPONGE HOLIDAY DETECTOR: See HOLIDAY DETECTOR, LOW VOLTAGE WET SPONGE TYPE.

LOWER EXPLOSIVE LIMIT (LEL): The concentration, at ordinary ambient temperatures, of a compound in air below which an explosion will not occur if the mixture is ignited. The concentration is expressed as a percent of the gas vapor in air by volume. When the concentration of a substance in air is above the lower explosive limit and below the upper explosive limit (UEL), the mixture will burn and explode. [IM, VI]

LOWER FLAMMABLE LIMIT (LFL): The minimum concentration of a combustible substance that is capable of propagating a flame through a homogeneous mixture of the combustible and a gaseous oxidizer under the specified conditions of test. [ASTM]

MAGNETIC BASE READING (MBR): The surface profile or roughness measured using a dry film thickness gage. Magnetic base reading is the measurement obtained when placing a dry film thickness gage on a magnetic substrate that has been blast cleaned.

MAGNETIC FIXED PROBE GAGE, TYPE 2: A dry film thickness gage whose operation depends on changes in magnetic flux within the probe or the instrument. The magnitudes of these changes are an inverse (nonlinear) function of the distance between the probe and the steel surface under the paint. Type 2 refers to the gage's designation in SSPC-PA 2.

MAGNETIC GAGE: See DRY FILM THICKNESS GAGE, MAGNETIC.

MAGNETIC PULL-OFF GAGE, TYPE 1: A dry film thickness gage that uses a type of spring balance to pull a small permanent magnet from the surface of the painted steel. The magnetic force holding to the surface varies inversely as a non-linear function of the distance between magnet and steel, i.e., the thickness of the dry paint film (plus any other films present). Type 1 refers to the gage's designation in SSPC-PA 2.

MANDREL: In bend testing, the tool used to control the strain on the concave side of a bend in a wrap-around bend test and also to apply the bending force in a semi-guided or guided bend test. [ASTM]

uously on wheels or other means along the length of the pipeline.

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MANDREL: In bend testing, the tool used to control the strain on the concave side of a bend in a wrap-around bend test and also to apply the bending force in a semi-guided or guided bend test. [ASTM]

MANHOLE: A precast concrete structure for vertical access to a pipeline or other closed structure. [ASTM]

MANUFACTURER'S TECHNICAL DATA SHEET: Sheet printed by the supplier of a product to provide instructions and information on its use.

MASONRY: Construction, usually set in mortar, of natural building stone or manufactured units such as brick, concrete block, adobe, glass block, tile, manufactured stone, or gypsum block. [ASTM]

MASTIC: (1) A high-build coating. (2) An adhesive material. [IM]

MATERIAL SAFETY DATA SHEET (MSDS): OSHA's established guidelines for the descriptive data that should be concisely provided on a data sheet to serve as the basis for written hazard-communication programs. The thrust of the law is to have those who make, distribute, and use hazardous materials be responsible for effective communication. [CED]

MBR: See MAGNETIC BASE READING.

MECHANICAL ADHESION TESTING: Adhesion testing performed using a pull-off type instrument. An aluminum pull stub (loading fixture) is bonded onto a coated surface. After the bonding adhesive cures, the pulling force on the pull stub is continuously increased and monitored by the instrument until the pull stub becomes detached or until a specific force is attained (ASTM D 4541; Annex A.1).

MEK: See METHYL ETHYL KETONE.

MERCURY: A toxic heavy metallic element that is liquid at usual temperatures. Mercury compounds have been used extensively in the past in paints as a mildewicide. The toxicity of these products varies depending upon the compound.

METALLIZING: Spraying a coating of metal onto a surface. See also FLAME SPRAYING, PLASMA SPRAYING, and THERMAL SPRAYING. [IM, V1]

METAL SPRAY COATING: A film of molten metal, often zinc or aluminum, dispersed (sprayed) onto a surface such as steel for corrosion control.

METHYL ETHYL KETONE (MEK): A low-boiling strong solvent, similar to acetone but less volatile. [IM]

METHYL ETHYL KETONE PEROXIDE: A chemical used in small amounts to accelerate the curing of polyester coatings.

METHYL ISOBUTYL KETONE (MIBK): A medium-boiling strong solvent. [IM]

MIBK: See METHYL ISOBUTYL KETONE.

MIC: See MICROBIOLOGICALLY INDUCED CORROSION.

MICA: See ALUMINUM POTASSIUM SILICATE.

MICROBIOLOGICALLY INDUCED CORROSION (MIC): Corrosion that is affected by the action of microorganisms in the environment, e.g., sulfate-reducing bacteria found in some petroleum products and in sewage.

MICROMETER: (1) One millionth of a meter, abbreviated as μm . Also sometimes called a micron. Coating thickness often is expressed in micrometers; 25.4 micrometers = 1 mil. (2) A stationary or hand-held instrument used to measure thickness of free (unattached films). [IM]

MIL: One thousandth (0.001) of an inch. 1 mil = 25.4 micrometers. The thickness of a coating on a surface is often expressed in mils or in micrometers. [IM]

MIL PROFILE: See SURFACE PROFILE.

MILDEW CHAMBER TEST: Accelerated laboratory method for determining the resistance of coatings to mildew growth; conducted in a special chamber that attempts to simulate natural conditions.

MILDEW RESISTANCE: A coating's ability to resist the growth of mildew (fungus growth) on its surface. Mildew can cause discoloration and ultimate decomposition of a coating's binding medium. [IM, V1]

MILL COATING: Shop coating.

MILL SCALE: The heavy, bluish oxide layer formed during hot fabrication or heat treatment of steel and other metals. [IM]

MINERAL ABRASIVE: Blast cleaning abrasive made from naturally occurring minerals, such as silica sand, olivine, staurolite, flint, garnet, zirconium, novaculite.

MINERAL SPIRITS: A petroleum-derived solvent used for thinning paint. Odorless mineral spirits have been refined to remove some odorous constituents. [IM]

MIST COAT: Also called a fog coat, a thin coat applied as a mist of spray and used as a tack coat or adhesive coat. [IM]

MIXING RATIO: The ratio, usually by volume, of mixed components for a thermosetting coating specified by the supplier for complete curing into the desired film.

MOISTURE METER: Instrument used for determining water (moisture) content of materials such as wood or concrete.

MONOMER: The starting compound for a polymerization reaction. A monomer can link with itself or with other monomers to form a polymer. [IM]

MONOLITHIC: Material of uniform composition applied as a continuous surface or structure. [ASTM]
Monolithic concrete is concrete cast with no joints other than construction joints. [ACI]

MORTAR: A mixture of cement paste and fine aggregate; in fresh concrete, the material occupying the interstices among particles of coarse aggregate; in masonry construction, mortar may contain masonry cement, or may contain hydraulic cement with lime (and possibly other admixtures) to afford greater plasticity and workability than are attainable with standard hydraulic cement mortar. [ACI]

MOVABLE BRIDGE: A bridge of any type having one or more spans capable of being raised, turned lifted, or slid from its normal vehicular and/or pedestrian service location to provide for the passage of vessels. [B]

MOVABLE SPAN: In the description of bridges, a general term applied to a superstructure span designed to be withdrawn, swung, lifted or otherwise moved longitudi-

nally, horizontally or vertically to free a navigable waterway of the obstruction it presents to navigation. [B]

MSDS: See MATERIAL SAFETY DATA SHEET.

MUD CRACKING: A paint failure that looks like cracked mud. It normally is caused by applying the paint in excessive thickness. [IM, V1]

MURIATIC ACID: An industrial form of hydrochloric acid used to clean concrete and masonry. [IM]

NDT: See NON-DESTRUCTIVE TESTING.

NEAR WHITE BLAST CLEANING: High grade of blast cleaning. According to SSPC-SP 10/NACE No. 2, Near-White Blast Cleaning, a near-white blast cleaned surface is free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter; staining is limited to no more than 5 percent of each unit area of surface. [IM, V1]

NEEDLE GUN: A power impact tool with a bundle of steel needles with chiseled ends mounted in front of a piston that strikes them several times per second and pushes them against the surface being cleaned. Needle guns work best at removing loose or brittle material. Because each needle hits the surface individually, needle guns are useful for cleaning irregular surfaces, such as corners and crevices, or around bolt and rivet heads. [IM]

NIST PLATES: See NIST STANDARD THICKNESS PLATES.

NIST STANDARD THICKNESS PLATES: Small, thin reference squares of 1010 steel covered with different thicknesses of a non-magnetic metal (copper-chromium alloy with a nickel finish); used to calibrate magnetic dry film thickness gages; made by the National Institute of Standards and Technology (NIST).

NON-CONDUCTIVE: A surface or material that will not conduct electricity.

NON-CONTACT THERMOMETER: An instrument that determines the temperature of a surface by measuring the amount of energy being emitted by the surface. The accuracy of this instrument is dependent upon knowing the emissivity of the surface.

NON-CONVERTIBLE COATING: Film-former which, after being deposited from a solution, dries to give a film which is unchanged chemically from its original composition and can be redissolved in a solvent from which it was originally deposited. See THERMOPLASTIC. [CED]

NONDESTRUCTIVE TESTING (NDT): Determining physical or chemical properties without damaging item being investigated.

NON-FERROUS: Not containing iron; pertaining to metals other than iron.

NONVOLATILE CONTENT: See NONVOLATILE MATTER.

NONVOLATILE MATTER (NVM): Of a coating, the solid material remaining after the volatiles have been driven from the film under specified test conditions. The total percentage volatile present is obtained by subtracting the nonvolatile content from 100. Synonyms: nonvolatile content, solids, total solids.

NONVOLATILE VEHICLE: The coating binder dissolved or dispersed in the solvent (volatile vehicle) that remains to form a film after solvent evaporation.

NON-WOVEN ABRASIVE PAD: A web of nylon fibers imbedded with abrasive material in different sizes and densities. These pads can be used to remove dried soil, debris, and loose paint from all types of surfaces, as well as loose rust and loose mill scale from steel. They can also be used to feather, or blend the edges of a repair area, with the surrounding surface. [IM]

NOTCH GAGE: See WET FILM THICKNESS GAGE, NOTCH TYPE.

NOVOLAC (or NOVOLAK): Class of resins produced by the chemical reaction of phenol and formaldehyde; often used in high performance phenolic or epoxy coatings. See BISPHENOL F.

NOZZLE ORIFICE GAUGE: A tapered metal rod that can be inserted into the rear of a blast cleaning nozzle to determine the size of its orifice. The nozzle normally is replaced when the orifice size increases by 1/16 inch (1.6 mm). [IM]

NUCLIDE: A species of atom characterized by the constitution of its nucleus and hence by the number of protons, the number of neutrons, and the energy content.

NVM: See NONVOLATILE MATTER.

OFFSHORE PLATFORM: A stationary steel structure in ocean or bay type waters that is used by oil and gas industry operators for drilling or oil and gas production activities.

OIL CANNING: Bowing of the edges of a steel plate due to thermal expansion and contraction. Oil canning can lead to cracking of the coating at the edges.

OPACITY: The degree to which a material obscures a substrate, as opposed to the transparency, which is the degree to which a material does not obscure a substrate. [CED]

OPEN BLAST CLEANING: See AIR ABRASIVE BLAST CLEANING.

OPERATING MIX: See ABRASIVE MIX.

ORANGE PEEL: A coating film defect with the textured look of an orange peel. [IM, VI]

ORGANIC SOLVENT: Liquid organic material including diluents and thinners that is used as dissolver, viscosity reducer, or cleaning agent. [VI]

ORGANOTIN: Tin compounds used in anti-fouling paints and wood preservatives. Their use is currently curtailed because of toxicity concerns.

OSMOTIC BLISTERING: Formation on paint films of raised areas (blisters) containing water. This occurs by water diffusion through the film to dissolve underlying solvents or salts. The diffusion is caused by a difference in pressure or concentration between the metal-coating interface and the exposed film.

OVER-THE-DITCH: In pipeline work, describes a process that is executed after the pipeline is welded together but before lowering the pipeline into the trench.

OVERBLAST: Areas where abrasive blasting has impinged on surfaces that were not intended to be blasted.

OVERSPRAY: (1) Atomized paint particles that deflect from or miss the surface being sprayed. (2) Spray particles that are not wet enough to fuse when they reach the surface being sprayed. As a result, overspray may contaminate property beyond the surface being sprayed. [IM, V1]

OXIDATION: (1) In coatings, the introduction of oxygen into a molecule, thereby producing a cured film. [Paint/Coatings dictionary] Alkyds and drying oil-based coatings cure by oxidation. Oxidation can also destroy a film. (2) Corrosion of metals and degradation of other substances caused by oxygen in the air. [IM]

OXYGEN DEFICIENCY: Low oxygen in atmospheric environment, generally below 19.5%, that is a health hazard.

OXYGENATED SOLVENT: An organic solvent containing oxygen as part of its molecular structure. Alcohols, esters, and ketones are oxygenated compounds often used as paint solvents. [EPA, IM]

OZONE: A highly reactive form of oxygen which occurs in the atmosphere. It is formed in the stratosphere through the photolysis of molecular oxygen at wavelengths less than 240 nm. Ozone is a common secondary pollutant which is formed in a polluted air mass through the action of sunlight on NO_2 . This is the most abundant of the oxidants formed in photochemical smog. [IUPAC, CED]

PAINT THERMOMETER: Instrument designed for measuring the temperature of liquid coating materials by immersion.

PAPER MACHINE: In pulp and papermaking, the complex processing equipment where the pulp slurry is laid out in a thin sheet on a wire, then pressed, dried, coated, and rolled into the final paper form. Paper machine designs vary according to product.

PARAFFIN WAX: Inert hydrocarbon wax derivative of crude petroleum. Paraffin waxes are distinguished by their melting points. Their main uses include the conferring of water resistance, slip, or solvent retention in special types of compositions. [CED]

PARTS PER MILLION (PPM): Measure of proportional content (e.g., of small amounts of contamination).

PATTI: See PNEUMATIC ADHESION TENSILE STRENGTH TESTING INSTRUMENT.

PEL: See PERMISSIBLE EXPOSURE LIMIT.

PENCIL TESTING: See HARDNESS TESTING, PENCIL METHOD.

PENCIL-TYPE PULL-OFF GAGE: A pencil-shaped magnetic pull-off gage for determining dry film thickness. See MAGNETIC GAGE.

PERCENT SOLIDS: See NON-VOLATILE MATTER.

PERMISSIBLE EXPOSURE LIMIT (PEL): The amount of a toxic material or harmful substance to which a worker may be exposed under OSHA regulations. If OSHA has established a PEL for a substance, by regulation the exposure must be kept at or below that level. PELs are expressed as parts per million (ppm) or as micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) and typically are based on time-weighted average concentrations for a normal 8-hour workday and a 40-hour workweek. See also THRESHOLD LIMIT VALUE. [IM, V1]

PERSONAL PROTECTIVE EQUIPMENT (PPE): Devices worn by the worker to protect against hazards in the environment. Respirators, gloves, and ear protectors are examples.

PETROLATUM: Purified mixture of semisolid hydrocarbons with unctuous nature derived from petroleum. Synonym: petroleum jelly. [CED]

pH: The negative logarithm of the hydrogen ion concentration, in mol/liter. Measure of the acidity or alkalinity of an aqueous solution. $\text{pH} = 7$ represents neutrality, i.e., the solution is neither acid nor alkaline. pH values from 0 to 7 are acidic, the lower the pH value, the higher the degree of acidity; pH values from 7 to 14 represent alkalinity. The higher the pH value above 7, the greater the degree of alkalinity. [CED]

PIER: A support for a bridge at some point between the end abutments; a waterfront structure for docking of ships.

PIGMENT: Finely ground, natural or synthetic, inorganic or organic, insoluble particles that, when dispersed in a liquid vehicle to make paint, may provide color and other

properties, including opacity, hardness, durability, and corrosion resistance. The term is used to include extenders as well as white or colored pigments. (Note: The distinction between powders that are pigments and those that are dyes is generally made on the basis of solubility, pigments being insoluble and dispersed in the material, and dyes being soluble or in solution as used.) [IM, V1]

PIGMENT VOLUME CONCENTRATION (PVC): Ratio of the volume of pigment to the volume of total non-volatile material (i.e., pigment and binder) present in a coating. The figure is usually expressed as a percentage. [CED]

PILES: Vertical members, embedded partly or entirely in the ground, used to provide support for a structure where the ground is not firm enough or over or adjacent to water. [B]

PINHOLE: A holiday or discontinuity in a coating film approximately the size of a pin point, and extending entirely through the applied film, normally caused by solvent bubbling, moisture, or foreign particles. [IM]

PINHOLE DETECTION: See HOLIDAY TEST.

PINPOINT RUSTING: Tiny, dispersed points of rust that can appear at pinholes and holidays in a coating. Very dense pinpoint rusting can appear on painted steel surfaces where the coating does not completely cover the blast cleaning profile. [IM]

PIPE CAP: A plumbing fixture to terminate (cap) a pipe line; used in testing the surface tensile strength of concrete surfaces (ACI 503R, Appendix A).

PIT-DEPTH MEASUREMENT: Determining the depth of pits such as caused by corrosion of steel from the depth that instrumented probes penetrate them.

PITTING: (1) Localized corrosion of a metal surface, confined to a point or small area, that takes the form of cavities. [ASM] (2) In concrete, pitting is localized disintegration, such as a popout. [ACI]

PLACING: The deposition, distribution, and consolidation of freshly mixed concrete in the place where it is to harden; inappropriately referred to as pouring. [ACI]

PLASMA SPRAYING: A spray application process in which metallic or thermoplastic powders are introduced into a plasma arc cavity that contains the gas stream of a plasma gun. After being melted, the powders are projected onto the surface being coated via the flow of the plasma jet. See also FLAME SPRAYING, METALLIZING, and THERMAL SPRAYING. [IM]

PLASTER: A cementitious material or combination of cementitious material and fine aggregate that, when mixed with a suitable amount of water, forms a plastic mass or paste which when applied to a surface, adheres to it and subsequently hardens, preserving in a rigid state the form or texture imposed during the period of plasticity; also the placed and hardened mixture. [ACI]

PLASTIC SHIMS: See CALIBRATION SHIMS.

PLASTICIZER: (1) A paint, varnish, or lacquer additive designed to soften and promote flexibility in the coating. [IM, V1] (2) A material that increases the plasticity of a fresh cement paste, mortar, or concrete. [ACI]

PLIMSOL MARKS: A set of load line markings on the midship center of the ship which are certified by the vessel's classification society. They prescribe the maximum depth allowed for different sea conditions, i.e., tropical, winter, summer, fresh water, etc.

PLURAL COMPONENT SPRAYING: A paint application method that automatically proportions and mixes two or more components of a paint material in the process of delivering them to the spray gun. Plural component spray equipment is used to apply coatings with a pot life that is too short to permit mixing and application by conventional air and airless spray equipment. [IM]

PNEUMATIC ADHESION TENSILE STRENGTH TESTING INSTRUMENT (PATI): An instrument for determining the tensile adhesion of coatings to a surface, according to ASTM D 4541. This instrument is self-aligning, and consists of detachable loading fixtures having a flat, cylindrical base, a central grip for engaging the loading fixture, and a pressurized gas system for applying a continuous pull to the loading fixture. See ADHESION TEST, TENSILE (PULL-OFF).

PNEUMATIC POWER TOOL: Tool that is powered by air pressure

POLYMER CONCRETE: Concrete in which a polymer is added or used instead of portland cement to bond the aggregate together.

POLYMERIZATION: Chemical reaction in which two or more small molecules (monomers) combine to form large molecules (polymers, macromolecules) that contain repeating structural units of the original molecules and have the same percentage composition as the small molecules if the small ones were of the same kind. [CED]

PONTOON BRIDGE: A bridge ordinarily composed of boats, scows or pontoons so connected to the deck or floor construction that they are retained in position and serve to support vehicular and pedestrian traffic. [B]

POROSITY: (1) Small interconnected voids, such as in concrete, which allow fluids to penetrate an otherwise impervious material. (2) The ratio, usually expressed as a percentage of the volume of voids in a material to the total volume of the material including the voids. [ACI]

PORTLAND CEMENT: A hydraulic cement produced by pulverizing portland-cement clinker and usually containing calcium sulfate. [ACI]

POST-TENSIONED CONCRETE: Concrete that is stressed (tensioned) with steel tendons after curing of the concrete.

POT LIFE: The time during which a coating material can be successfully applied to a substrate after the initial opening of its container, or after catalysts, activators, hardeners, or other ingredients are added to initiate the curing reaction. Pot life often depends on temperature and/or humidity. [IM, V1]

POTABLE WATER: Water that is fit for human consumption; mainly drinking water.

POWDER COATING: (1) A 100% solids coating applied as a dry powder which, when baked at a sufficiently high temperature, melts out to form a continuous film. For thermosetting materials, a chemical reaction, either condensation or addition polymerization, also takes place. This fused film has the uniformity, color, toughness, and other properties generally associated with protective and decorative coatings. (2) A coatings application method which utilizes a solid binder and pigment. The solid binder melts

upon heating and results in a pigmented coating upon cooling. [CED]

POWER GRINDING: Abrading a metal or other hard surface using a motor-driven tool.

POWER TOOL CLEANING: The use of power impact, rotary, or rotary impact tools to remove loose paint, rust, mill scale, and other loose contaminants from a surface. The specification SSPC-SP 3, Power Tool Cleaning, is a consensus standard covering the procedures necessary for power tool cleaning of steel surfaces. Some tools can remove all paint, rust, and mill scale, and produce a surface profile in accordance with SSPC-SP 11, Power Tool Cleaning to Bare Metal. Consult these consensus standards for specific details and requirements. Pictorial standards for SSPC-SP 3 and SSPC-SP 11 can be found in SSPC-Vis 3. [IM, V1]

POWER TOOL CLEANING TO BARE METAL: Standard for cleaning steel surfaces for coating described in SSPC-SP 11. See POWER TOOL CLEANING.

POWER WASHING: The use of pressurized water (typically less than 5000 psi [34 MPa]) with or without chemical additives, detergents, etc., to remove contamination and debris from a surface. [IM]

POWER WIRE BRUSH: A power tool with a brush made of knotted or crimped wire bristles in the form of a wheel or a cup used to clean steel, concrete, or masonry surfaces. [IM]

PPE: See PERSONAL PROTECTIVE EQUIPMENT.

PPM: See PARTS PER MILLION.

PRE-JOB CONFERENCE: Conference held before construction work is started to permit the contractor, owner, and other concerned parties to come to a common understanding of all work requirements.

PRESSURIZED WATER REACTOR (PWR): A nuclear reactor using water cooling at a pressure such that its boiling point is above the highest temperature reached.

PRE-STRESSED CONCRETE: Concrete in which internal stresses of such magnitude and distribution are introduced that the tensile stresses resulting from the ser-

vice loads are counteracted to a desired degree; in reinforced concrete the prestress is commonly introduced by tensioning the tendons. [ACI]

PRETREATMENT WASH PRIMER: See WASH PRIMER.

PRIMARY CONTAINMENT: (1) The main method of containing a stored product, e.g., a steel storage tank. (2) That portion of a nuclear power plant reactor building housing the nuclear reactor, a Class I area.

PRIMER: First full coat of paint applied to a surface when a multicoat system is being used. Primers provide adhesion to a new substrate (wood, metal, masonry, or concrete), protect the substrate, and aid in the adhesion of additional coats of paint. The type and condition of the substrate and the painting system specified for a job affect the selection of the primer. Primers for steel work contain special anti-corrosive pigments. [IM, V1]

PROCUREMENT DOCUMENTS: Documents that describe the general terms and conditions of construction or other contracts.

PROFILE: See SURFACE PROFILE.

PROFILE COMPARATOR: See SURFACE PROFILE COMPARATOR.

PROFILE DEPTH: A measure of the roughness of a surface based on the distance between its peaks and valleys, expressed sometimes as an average. See SURFACE PROFILE. [IM]

PROFILE DEPTH GAGE: Gage with instrumented probe for determining the profile height (depth) of abrasive blasted steel, as described in ASTM D 4417, Method B.

PROMOTER: See CATALYST.

PSYCHROMETER: An instrument used to measure the wet and dry bulb temperatures of air. With the aid of psychrometric tables, these measurements can be used to determine the dew point and relative humidity of the air. [IM, V1]

PSYCHROMETRIC TABLES: US Weather Bureau Tables originally published by the US Department of Commerce, used to determine the relative humidity and dew point temperature from the dry and wet bulb readings obtained from the psychrometer.

PULL-OFF ADHESION TEST: See ADHESION TEST, TENSILE (PULL-OFF).

PULL-OFF GAGE: See MAGNETIC PULL-OFF GAGE, TYPE 1; BANANA GAGE; and PENCIL-TYPE PULL-OFF GAGE.

PULL-OFF STRENGTH: Force necessary to pull a bonded probe from a coated surface in a coating adhesion test.

PULL STUB: Also called a dolly, the part of an adhesion testing apparatus that is affixed to the coated surface that is being tested.

PVC: (1) See PIGMENT VOLUME CONCENTRATION. (2) Abbreviation for POLYVINYL CHLORIDE.

PWR: See PRESSURIZED WATER REACTOR.

QUALITY ASSURANCE: The guarantee that the quality of a product (analytical data set, etc.) is actually what is claimed on the basis of the quality control applied in creating that product. Quality assurance is not synonymous with quality control. Quality assurance is meant to protect against failures of quality control. [IUPAC, CED]

QUALITY CONTROL: The maintenance and statement of the quality of a product (data set, etc.) specifically that it meets or exceeds some minimum standard based on known, testable criteria. [CED]

QUANTAB STRIP: Trade name for a commercial test strip used to determine chloride content of an aqueous solution.

QUICKLIME: See CALCIUM OXIDE.

RADWASTE BUILDING: Building for handling or storage of radioactive waste.

REBAR: Colloquial term for reinforcing bar. See REINFORCEMENT. [ACI]

RECLAIMED ABRASIVE: Abrasive that has been retrieved and reprocessed for reuse. Some shipyards or blasting contractors use reclaimed abrasive.

RED LEAD: A reddish-orange anti-corrosive pigment used in primers for iron and steel, and consisting of lead tetroxide. Today it is rarely used in paints because of the hazards of toxic exposure associated with manufacturing, applying, and removing. [IM, V1]

REFERENCE CELL: Standard receptacle containing an electrode and electrolyte used as a point of reference for measuring electrical potentials; used in sacrificial anode and impressed current cathodic protection.

REFLECTANCE: The ability of a coating film to reflect or return the light that falls upon its surface. [IM]

REFLECTIVITY: (1) Reflectance which would be attained if a material were completely opaque; reflectance of a layer of material of such thickness that an increase in thickness will not change its reflectance; (2) The reflectance of a film so thick that a further increase in thickness does not change the reflectance. [CED]

REFRACTORY BRICK: Heat-resisting compressed blocks of clay or other earth material hardened by heat.

REINFORCED CONCRETE: Concrete containing adequate reinforcement (prestressed or not prestressed) and designed on the assumption that the two materials act together in resisting forces. [ACI]

REINFORCEMENT: Bars, wires, strands, or other slender members which are embedded in concrete in such a manner that they and the concrete act together in resisting forces. [ACI]

RELATIVE HUMIDITY: The ratio of the actual pressure of existing water vapor to the maximum possible (saturation) pressure of water vapor in the atmosphere at the same temperature, expressed as a percentage. [ASTM, IM]

RELEASE AGENTS: Materials used to prevent bonding of concrete to a surface. [ACI] See FORM RELEASE AGENT.

REMOTE OPERATED VEHICLE (ROV): An unmanned vehicle fitted with a video camera and/or other

equipment that can be used for underwater inspection when extreme depth or personnel hazards exist.

REPLICA TAPE: A specially constructed tape (e.g., Testex PRESS-O-FILM) used to measure surface profile. The tape is pressed against the surface to produce an impression of the surface profile; then, the impression in the tape is measured with a micrometer. The use of replica tape is described in ASTM D 4417 and NACE RP0287. [V1]

RESERVOIR: Storage tank in which the diameter is greater than the height; the reverse is true for a standpipe.

RESIN: General term applied to a wide variety of more or less transparent and fusible products, which may be natural or synthetic. They vary widely in color. Higher molecular weight synthetic resins are more generally referred to as polymers. In a broad sense, this term is used to designate any polymer that is a basic binder material for coatings and plastics. [IM]

RESPIRATOR: (1) A device that supplies oxygen or a mixture of oxygen and carbon dioxide for breathing, used especially in artificial respiration. (2) A screenlike device worn over the mouth or nose or both to protect the respiratory tract. Synonym: inhalator. There are quite a variety of respirators, ranging from disposable dust masks to self-contained breathing apparatus. All have specific uses and limitations. [CED]

RIGGING: (1) The process of selecting and setting up supports, cables and ropes, and scaffolding systems to provide safe access to an elevated work area. (2) The cables, ropes, and related equipment used with scaffolding. [IM]

RIGHT TO KNOW LEGISLATION: See HAZCOM.

RING EXTRUSION PROCESS: A method for extruding thermoplastic coatings onto pipe. In this method, the die slit encircles the advancing pipe and the thermoplastic is extruded without seams as a plastic pipe over the steel pipe. Compare SIDE EXTRUSION PROCESS.

RISER PIPE: An upright pipe such as used to conduct water upward to an elevated water storage tank.

RIVETED CONNECTION: A joint in which the assembled elements and members are united by rivets. A bolted

joint differs from a riveted one only in the use of high strength bolts as the uniting medium instead of rivets. [B]

RODDING: (1) Consolidation of concrete by means of a tamping rod. [ACI] (2) Inserting a rod into a heat exchanger tube or other structural configuration difficult to clean otherwise.

ROLLING SCAFFOLD: A built-up tubular scaffold with casters on the bottom of the frame legs or posts. The height of a rolling scaffold tower must not exceed four times the minimum base dimension. [IM]

ROTARY FLAP PEEN: See ROTARY PEENER.

ROTARY PEENER: A rotary impact power tool that uses rotating action to impact different shapes of heavy-duty steel cutters against a steel or concrete surface to remove heavy coatings and contaminants. Rotary peeners also can be used to grind concrete. Commonly used types of cutters are cutter bundles or "stars," rotary hammers, and rotary flaps or "roto peens." [IM]

ROV: See REMOTE OPERATED VEHICLE.

RUST BLOOM: The first sign of rust on newly cleaned steel, indicated by slight surface discoloration. See FLASH RUSTING. [IM]

RUST GRADE: In visual standards, the initial condition of unpainted steel before surface preparation. SSPC-Vis 1, a visual standard for the surface preparation of steel, outlines the following four rust grades: (1) RUST GRADE A- the steel surface is completely covered with adherent mill scale; little or no rust is visible. (2) RUST GRADE B- The steel surface is covered with both mill scale and rust. (3) RUST GRADE C- The steel surface is completely covered with rust; little or no pitting is visible. (4) RUST GRADE D- the steel surface is completely covered with rust; pitting is visible. [IM]

SACRIFICIAL PROTECTION: (1) The use of a metallic coating, such as galvanizing or zinc-rich paint, to protect steel. In the presence of an electrolyte, such as salt water, a galvanic cell is set up and the metallic coating corrodes instead of the steel. [DAC; reproduced with permission from the McGraw-Hill Companies, from the Dictionary of Architecture and Construction, C.M. Harris, Ed., 1975.] (2) The use of metal anodes that are slowly

consumed to protect immersed or buried metals. See also GALVANIC CORROSION and GALVANIC PROTECTION. [IM]

SAGGING: (1) A coating surface irregularity caused by the downward flow of wet paint that produces an uneven film with a thick lower edge. [IM] (2) Subsidence of shotcrete, plaster, or the like, due generally to excessive water in the mixture; also called sloughing. [ACI]

SAG RESISTANCE: The ability of a wet paint film to resist the downward flow that results in an uneven film with thick edges and runs. [IM]

SALT FOG RESISTANCE: Resistance to deterioration during salt spray testing. See SALT SPRAY TEST. [IM]

SALT SPRAY TEST: Test used to evaluate the resistance of coated metals or alloys to corrosion. It consists of a fine mist or fog of common salt (sodium chloride) solution sprayed on the surface. The test is described in ASTM B 117. [IM]

SANDING DISC: Flat, circular, powered implement used to abrade a surface.

SAPONIFICATION: Alkaline hydrolysis of fats, drying oils, or other esters whereby a soap is formed. Saponified paint may become sticky and discolored. In severe cases, the film may be completely liquefied by saponification. Loss of adhesion may occur as a saponified layer develops next to the substrate. [IM]

SCAFFOLD: Equipment in variety of types, sizes, and rigging configurations used to support workers, materials, and equipment at elevated or otherwise inaccessible work sites. [IM]

SCALING HAMMER: Tool used to remove corrosion products and other undesired materials from metal surfaces by impact.

SCARIFYING: A method of mechanically preparing concrete or other surfaces for coating by scuffing. Scarifiers are sharp rotating knives in a self-contained unit resembling a plant sweeper. [IM, V1]

SCHMIDT HAMMER: An apparatus (also called a rebound hammer) that provides a rapid indication of the

mechanical properties of concrete based on the distance of rebound of a spring driven plunger. [ACI]

SCRATCH HARDNESS: In determining coating hardness by pencil testing (ASTM D 3363), the scratch hardness is defined by the hardest pencil that will not scratch the film. See also **GOUGE HARDNESS**.

SCRUB RESISTANCE: The ability of a coating to resist being worn away or to maintain its original appearance when rubbed repeatedly with an abrasive material. Typically, the rubbing procedure can employ a brush, sponge, or cloth, wetted with an abrasive soap solution, in which case it is more accurately referred to as wet scrub resistance. Syn: Wet abrasion resistance. [CED]

SCUPPER: Also called a curb inlet, an opening in the floor portion of a bridge, commonly located adjacent to the curb to provide means for rain or other water accumulated upon the roadway surface to drain through it into the space beneath the structure. [B]

SEALANT: See **SEALING COMPOUND**.

SEALING COMPOUND: A liquid that is applied as a coating to the surface of hardened concrete to either prevent or decrease the penetration of liquid or gaseous media, e.g., water, aggressive solutions, and carbon dioxide, during service exposure. [ACI]

SECONDARY CONTAINMENT: A second or backup containment vessel surrounding a primary containment vessel. Under 40 CFR 264.193, the EPA lists requirements for lining secondary containment vessels so that they meet the standards for impermeability and for containing the liquid in the primary containment vessel should a leak or spill occur. [IM]

SEDIMENTATION: Action or process of depositing matter (sediment) that settles to the bottom of a liquid (sediment).

SELENIUM: A non-metallic element. Selenium compounds have been used as fungicides. Selenium pigments are considered by some authorities to be hazardous.

SELF-PRIMING: A paint that can be used, perhaps in different consistencies, both to prime and to coat a painted surface. [IM, V1]

SELF-CURING: A coating that cures (crosslinks) without any special treatment after application. [IM, V1]

SELF-LEVELING: The ability of a wet coating to form a uniformly flat or level surface.

SENSITIZATION: A state of immune-response reaction in which further exposure elicits an immune or allergic response. A person previously exposed to a certain material is more sensitive when further exposed to it if that person had been sensitized to it originally. [CED]

SETTLEMENT POND: Pond where sedimentation takes place. See **SEDIMENTATION**.

SHELF LIFE: The amount of time a coating or other material remains in usable condition during normal storage. [IM]

SHIM: (1) A thin strip of non-magnetic plastic, metal, or other material of known uniform thickness used to calibrate coating dry film thickness gages. (2) A strip of metal, wood, or other material employed to set base plates or structural members at the proper level for placement of grout, or to maintain the elongation in some types of post-tensioning anchorages. [ACI]

SHORT-TERM EXPOSURE LIMIT (STEL): Maximum quantity or concentration of toxic material in working environment for limited working times, usually 15 minutes.

SHOT ABRASIVE: Smooth, rounded abrasive normally made of steel. See **CHILLED IRON** and **STEEL ABRASIVE**. [IM]

SHOTCRETE: Mortar or concrete pneumatically projected at high velocity onto a surface; also known as air-blown mortar, pneumatically applied mortar or concrete, sprayed mortar, and gunned concrete. [ACI] Guniting is a proprietary term for shotcrete.

SIDE EXTRUSION PROCESS: A method for extruding thermoplastic coatings onto pipe. In this process, the thermoplastic coating is extruded from a straight slit in a die located beside the revolving and advancing pipe. The extruded coating forms a hot ribbon of plastic that flows onto the pipe surface as a spiral wrap, the edges of each

ribbon melting into and fusing with the edge of the adjacent ribbon. Compare RING EXTRUSION PROCESS.

SIEVE ANALYSIS: A procedure for determining the size distribution of a blast cleaning abrasive or other particulate matter based on the percentage of material that is retained on and passed through one or more standard screens. [IM]

SIEVE SIZE: Size of an abrasive or other particulate matter determined from ability to pass through a series of differently sized standard screens; the lowest screen size through which it will pass.

SILICA GEL: A regenerative moisture absorbent consisting of the amorphous silica manufactured by the action of HCl on sodium silicate. Hard, glossy, quartz-like in appearance. Used in dehydrating and in drying and as a catalyst carrier. [CED]

SILICA SAND ABRASIVE: A blast cleaning abrasive manufactured from material consisting predominantly of the mineral quartz, which is washed, dried, and screened (sieved). Exposure to breathable sizes of crystalline silica (10 micrometer [0.4 mil] or smaller) can cause silicosis, a progressive lung disease. [IM]

SILICATE: Any member of the very widely occurring compounds characterized by the presence of the elements, silicon, oxygen, and one or more metals with or without hydrogen (e.g., talc). [CED]

SILICATE RESIN: Inorganic polymer product with high temperature resistance based upon the hydrolysis of alkali silicates (e.g., potassium silicate) or alkyl silicates (e.g., ethyl silicate); used mostly for inorganic zinc-rich coatings.

SILICOSIS: A chronic disease of the lungs caused by the continued inhalation of silica dust. [CED]

SKIN TANKS: On ships, tanks constructed inside the hull for ballast, fuel oil, and void spaces. Some tanks are bounded by the side shell or bottom plating. The shell of the vessel is often referred to as the skin of the vessel. The significance is that these tanks can contain hot oil or cold water which influence the temperature of the steel of the outside surface.

SKIP WELDS: Welds on metal components that are intermittent rather than continuous.

SLAG ABRASIVE: A blast cleaning abrasive made from slag produced by metal-smelting operations or by coal-fired boilers and power plants. Most slags are processed by quenching in water, crushing when necessary, washing, and screening to produce an acceptable abrasive. Slag abrasive manufactured by an air-cooling process has a different mineral structure. The quality and durability of the abrasive depends upon the processing and can vary widely from batch to batch and from source to source. Typical slag abrasives include copper and nickel slag from metal smelting and coal slag from electric power generation. [IM]

SLING PSYCHROMETER: A psychrometer with wet bulb and dry bulb thermometers and a swivel handle that allows the instrument to be whirled through the air to obtain constant wet and dry bulb temperature readings. These temperatures can be used with psychrometric tables to determine the relative humidity. See PSYCHROMETER. [IM]

SLUDGE: Muddy sediment or deposit; precipitated solid matter produced during water or waste water treatment.

SLUMP: A measure of the consistency of freshly mixed concrete, mortar, or stucco equal to the subsidence measured to the nearest 1/4 inch (6 mm) of the molded specimen immediately after removal of the slump cone. [ACI]

SLURRY: A pourable mixture of liquid, generally water, and any finely divided insoluble solid such as pigment, extender, or Portland cement. [CED]

SLURRY BLASTING: Surface preparation method using pressurized air to propel an abrasive slurry. See WET ABRASIVE BLAST CLEANING.

SODIUM HYPOCHLORITE: Alkaline compound in bleach solution (household bleach) used to disinfect and kill mildew and other microorganisms, frequently before painting surfaces.

SOLIDS: See NONVOLATILE MATTER.

SOLIDS BY VOLUME (%): The volume of the nonvolatile portion of a composition divided by the total volume, expressed as a percent. Synonym: volume solids. [CED]

SOLTZ CELL: See LIMPET CELL.

SOLUBLE SALT CONTAMINANTS: Water-soluble inorganic compounds (such as chlorides and sulfates) that contaminate a product. When soluble salts are present on a prepared steel surface, they may cause premature coating failure. Soluble salt contaminants are sometimes referred to as "ionic contaminants" or "invisible contaminants."

SOLVENT: (1) Liquid, usually volatile, which is used in the manufacture of paint to dissolve or disperse the film-forming constituents, and which evaporates during drying and therefore does not become a part of the dried film. [CED] (2) Liquid used to dissolve and remove oil, dirt, grease, soil, and waxes from metal surfaces. [IM]

SOLVENT CLEANING: The use of organic solvents, detergents, alkaline cleaners, and steam cleaning to remove oil, grease, dirt, soil, and other, similar organic compounds from a surface. The specification SSPC-SP 1, Solvent Cleaning, is a consensus standard covering the procedures necessary for solvent cleaning of steel surfaces. Consult the document for specific details and requirements. [IM]

SOLVENT RESISTANCE: The ability of a coating to resist solvent attack, solution or disfigurement. See SOLVENT RUB TEST. [CED]

SOLVENT RUB TEST: A practice for assessing the solvent resistance and/or cure of an organic coating that chemically changes during the curing process. ASTM D 4752 is the preferred solvent resistance test for ethyl silicate zinc-rich primer. [CED]

SPALLING: (1) The chipping or fragmenting of a surface or surface coating, such as occurs due to differential thermal expansion or contraction. (2) In concrete, the development of spalls (fragments) usually in the shape of a flake, detached from a larger mass by a blow, by the action of weather, by pressure, or by expansion within the larger mass. [ACT]

SPARK TESTER: See HOLIDAY DETECTOR, HIGH VOLTAGE TYPE.

SPECIFICATION: A word that is used in several ways in the coatings industry. The term "job specification" refers to the written, legal document, usually part of a contract, that precisely describes an item of work that is to be accomplished. Many technical organizations prepare documents called specifications that describe products, procedures, or conditions. For example, SSPC's Steel Structures Painting Manual Volume 2 includes dozens of specifications covering surface preparation, abrasives, paints and paint systems, and paint application. Military, federal, state, and other agencies also have paint and related specifications. The Army and Navy also have documents called "guide specifications" (formerly called "type specifications") which are called "engineering standards" by private industry.

SPECULAR GLOSS: Reflection of light in one path, as from a mirror, as opposed to diffuse reflection in all directions.

SPILLWAY: A passage system for surplus water to pass over or around a dam or similar structure.

SPIRAL WRAP: The technique for application of a continuous ribbon or tape to a length of a pipe. The ribbon is positioned at an angle (less than 90 degrees) to the axis of the pipe such that each revolution of wrap results in one side of the ribbon being applied over the previous wrap and the other side being applied to bare pipe surface. The amount of overlap is governed by the width of the ribbon and the angle the ribbon makes with the pipe. Compare CIGARETTE WRAP.

SPLASH ZONE: Area on ship or fixed marine structure subject to frequent splattering by water.

SPOT-BLAST: Localized high-pressure cleaning as used in surface preparation for maintenance painting.

SPRAY PATTERN: Shape of the area where atomized paint is deposited during air or airless spray application. [IM]

SQUARING UP: A field term often used where production blasting and painting is conducted on a large area that will require several days for completion. An area (e.g., 1,000 sq. ft.) is chosen each day, using natural partitions as far as possible, that can be readily blasted, inspected, and primed (squared up) that day. The term may also be used

to describe the application of topcoats on subsequent days according to a selected time schedule.

STACK LINER: Protective lining for chimney, flue, or other exhaust interior subject to high temperatures or otherwise corrosive conditions.

STAINLESS STEEL: Any of several steels containing 12 to 30% chromium as the principal alloying element; they usually exhibit passivity in aqueous environments. [ASM]

STANDARD JETTING WATER: Water of sufficient purity and quality that it does not impose additional contaminants on the surface being cleaned and, of critical importance to water jetting operations, does not contain sediments or other impurities that are destructive to the proper functioning of the water jetting equipment being used. [SSPC-SP 12/NACE 5] See **WATER JETTING**.

STANDPIPE: A water tank with a greater height than diameter.

STEAM CLEANING: A cleaning process using low pressure steam, described in SSPC-SP 1. [IM]

STEEL ABRASIVE: Cast steel shot or grit used for abrasive blast cleaning. Cast steel shot consists of nearly spherical particles of steel obtained by granulating a molten stream of metal with water or air, or by other methods. Cast steel grit consists of angular particles produced by crushing steel shot. [IM]

STEEL GRIT: See **STEEL ABRASIVE**.

STEEL SHOT: See **STEEL ABRASIVE**.

STEL: See **SHORT TERM EXPOSURE LIMIT**.

STIFFENER: An angle, tee, plate or other rolled section riveted, bolted or welded upon the web of a plate girder or other "built-up" member to transfer stress. [B]

STITCH WELDING: Discontinuous welding; skip welding.

STONING: Smoothing (as an irregular concrete surface) with an abrasive tool (stone).

STRESS CORROSION CRACKING: Cracking caused by corrosion together with the stresses in a metal. [IM]

STRINGER: A longitudinal beam supporting the bridge deck, and in large bridges or truss bridges, framed into or upon the floor beams. [B]

STRIPING: Painting the edges of a surface or welds to give them extra protection. Striping is done before priming or before the application of a full coat of paint. [IM]

STUCCO: A cement plaster used for coating exterior walls and other exterior surfaces of buildings. [ACI]

STYRENE: Colorless to yellowish oily liquid. A monomer used to make synthetic resins and elastomers. Synonyms: vinylbenzene, styrol, styrolene, cinnamene, phenylethylene. $C_6H_5CH=CH_2$. [CED]

SUB-ASSEMBLY: The ship's hull is constructed of steel plates, stiffeners, and other members which are formed into shapes. The shapes are put together to form sub-assemblies (sometimes called modules or blocks), then the sub-assemblies are put together to form the hull.

SUBSTRUCTURE: The abutments, piers, grillage or other constructions built to support the span or spans of a bridge superstructure whether consisting of beam, girder, truss, trestle or other type or types of construction. [B]

SULFATE-REDUCING BACTERIA: Bacteria found in many soils, particularly in boggy areas, in some petroleum products, and in sewage that have the ability to convert sulfate salts to sulfides. This type of bacteria reacts with sulfur-containing organic matter to produce hydrogen sulfide (H_2S), a contaminant that reacts rapidly with both concrete and steel. Sulfide-contaminated surfaces must be cleaned and completely freed of sulfide prior to the application of coatings.

SUPERPLASTICIZER: A water-reducing (high-range) admixture capable of producing large water reduction or great flowability without causing undue set retardation or entrainment of air in mortar or concrete. [ACI]

SUPERSTRUCTURE: (1) Ships - The part of the ship above the main deck. (2) Bridges - The entire portion of a bridge structure that primarily receives and supports highway, railway, canal, or other traffic loads and in its turn

transfers the reactions resulting therefrom to the bridge substructure. The superstructure may consist of beam, girder, truss, trestle or other type or types of construction. [B]

SUPPRESSION CHAMBER: A large volume of water, or wet well in a boiling water reactor (BWR), used to suppress a pressure rise in the containment, in the event of a Loss of Coolant Accident (LOCA), by absorption of thermal energy. See also **BOILING WATER REACTOR** and **MARK I, MARK II, MARK III**.

SURFACE CONDITIONER: Chemical material that prepares a surface to receive a coating or other material.

SURFACE PREPARATION: Any method of treating a surface to prepare it for coating. Surface preparation methods include washing with water, detergent solution, or solvent; cleaning with hand or power tools; water washing or jetting with or without abrasive; or abrasive blast cleaning. SSPC and NACE International have a number of written and visual standards describing the surface preparation of steel surfaces prior to painting. [IM, V1]

SURFACE PROFILE: Contour of a blast-cleaned surface on a plane perpendicular to the surface. For steel, surface profile is the roughened surface that results from abrasive blast cleaning or power tool cleaning to bare metal, also call the anchor pattern. For wood and concrete, surface profile is simply the texture of the cleaned surface. Surface profile of steel is classified by its depth and its texture (rounded or angular). Surface profile depth is defined as the average peak-to-valley height of the roughness and typically ranges from less than 1 mil up to 5 mils (25 to 127 micrometers). See **PROFILE DEPTH**.

SURFACE PROFILE COMPARATOR: An instrument used to determine the profile of a blast cleaned surface by visual or tactile comparison of the surface with a series of reference surfaces of known profile depths. [IM, V1]

SURFACER: Pigmented composition for filling minor irregularities to obtain a smooth, uniform surface preparatory to applying finish coats; usually applied over a primer and sandpapered for smoothness. [ASTM]

SUSPENDED SPAN: A superstructure span having one or both of its ends supported upon or from adjoining cantilever arms, brackets or towers, and designed to be unaf-

ected by other stress transmission to or from an adjacent structure. [B]

SUSPENSION BRIDGE: A bridge in which the floor system and its incidental parts and appliances are supported in practically horizontal position by being suspended from cables which are supported at two or more locations upon towers and are anchored at the their extreme ends. The cables constitute the main suspension members. [B]

SUSPENSION CABLE (SUSPENSION CHAIN): One of the main members upon which the floor system of a suspension bridge is supported. [B]

SUSPENSION CHAIN: See **SUSPENSION CABLE**.

SWEAT-IN TIME: See **INDUCTION TIME**.

SWEEP BLAST CLEANING: A fast pass of the abrasive blasting pattern over a surface to remove loose material and to roughen the surface sufficiently to successfully accept a coat of paint. This method of cleaning sometimes is specified as SSPC-SP 7, Brush-off Blast Cleaning. See also **BRUSH-OFF BLAST CLEANING**. [IM]

SWING BRIDGE: A bridge having a superstructure designed to revolve in a horizontal plane upon a pivot from its "closed" position to an "open" one wherein its alignment is normal or nearly normal to the original alignment. [B]

SWING SCAFFOLD: A scaffold with a platform or stage suspended from a structure by two ropes or cables so it can be raised or lowered as needed. The scaffold height can be adjusted either manually or with a hoist powered by electricity or compressed air. [IM]

TABER ABRASER: An instrument used to measure abrasion resistance (ASTM D 4060). Specimen on a turntable rotates under a pair of weighted abrading wheels that produce abrasion through side slip. [CED]

TACK-FREE: Absence of tack or stickiness in an applied coating. Freedom from tack of a coating after suitable drying time. [IM, V1]

TAGGING: Tagging is a means of protecting workers from injury or death caused by the accidental start-up or

release of stored energy from equipment. It involves placing a tag on the power source as a warning not to restore energy to the piece of equipment. See also LOCKOUT.

TAPE TEST: See ADHESION TEST, CROSSCUT.

TAPE WRAPPING MACHINE: Machine to wrap piping or other components with a protective covering such as tape.

TENSILE ADHESION TEST: See ADHESION TEST, TENSILE (PULL-OFF).

TENSILE STRENGTH: The maximum tensile stress that a material is capable of sustaining. Tensile strength is calculated from the maximum load during a tension test carried to rupture and the original cross-sectional area of the specimen. [ASTM]

TEST STRIP: Paper strip dipped into solution for estimate of amount of contaminant or other material present.

THERMAL SPRAY COATING (TSC): Solid coating materials that is melted before dispersion (spraying) to a surface.

THERMAL SPRAYING: A process for applying metallic wire, metallic powder, and thermoplastic powder. The material is melted and sprayed onto a surface to produce a uniform coating. Gas wire guns and electric arc guns are used for spraying metallic wire; plasma guns are used for spraying metallic and thermoplastic powders. See also FLAME SPRAYING, METALLIZING, and PLASMA SPRAYING. [IM]

THERMIT REACTION: Explosive effect that occurs when aluminum and iron oxide are heated. Aluminum pigmented paints associated with rusty steel are susceptible to the effect, leading to potential problems in hazardous environments such as gas, fuel oils, etc.

THERMOPLASTIC: A material that becomes soft when heated and hard when cooled without undergoing chemical change. While the material is soft, it can be reformed or molded. As used in the coatings industry today, the original meaning of the term thermoplastic has changed somewhat. It is now used to classify coating types according to how the resins cure, and the solubility of the cured film. The term thermoplastic is virtually synonymous with

the term non-convertible. See NON-CONVERTIBLE COATING. [IM, V1]

THERMOPLASTIC POWDER: Powdered organic polymeric materials that are melted by heat; some are sprayed through a flame to melt them, so that they are applied to a substrate as a liquid and then solidify on cooling to form a protective film without undergoing chemical change.

THERMOSETTING: A material that permanently sets when subjected to heat, catalysts, ultraviolet light, or chemical reaction, and cannot be softened and reformed by reheating. As used in the coatings industry today, the original meaning of the term thermosetting has changed somewhat. It is now used to classify coating types according to how the resins cure, and the solubility of the cured film. Thus, the terms thermosetting is virtually synonymous with the term convertible. See CONVERTIBLE COATING. [IM, V1]

THINNER: (1) The portion of a paint, varnish, lacquer, or printing ink, or related product that volatilizes during the drying process. [ASTM] (2) Any volatile liquid used for reducing the viscosity of coating compositions or components; may consist of a simple solvent or diluent or a mixture of solvents and diluents. [CED]

THIXOTROPIC: Having a gel consistency that becomes liquid when stirred or brushed to permit application but returning to its original consistency upon standing. Thixotropic paints are less likely to drip from a brush than other types and can be applied in rather thicker films without running or sagging. [V1]

THRESHOLD LIMIT VALUE (TLV): The TLV is the concentration of chemical substances in the air that workers may be exposed to daily without adverse effect. TLVs are recommended exposure limits and are not required by law to be met. See also PERMISSIBLE EXPOSURE LIMIT and SHORT TERM EXPOSURE LIMIT. [IM]

TIE-COAT: A paint specifically formulated to provide a transition from a primer or undercoat to a finish coat. Tie-coats may be used to seal the surface of a zinc-rich primer, to bond generically different types of coating, or to improve the adhesion of a succeeding coating. [IM, V1]

TIE ROD: A mechanical connection in tension used to prevent concrete forms from spreading due to the fluid pressure of fresh unhardened concrete. Also called a form tie. [ACI]

TIME WEIGHTED AVERAGE (TWA): Maximum allowed exposure to toxic materials over a working period, usually 8 hours.

TIN: A soft, silvery-white metallic element. Organotin compounds, once widely used in anti-fouling paints, have been widely restricted because toxic tin compounds were picked up by marine organisms and got into their food chain.

TITANIUM DIOXIDE: TiO_2 . A high-opacity, bright white pigment, used as a prime pigment in paints, rubber, plastics. Synonym: titania. [CED]

TITRATION: In chemical analysis, the determination of the reactive capacity, usually of a solution, especially, the analytical process of successively adding measured amounts of a reagent (as a standard solution) to a known volume or weight of a sample or sample solution until a desired end point is reached. [ASTM]

TLV: See THRESHOLD LIMIT VALUE.

TOLERANCE: The total range of variation (usually bilateral) permitted for a size, position, or other required quantity; the upper and lower limits between which a dimension must be held. [ASTM, CED]

TOLUENE: An aromatic solvent used in paint manufacturing and as a thinner and cleanup solvent. The flash point of toluene is about 30°F (-1°C). [IM]

TOOKE GAGE: See DESTRUCTIVE DRY FILM THICKNESS GAGE.

TOOL-BOX TALK: Informal discussion of a working group concerning important aspects of work before starting it.

TOP COAT: The last coating material applied in a coating system, specifically formulated for aesthetic and/or environmental resistance. Also referred to as finish coat. [IM, V1]

TOPSIDE: The area on the sides of the hull which are above the deep load line. Topside usually refers to the area from the deep load line to the rail (above the boottop). Sometimes the word encompasses the decks and areas above deck, such as hatches, masts, pipes, etc. These areas are exposed to the weather as opposed to immersion in the sea.

TOTAL SOLIDS: See NONVOLATILE MATTER.

TOXICITY: The capacity of a substance to injure by chemical means. [IM, V1]

TRAVERSE DRAW BRIDGE: See RETRACTILE DRAW BRIDGE.

TRESTLE: A bridge structure consisting of beam, girder or truss spans supported upon bents. [B]

TRUSS: A jointed structure having an open built web construction so arranged that the frame is divided into a series of triangular figures. [B]

TRUSS BRIDGE: A bridge having a truss for a superstructure: the ordinary single span rests upon two supports, one at each end, which may be abutments, piers, bents, or towers, or combinations thereof. the superstructure span may be divided into three parts: 1) the trusses, 2) the floor system and 3) the bracing. [B]

TSC: See THERMAL SPRAY COATING.

TURBIDITY: Term used to indicate the degree of cloudiness of water samples, which is caused primarily by the presence of colloidal matter. [IUPAC, CED]

TWA: See TIME WEIGHTED AVERAGE.

TYPE 1 MAGNETIC PULL-OFF GAGE: See MAGNETIC PULL-OFF GAGE, TYPE 1.

TYPE 2 MAGNETIC FIXED PROBE GAGE: See MAGNETIC FIXED PROBE GAGE, TYPE 2.

UEL: See UPPER EXPLOSIVE LIMIT.

ULTRASONIC GAGE: Instrument for measuring thickness of a material by the time sound takes to travel through it.

ULTRASONIC THICKNESS MEASUREMENT:

Determining thickness of a solid substrate such as steel using equipment by applying wave energy above the normal hearing range and timing its retroreflection.

ULTRAVIOLET (UV): A band of electromagnetic radiation between 10 and 400 nanometers in wavelength. The part of the UV spectrum in the actinic region (280 to 315 nanometers) is especially destructive to paint films. Ultraviolet energy also sometimes is used to cure a coating. "Black light" is a popular term for UV radiation. [IM]

UNDERCUTTING: The penetration of a coating and the spread of delamination or corrosion from a break or pinhole in the film or from unprotected edges. [IM, V1]

UPPER EXPLOSIVE LIMIT (UEL): The concentration at ordinary ambient temperatures of a compound in air above which an explosion will not occur if the mixture is ignited. UEL is expressed in percent of the gas vapor in air by volume. When concentrations of a substance in air are below the upper explosive limit and above the lower explosive limit (LEL), the mixture will burn and explode. See also LOWER EXPLOSIVE LIMIT. [IM]

UV: See ULTRAVIOLET.

VACUUM BLASTING: Abrasive blast cleaning using a vacuum shroud to capture dust, debris, and other materials while they are being generated and prevent them from escaping into the environment. See ABRASIVE BLAST CLEANING. [IM]

VACUUM SHROUDED POWER TOOL: Power tool equipped with a vacuum shroud to capture dust, debris, and other materials while they are being generated and prevent them from escaping into the environment. See POWER TOOL CLEANING. [IM]

VAPOR PRESSURE: Pressure (usually expressed in millimeters of mercury) characteristic at any given temperature of a vapor in equilibrium with its liquid or solid form. [CED]

VEHICLE: The liquid portion of paint, in which the pigment is dispersed; it is composed of binder and thinner. [CED]

VERTICAL LIFT BRIDGE: A bridge having a superstructure designed to be lifted vertically by cables or chains attached to the ends of the movable span with its ends seated upon bridge seat pedestals. [B]

VISCOMETER: An instrument for measuring flow properties. The chief types of viscometers are as follows: capillary, rotational, outflow or efflux (Ford cup, usually called orifice type), falling ball, tackmeter (radial flow type) bubble tube. The term "viscometer" is preferred to "viscosimeter." [CED]

VISCOSITY: The quality or property of a fluid (i.e., paint) that causes it to resist flow. A high viscosity coating is thick; a low viscosity coating is thin. [IM]

VISCOSITY CUP: A laboratory or field instrument for measuring the viscosity of a liquid by timing the liquid's flow through an opening in the bottom of a small open bowl.

VISUAL COMPARATOR: One of several visual systems used to estimate the profile of an abrasive blasted steel surface. See SURFACE PROFILE COMPARATOR.

VOC: See VOLATILE ORGANIC COMPOUND.

VOC-COMPLIANT: Conforming to VOC regulations. See VOLATILE ORGANIC COMPOUND.

VOLATILE: (1) Easily evaporated. (2) Any liquid that evaporates quickly. [IM, V1]

VOLATILE ORGANIC COMPOUND (VOC): (1) Any organic compound that reacts in the atmosphere with nitrogen oxides in the presence of heat and sunlight to form ozone. (2) Any organic compound (other than those designated by EPA as having negligible photochemical reactivity) that is emitted into the atmosphere during the application or curing of a coating. It is detected by reference methods such as EPA Method 24 or ASTM D 2369. [IM]

WASHABILITY: Ease with which the dirt can be removed from a paint surface by washing; also refers to the ability of the coating to withstand washing without removal or substantial damage. [CED]

WASH PRIMER: Priming paint usually supplied as one- or two-component systems. The paint contains carefully balanced proportions of an inhibiting chromate pigment, phosphoric acid, and a synthetic resin binder mixed in an alcohol. On clean, light alloy or ferrous surfaces, and on many nonferrous surfaces, such paints give excellent adhesion, partly due to chemical reaction with the substrate, and give a corrosion-inhibiting film which is a good basis for the application of subsequent coats of paint. Syn: pretreatment primers, etch primers, and self-etch primers. [CED]

WATER BLAST CLEANING: A water cleaning method in which abrasive is injected into the water stream.

WATER-BORNE COATINGS: Paint, the vehicle of which is a water emulsion, water dispersion, or ingredients that react chemically with water. Also called water-based coatings and water-reducible coatings. [V1]

WATER BREAK: The appearance of a discontinuous film of water on a surface, signifying nonuniform wetting and usually associated with a surface contamination. [ASTM, CED]

WATER CLEANING: A method of using pressurized water, heated or unheated, with or without detergent, to prepare surfaces for coating. Low-pressure water cleaning uses pressures up to about 34 MPa (5,000 psi); high-pressure water cleaning ranges from 34 MPa (5,000 psi) to 170 MPa (25,000 psi); and ultrahigh-pressure water cleaning uses pressures above 170 MPa (25,000 psi). When pressures exceed 69 MPa (10,000 psi), a jet nozzle is used and the process is called water jetting.

WATER JET CLEANING: See WATER JETTING.

WATER JETTING: Water jetting is the use of standard jetting water at high or ultrahigh pressure (pressures above 69 MPa/10,000 psi) to prepare a surface for recoating. High pressure water jetting is cleaning performed at pressures from 69 to 170 MPa (10,000 to 25,000 psi). Ultrahigh pressure water jetting is cleaning performed at pressures above 170 MPa (25,000 psi). [SSPC-SP 12/NACE 5] See also HYDROJETTING, HYDROBLASTING, and STANDARD JETTING WATER.

WATER LINE: In general, a waterline is the interface between a body of water and the atmosphere, which typi-

cally varies with the level of water. On ships, waterlines are formed on the hull by the water at different levels of draft.

WATER TRAP: A structural feature in which liquid (such as rainwater) may accumulate from the environment.

WEATHERING: Behavior of paint films when exposed to natural weather or accelerated weathering equipment, characterized by changes in color, texture, strength, chemical composition, or other properties. [CED]

WEATHERING TOPCOATS: Exterior finishes designed to resist deterioration from ultraviolet light, rain, and other natural destructive elements in the atmosphere.

WEB: On bridges, a web is the portion of a beam, girder or truss, located between and connected to the flanges or the chords. [B]

WEEP HOLE: An open hole to provide means of drainage. [B]

WELD FLUX: A material used to promote fusion of metals, employed in welding.

WELD SLAG: Amorphous deposits formed during welding. [CED]

WELD SPATTER: Beads of metal produced during the welding process that adhere to the surface near the weld. [IM]

WET ABRASIVE BLAST CLEANING: Surface preparation method using conventional dry abrasive blasting equipment supplemented with modules to inject water into the abrasive stream. Ideally, the water encapsulates the abrasive particles with a thin film of moisture to suppress and contain the dust generated by the impact of the abrasive with the substrate.

WET ABRASIVE BLASTING: See WET ABRASIVE BLAST CLEANING.

WET BULB DEPRESSION, $t - t_w$: The difference between the dry-bulb temperature and the wet-bulb temperature. [ASTM]

WET BULB TEMPERATURE, t_w : The temperature recorded on a wet bulb thermometer. See also DRY BULB TEMPERATURE and PSYCHROMETER. [IM]

WET BULB THERMOMETER: The thermometer on a sling or other psychrometer whose bulb is covered with a wet cotton sock. See PSYCHROMETER.

WET DOCK: Pier or other waterfront facility for berthing ships where the ship remains afloat in water, as opposed to a graving dock or floating dry dock in which the entire hull is exposed.

WET FILM THICKNESS (WFT): Thickness of the liquid coating film immediately after application. [CFD]

WET FILM THICKNESS GAGE, NOTCH TYPE: Gage with one or more faces cut in a series of notches that is used to determine coating wet film thickness as described in ASTM D 4414.

WET SPONGE TESTER: See HOLIDAY DETECTOR, LOW VOLTAGE WET SPONGE TYPE.

WETTING: Power a vehicle possesses of spreading uniformly and rapidly over the surface of pigment particles. A vehicle with good wetting properties assists in the grinding or dispersion of pigments and the ability to wet the surface to which the finished coating is applied. [CFD] (2) The ability of a coating to come into close contact on surfaces over which it is applied. [IM]

WETTING AGENT: Material used in paint to reduce the surface tension of the vehicle or binder in order to assist in the grinding or dispersing of pigments or to improve the ability of the coating to wet the surface. [IM]

WFT: See WET FILM THICKNESS.

WHITE METAL BLAST CLEANING: Highest grade of blast cleaning. According to SSPC-SP 5/NACE No. 1, White Metal Blast Cleaning, a white metal blast cleaned surface is free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter. [IM, V1]

WIRE BRUSH CLEANING: Cleaning a surface with a wire brush that is either a hand tool or a power tool. [IM]

WIRE BRUSHING: See WIRE BRUSH CLEANING.

WOOD PROCESSING AREA: In pulp and papermaking, the wood processing area is where the woodchips are screened for oversized or undersized chips. Some mills may include the debarking drums and chipper in this area.

WOODYARD: The receiving station at the beginning of the papermaking process where the logs and chips are delivered and stored. In the woodyard, logs are debarked and chipped, and chips are screened. The woodyard is the doorway through which woodchips enter the paper mill.

WORK MIX: See ABRASIVE MIX.

WORK PERMIT: Formal instruction, issued daily or weekly, to allow working in a hazardous environment.

WOVEN ROVING: A cloth consisting of glass fibers woven in a pattern to impart strength when used to reinforce a coating or other composite system.

XYLENE: An aromatic solvent used in the manufacture of paints. It also is used widely as a thinner and cleanup solvent. The flash point of xylene is about 80°F (27°C). [IM]

ZINC: A hard, metallic element with a bluish tinge. Zinc or its compounds are used as reinforcing pigments and corrosion resistant pigments. Zinc dust is used in zinc-rich coatings to provide galvanic protection of steel. It is also the basis for galvanizing and sprayed zinc coatings.

ZINC-RICH: High in zinc dust content; a generic type of coating described in SSPC Paint 20.

ZINC-RICH COATING: Anti-corrosive coating for iron and steel. Zinc-rich coatings use zinc dust in a concentration sufficient to provide electrical conductivity in the dried film. This enables the zinc metal to corrode preferentially to the ferrous substrate, giving galvanic protection. [IM] See also GALVANIC PROTECTION.

KEY TO REFERENCES

Many of the definitions in this glossary are copied or adapted from other sources. Following is a key to these reference sources:

ACI: *Cement and Concrete Terminology*, Publication SP-19 (90), American Concrete Institute, Detroit, MI, 1990.

ASM: Reproduced with permission from (1) *ASM Metals Handbook, Ninth Edition*, Volume 13, (1987) *Corrosion*, ASM International, Metals Park, OH, 1978; and *Metals Handbook, Desk Edition*, ASM International, Metals Park, OH 44073-0002, p. 1 (anode), p. 2 (cathode), p. 7 (galvanic corrosion) or (2) *Metals Handbook, Desk Edition*, (1985), ASM International, Materials Park, OH 44073-0002, (formerly American Society of Metals, Metals Park, OH 44073), p. 1.16 (fillet weld) 1.37 (stainless steel).

ASTM: Reprinted, with permission, from the Annual Book of ASTM Standards, copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

B: *Bridge Inspector's Training Manual/90*, US Department of Transportation/Federal Highway Administration, 1979.

CED: *Coatings Encyclopedic Dictionary*, Stanley LeSola, Ed., Federation of Societies for Coatings Technology, Blue Bell, PA, 1995.

DAC: Reproduced with permission from Dictionary of Architecture and Construction, C.M. Harris, Ed., McGraw-Hill Book Co., New York, 1975.

EPA: *Glossary for Air Pollution of Industrial Coatings Operation*, 2nd Edition, EPA-450/3-83-013 R, US Environmental Protection Agency, N.C., Dec. 1983.

ILPR: Kenneth A. Trimber, *Industrial Lead Paint Removal Handbook*, 2nd Edition, KTA-Tator, Inc., Pittsburgh, PA, 1993.

IM: Reproduced with permission from *Industrial Maintenance Coatings Glossary*, Joseph A. Bruno, Jr., Ed., Technology Publishing Company, Pittsburgh, PA 1994.

IUPAC: Reproduced with permission from J.G. Calvert, *IUPAC Glossary of Atmospheric Chemistry Terms*, Atmospheric Chemistry Division, National Center for Atmospheric Research, Boulder, CO, 1990.

MPDA: Reproduced with permission from *The Master Painter's Painting and Decorating Terminology Glossary*, Master Painters & Decorators Association of B.C., Burnaby, B.C., 1988.

PDC: *Painting and Decorating Craftsman's Manual and Textbook*, Painting and Decorating Contractors of America, Fairfax, VA, 1975.

VI: *Steel Structures Painting Manual, Volume 1, Good Painting Practice*, SSPC: The Society for Protective Coatings, Pittsburgh, PA 1993.

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Appendix C

Standards Referenced

NOTES

Joint standards have been listed under both of the sponsoring organizations' names, e.g., ANSI/AWWA standards are listed under both ANSI and AWWA.

The latest issue, revision, or amendment of these reference standards should be used unless otherwise specified.

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 503R Use of Epoxy Compounds with Concrete

ACI 515.1R Guide to the Use of Waterproofing, Damp-proofing, Protective and Decorative Barrier Systems for Concrete

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

(Note: ANSI standards are listed here in alphanumeric order strictly according to the letter and number of the standard. Acronyms of co-sponsoring organizations do not figure into this ordering scheme.)

ANSI/NSF 61 Drinking Water System Components - Health Effects

ANSI/AWS C2.18 Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and Their Alloys and Composites

ANSI/AWWA C203 Coal-Tar Protective Coatings and Linings for Steel Water Pipelines - Enamel and Tape - Hot Applied

ANSI/AWWA C205 Cement Mortar Protective Lining and Coating for Steel Water Pipe - 4 in. and Larger - Shop Applied

ANSI/AWWA C209 Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines

ANSI/AWWA C210 Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines

ANSI/AWWA C213 Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines

ANSI/AWWA C215 Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines

ANSI/AWWA C216 Heat-Shrinkable Cross-Linked Polyolefin Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines

ANSI/AWWA C217 Cold-Applied Petrolatum Tape and Petroleum Wax Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Buried Steel Water Pipelines

ANSI/AWWA C652 Disinfection of Water - Storage Facilities

ANSI/AWS D1.1 Structural Welding Code, Steel

ANSI N5.12 Protective Coatings (Paints) for the Nuclear Power Industry (withdrawn)

ANSI/ASME N45.2.6 Qualification of Inspection, Examination, and Testing Personnel for Nuclear Power Plants (replaced by ANSI/ASME NQA -1-1994)

ANSI N101.2 Protective Coatings (Paints) for Light Water Nuclear Reactors (withdrawn)

ANSI N101.4 Quality Assurance for Protective Coatings Applied to Nuclear Facilities Containment Facilities (withdrawn)

ANSI/ASME NQA -1-1994 Quality Assurance Requirements for Nuclear Facility Applications (replaces ANSI/ASME N45.2.6)

ANSI Z87.1 Practice for Occupational and Educational Eye and Face Protection

ANSI Z89.1 Personnel Protection - Protective Headwear for Industrial Workers

ANSI/AWS Z49.1 Safety in Welding, Cutting and Allied Processes

ANSI Z117.1 Safety Requirements for Working in Tanks and Other Confined Spaces

AMERICAN PETROLEUM INSTITUTE (API)

API RP 652 Lining of Aboveground Petroleum Storage Tank Bottoms

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

(Note: For ASTM standards, volume number, in parentheses, follows designation.)

ASTM B 117 (03.02) Practice for Operating Salt Spray (Fog) Testing Apparatus

ASTM B 833 (02.05) Specification for Zinc Wire for Thermal Spraying (Metallizing)

ASTM C 136 (04.02) Test Method for Sieve Analysis of Fine and Coarse Aggregates

ASTM C 267 (04.05) Test Method for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacing

ASTM C 279 (04.05) Specification for Chemical-Resistant Masonry Units

ASTM C 287 (04.05) Specification for Chemical-Resistant Sulfur Mortar

ASTM C 386 (04.05) Practice for Use of Chemical-Resistant Sulfur Mortar

ASTM C 395 (04.05) Specification for Chemical-Resistant Resin Mortars

ASTM C 397 (04.05) Practice for Use of Chemically Setting Chemical-Resistant Silicate and Silica Mortars

ASTM C 398 (04.05) Practice for Use of Hydraulic Cement Mortars in Chemical-Resistant Masonry

ASTM C 399 (04.05) Practice for Use of Chemical-Resistant Resin Mortars

ASTM C 466 (04.05) Specification for Chemically Setting Silicate and Silica Chemical-Resistant Mortars

ASTM C 582 (08.04) Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment

ASTM C 658 (04.05) Specification for Chemical-Resistant Resin Grouts for Brick or Tile

ASTM C 661 (04.07) Test Method for Indentation Hardness of Elastomeric-Type Sealants by Means of a Durometer

ASTM C 723 (04.05) Practice for Chemical-Resistant Resin Grouts for Brick or Tile

ASTM C 805 (04.02) Test Method for Rebound Number of Hardened Concrete

ASTM C 811 (04.05) Practice for Surface Preparation of Concrete for Application of Chemical-Resistant Resin Monolithic Surfacing

ASTM C 868 (04.05) Test Method for Chemical Resistance of Protective Linings

ASTM C 1106 (04.05) Test Method for Chemical Resistance and Physical Properties of Carbon Brick

ASTM C 1140 (04.02) Practice for Preparing and Testing Specimens From Shotcrete Test Panels

ASTM D 36 (04.04) Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)

ASTM D 344 (06.01) Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts

ASTM D 412 (09.01) Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers - Tension

ASTM D 413 (09.01) Test Methods for Rubber Property - Adhesion to Flexible Substrate

ASTM D 429 (09.01) Test Methods for Rubber Property - Adhesion to Rigid Substrates

ASTM D 470 (10.01) Test Methods for Crosslinked Insulations and Jackets for Wire and Cable

ASTM D 522 (06.01) Test Methods for Mandrel Bend Test of Attached Organic Coatings

ASTM D 523 (06.01) Test Method for Specular Gloss

ASTM D 562 (06.01) Test Methods for Consistency of Paints Using the Stormer Viscometer

ASTM D 573 (09.01) Test Method for Rubber - Deterioration in an Air Oven

ASTM D 610 (06.02) Test Method for Evaluating Degree of Rusting On Painted Steel Surfaces (SSPC-Vis 2)

ASTM D 624 (09.01) Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers

ASTM D 638 (08.01) Test Method for Tensile Properties of Plastics

ASTM D 658 (06.01) Test Method for Abrasion Resistance of Organic Coatings by Air Blast Abrasive

ASTM D 660 (06.01) Test Method for Evaluating Degree of Checking of Exterior Paints

ASTM D 661 (06.01) Test Method for Evaluating Degree of Cracking of Exterior Paints

ASTM D 714 (06.01) Test Method for Evaluating Degree of Blistering of Paints

ASTM D 790 (08.01) Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

ASTM D 962 (06.03) Specification for Aluminum Powder and Paste Pigments for Paints

ASTM D 1005 (06.01) Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

ASTM D 1186 (06.01) Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base

ASTM D 1210 (06.01) Test Method for Fineness of Dispersion of Pigment-Vehicle Systems

ASTM D 1400 (06.01) Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base

ASTM D 1475 (06.01) Test Method for Density of Paint, Varnish, Lacquer, and Related Products

ASTM D 1654 (06.01) Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments

ASTM D 2196 (06.01) Test Method for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer

ASTM D 2240 (09.01) Test Method for Rubber Property - Durometer Hardness

ASTM D 2369 (06.01) Test Method for Volatile Content of Coatings

ASTM D 2370 (06.01) Test Method for Tensile Properties of Organic Coatings

ASTM D 2371 (06.01) Test Method for Pigment Content of Solvent- Reducible Paints

ASTM D 2372 (06.01) Practice for Separation of Vehicle from Solvent-Reducible Paints

ASTM D 2471 (08.02) Test Method for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins

ASTM D 2556 (15.06) Test Method for Apparent Viscosity of Adhesives Having Shear-Rate Dependent Flow Properties

ASTM D 2583 (08.02) Test Method for Indentation Hardness of Rigid Plastics by Means of Barcol Impressor

ASTM D 2697 (06.01) Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings

ASTM D 2794 (06.01) Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

ASTM D 3273 (06.01) Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber

ASTM D 3335 (06.01) Test Method for Low Concentrations of Lead, Cadmium, and Cobalt in Paint by Atomic Absorption Spectroscopy

ASTM D 3359 (06.01) Test Methods for Measuring Adhesion by Tape Test

ASTM D 3363 (06.01) Test Method for Film Hardness by Pencil Test

ASTM D 3450 (06.02) Test Method for Washability Properties of Interior Architectural Coatings

ASTM D 3486 (09.02) Practices for Installation of Vulcanizable Rubber Tank Linings and Pipe Linings (discontinued, 1984)

ASTM D 3723 (06.01) Test Method for Pigment Content of Water-Emulsion Paints by Low-Temperature Ashing

ASTM D 3843 (06.02) Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities

ASTM D 3911 (06.02) Test Method for Evaluating Coatings Used In Light-Water Nuclear Power Plants at Simulated Design Basis Accident (DBA) Conditions

ASTM D 3912 (06.02) Test Method for Chemical Resistance of Coatings Used in Light-Water Nuclear Power Plants

ASTM D 3925 (06.01) Practice for Sampling Liquid Paints and Related Pigmented Coatings

ASTM D 3941 (06.01) Test Method for Finite Flash Point of Liquids by the Equilibrium Closed Cup Method

ASTM D 4060 (06.01) Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

ASTM D 4082 (06.02) Test Method for Effects of Radiation On Coatings Used in Light-Water Nuclear Power Plants

ASTM D 4097 (08.04) Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks

ASTM D 4138 (06.02) Test Method for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means

ASTM D 4212 (06.01) Test Method for Viscosity by Dip-Type Viscosity Cups

ASTM D 4214 (06.01) Test Method for Evaluating Degree of Chalking of Exterior Paint Films

ASTM D 4227 (06.02) Practice for Qualification of Journeyman Painters for Application of Coatings to Concrete Surfaces of Safety-Related Areas in Nuclear Facilities

ASTM D 4228 (06.02) Practice for Qualification of Journeyman Painters for Application of Coatings to Steel Surfaces of Safety Related Areas in Nuclear Facilities

ASTM D 4256 (06.02) Test Method for Determination of the Decontaminability of Coatings Used in Light-Water Nuclear Power Plants

ASTM D 4258 (06.02) Practice for Surface Cleaning Concrete for Coating

ASTM D 4259 (06.02) Practice for Abrading Concrete

ASTM D 4260 (06.02) Practice for Acid Etching Concrete

ASTM D 4261 (06.02) Practice for Surface Cleaning Concrete Unit Masonry for Coating

ASTM D 4262 (06.02) Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces

ASTM D 4263 (06.02) Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method

ASTM D 4285 (06.02) Method for Indicating Oil or Water in Compressed Air

ASTM D 4357 (08.03) Specification for Plastic Laminates Made from Woven Roving and Woven Yarn Glass Fabrics

ASTM D 4400 (06.02) Test Methods for Sag Resistance of Paints Using a Multinotch Applicator

ASTM D 4414 (06.01) Practice for Measurement of Wet Film Thickness of Organic Coatings by Notched Gages

ASTM D 4417 (06.02) Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

ASTM D 4537 (06.02) Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work In Nuclear Facilities

ASTM D 4541 (06.02) Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers

ASTM D 4618 (06.02) Specification for the Design and Fabrication of Flue Gas Desulfurization System Components for Protective Linings

ASTM D 4752 (06.02) Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub

ASTM D 4787 (06.02) Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates

ASTM D 4796 (06.02) Test Method for Bond Strength of Thermoplastic Traffic Marking Materials

ASTM D 4828 (06.02) Test Method for Practical Washability of Organic Coatings

ASTM D 4940 (06.02) Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives

ASTM D 5162 (06.02) Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coatings on Metallic Substrates

ASTM D 5962 Standard Guide for Maintaining Unqualified Coatings (Paints) Within Level 1 Areas of a Nuclear Power Facility

ASTM E 11 (14.02) Specification for Wire Cloth and Sieves for Testing Purposes

ASTM E 96 (04.06) Test Methods for Water Vapor Transmission of Materials

ASTM E 337 (11.03) Test Method for Measuring Humidity with a Psychrometer (The Measurement of Wet- and Dry-Bulb Temperatures)

ASTM G 8 (06.02) Test Method for Cathodic Disbonding of Pipeline Coatings

ASTM G 42 (06.02) Test Method for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME/ANSI N45.2.6 Qualification of Inspection, Examination, and Testing Personnel for Nuclear Power Plants (replaced by ANSI/ASME NQA -1-1994)

ASME/ANSI NQA -1-1994 Quality Assurance Requirements for Nuclear Facility Applications (replaces ANSI/ASME N45.2.6)

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA/ANSI C203 Coal-Tar Protective Coatings and Linings for Steel Water Pipelines - Enamel and Tape - Hot Applied

AWWA/ANSI C205 Cement Mortar Protective Lining and Coating for Steel Water Pipe - 4 in. and Larger - Shop Applied

AWWA/ANSI C209 Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines

AWWA/ANSI C210 Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines

AWWA/ANSI C213 Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines

AWWA/ANSI C215 Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines

AWWA/ANSI C216 Heat-Shrinkable Cross-Linked Polyolefin Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines

AWWA/ANSI C217 Cold-Applied Petrolatum Tape and Petroleum Wax Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Buried Steel Water Pipelines

AWWA/ANSI C652 Disinfection of Water - Storage Facilities

AMERICAN WELDING SOCIETY (AWS)

AWS/ANSI C2.18 Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and Their Alloys and Composites

AWS/ANSI D1.1 Structural Welding Code, Steel

AWS/ANSI Z49.1 Safety in Welding, Cutting and Allied Processes

BRITISH STANDARDS INSTITUTION (BSI)

BS 2569 Sprayed Metal Coatings Part 1: Protection of Iron and Steel by Aluminum and Zinc Against Atmospheric Corrosion

BS 5493 Code of Practice for Protective Coating of Iron and Steel Structures Against Corrosion

CANADIAN STANDARDS ASSOCIATION (CSA)

CSA G-189 Sprayed Metal Coatings for Atmospheric Corrosion Protection

COMPRESSED GAS ASSOCIATION, INC. (CGA)

CGA G-7.1 Commodity Specification for Air

DEUTSCHES INSTITUT FÜR NORMUNG E. V. (GERMAN STANDARDS ORGANIZATION; DIN)

DIN 30672 Corrosion Protection, Tapes and Shrink Sleeves, Pipe Wrappings of Corrosion Protection Tape and Shrink Sleeves for Underground Pipelines Destined for Gas and Water Supply

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN)

CEN EN 22063/ISO 2063 Metallic and other Organic Coatings - Thermal Spraying--Zinc, Aluminum, and their Alloys

INTERNATIONAL CONCRETE REPAIR INSTITUTE (ICRI)

Technical Guideline No. 03732 Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 1127-6 Determination of Water-Soluble Contaminants by Conductivity Measurement

ISO 1127-7 Determination of Water-Soluble Chlorides

ISO 2063/CEN EN 22063 Metallic and other Organic Coatings - Thermal Spraying--Zinc, Aluminum, and their Alloys

ISO 8501-1-1988 Rust Grades and Preparation Grades of Uncoated Steel Substrates (Incorporated into ASTM D 2200)

ISO 8502-1 Field Tests for Soluble Iron Corrosion Products

ISO 8502-2 Laboratory Determination of Chloride on Cleaned Surfaces

ISO 8502-3 Assessment of Dust on Steel Surfaces Prepared for Painting (Pressure-Sensitive Tape Method)

ISO 8502-5 Chloride Ion Detection Tube

ISO 8502-6 Extraction of Soluble Contaminants for Analysis - The Bresle Method

ISO 8502-9 Field Method for the Conductimetric Determination of Water-Soluble Salts

NACE INTERNATIONAL (NACE)

NACE No. 1 White Metal Blast Cleaning (SSPC-SP 5)

NACE No. 2 Near White Blast Cleaning (SSPC-SP 10)

NACE No. 3 Commercial Blast Cleaning (SSPC-SP 6)

NACE No. 4 Brush-Off Blast Cleaning (SSPC-SP 7)

NACE No. 5 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating (SSPC-SP 12)

NACE RP0169-92 Control of External Corrosion on Underground or Submerged Metallic Piping Systems

NACE RP0178-95 Fabrication Details, Surface Finish Requirements and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service (Note: A visual aid is available, which should be used with the written standard.)

NACE RP0188-90 Discontinuity (Holiday) Testing of Protective Coatings

NACE RP0274-93 High Voltage Electrical Inspection of Pipeline Coatings Prior to Installation

NACE RP0287-91 Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using a Replica Tape

NACE RP0375-94 Wax Coating Systems for Underground Piping Systems

NACE RP0490-95 Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 10 to 30 mils (0.25 to 0.76 mm)

NACE TM0186-94 Holiday Detection of Internal Tubular Coatings of 250 to 760 Micrometers (10 to 130 Mils) Dry Film Thickness

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 58 Standard for the Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants

NSF INTERNATIONAL (NSF)

NSF/ANSI 61 Drinking Water System Components - Health Effects

SSPC: THE SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC-AB 1 Mineral and Slag Abrasives

SSPC-AB 2 Specification for Cleanliness of Recycled Ferrous Metallic Abrasives

SSPC-CS Guide 23.00 Guide for Thermal Spray Metallic System

SSPC-Guide 6 Guide for Containing Debris Generated During Paint Removal Operations

SSPC-Guide 7 Guide for the Disposal of Lead-Contaminated Surface Preparation Debris

SSPC-PA 1 Shop, Field and Maintenance Painting

SSPC-PA 2 Measurement of Dry Coating Thickness With Magnetic Gages

SSPC-PA Guide 3 A Guide to Safety in Paint Application

SSPC-PA Guide 4 Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems

SSPC-PA Guide 5 Guide to Maintenance Painting Programs

SSPC-Paint 16 Coal Tar Epoxy-Polyamide Black (Or Dark Red) Paint

SSPC-Paint 20 Zinc-Rich Primers (Type I - Inorganic and Type II - Organic)

SSPC-Paint 27 Basic Zinc Chromate - Vinyl Butyral Wash Primer (MIL-P-15328)

SSPC-Paint 29 Zinc Dust Sacrificial Primer, Performance-Based

SSPC-PS Guide 3.00 Guide for Selecting Phenolic Painting Systems

SSPC-PS Guide 8.00 Guide to Topcoating Zinc-Rich Primers

SSPC-PS Guide 12.00 Guide to Zinc-Rich Coating Systems

SSPC-PS Guide 17.00 Guide for Selecting Urethane Painting Systems

SSPC-SP 1 Solvent Cleaning

SSPC-SP 2 Hand Tool Cleaning

SSPC-SP 3 Power Tool Cleaning

SSPC-SP 5 White Metal Blast Cleaning (NACE No. 1)

SSPC-SP 6 Commercial Blast Cleaning (NACE No. 3)

SSPC-SP 7 Brush-Off Blast Cleaning (NACE No. 4)

SSPC-SP 8 Pickling

SSPC-SP 10 Near-White Blast Cleaning (NACE No. 2)

SSPC-SP 11 Power Tool Cleaning to Bare Metal

SSPC-SP 12 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating (NACE No. 5)

SSPC-Vis 1 Visual Standard for Abrasive Blast Cleaned Steel (Incorporated into ASTM D 2200)

SSPC-Vis 2 Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces (ASTM D 610)

SSPC-Vis 3 Visual Standard For Power- and Hand-Tool Cleaned Steel (Incorporated into ASTM D 2200)

UNDERWRITERS LABORATORIES INC. (UL)

UL 298 UL Standard for Safety, Portable Electric Hand Lamps

UL 781 UL Standard for Safety, Portable Electric Lighting Units for Use in Hazardous (Classified) Locations

US ARMY CORPS OF ENGINEERS

C200 Coal Tar Epoxy

US DEPARTMENT OF DEFENSE (DOD)

DOD-P-15328 Primer (Wash), Pretreatment (Formula No. 117 for Metals) (Metric) (SSPC Paint 27)

DOD-STD-2138 (SH) Metal Sprayed Coatings for Corrosion Protection Aboard Naval Ships (Metric)

MIL-P 85856 Powder Materials for Flame and Plasma Sprayed Coatings

MIL-W-6712C Wire, Metallizing

US FEDERAL SPECIFICATIONS

TT-C-555 Coating, Textured (for Interior and Exterior
Masonry Surfaces)

US FEDERAL TEST METHOD STANDARDS

FTMS 141 Method 627.12 Mildew Resistance

FTMS 141C Method 3011.2 Condition in Container

Appendix D

Regulations Referenced

US CODE OF FEDERAL REGULATIONS (CFR)

Title 10 - Energy

10 CFR 50 Domestic Licensing of Production and Utilization Facilities

10 CFR 50 Appendix B Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

10 CFR 21 Reporting of Defects and Noncompliance

Title 21 - Food and Drugs

21 CFR 175 Indirect Food Additives: Adhesives and Components of Coatings

21 CFR 177 Indirect Food Additives: Polymers

21 CFR 178 Indirect Food Additives: Adjuvants, Production Aids, and Sanitizers

Title 29 - Labor

29 CFR 1910 Occupational Safety and Health Standards

29 CFR 1910.29, Subpart T Commercial Diving Operations

29 CFR 1910.95 Occupational Noise Exposure

29 CFR 1910.134 Respiratory Protection

29 CFR 1910.146 Permit Required Confined Spaces

29 CFR 1926 Safety and Health Regulations for Construction

29 CFR 1926.52 Occupational Noise Exposure

29 CFR 1926.58 Asbestos

29 CFR 1926.59 Hazard Communication

29 CFR 1926.62 Lead

29 CFR 1926.64 Process Safety Management of Highly Hazardous Chemicals

29 CFR 1926.152 Flammable and Combustible Liquids

29 CFR 1926.417 Lockout and Tagging of Circuits

29 CFR 1926.451 Scaffolding

29 CFR 1926.500 Guardrails, Handrails, and Covers

29 CFR 1926.501 Duty to Have Fall Protection

29 CFR 1926.502 Fall Protection Systems Criteria and Practices

29 CFR 1926.503 Training Requirements

29 CFR 1926.1118 Inorganic Arsenic

29 CFR 1926.1127 Cadmium

Title 40 - Protection of Environment

40 CFR 261 Identification and Listing of Hazardous Waste

40 CFR 264 Standard for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities

US PUBLIC LAW

Public Law 85-172 Poultry Products Inspection Act

Public Law 90-201 Federal Meat Inspection Act

Public Law 90-201 Wholesome Meat Act of 1967

Public Law 90-492 Wholesome Poultry Products Act of 1968

Public Law 91-596 Occupational Safety and Health Act

Public Law 91-604 December 31, 1970, Clean Air Act

Public Law 101-549 November 15, 1990; and **Public Law 102-187**, September 4, 1991, Clean Air Act Amendments of 1990

Appendix E

Standards-Issuing Organizations and Regulatory Agencies

American Concrete Institute (ACI)

38800 Country Club Drive
Farmington Hills, MI 48331
Phone: 810/848-3700
FAX: 810/848-3701
Web: <http://www.aci-int.internet>

American Conference of Governmental Industrial Hygienists (ACGIH)

Suite 600, 1330 Kemper Meadow Drive
Cincinnati, OH 45240-1634
Phone: 513/742-2020
FAX: 513/742-3355
Web: <http://www.acgih.org>

American National Standards Institute (ANSI)

13th Floor, 11 West 42nd Street
New York, NY 10036-8002
Phone: 212/642-4900
FAX: 212/302-1286
Web: <http://www.ansi.org>

American Petroleum Institute (API)

1220 L Street, Northwest
Washington, DC 20005
Phone: 202/682-8000
FAX: 202/682-8030
Web: <http://www.api.org>

American Society for Testing and Materials (ASTM)

100 Barr Harbor Drive
West Conshohocken, PA 19428-2959
Phone: 610/832-9500
FAX: 610/832-9555
Web: <http://www.astm.org>

American Society of Mechanical Engineers (ASME)

345 East 47th Street
New York, NY 10017
Phone: 212/705-7722
FAX: 212/705-7674
Web: <http://www.asme.org>

American Water Works Association (AWWA)

6666 West Quincy Avenue
Denver, CO 80235
Phone: 303/794-7711
FAX: 303/794-7310
Web: <http://www.awwa.org>

American Welding Society, Inc. (AWS)

550 N.W. LeJeune Road
Miami, FL 33126
Phone: 305/443-9353
FAX: 305/443-7559
Web: <http://www.amweld.org>

ASM International (ASM)
9639 Kinsman Road
Materials Park, OH 44073-0002
Phone: 216/338-5151
FAX: 216/338-4634
Web: <http://www.asm-intl.org>

British Standards Institution (BSI)
P.O. Box 375
Milton Keynes MK14 6LL
UNITED KINGDOM
Phone: 01908 220908
FAX: 01908 320856
Web: <http://www.bsi.org.uk>

Canadian General Standards Board (CGSB)
222 Queen Street, Suite 1412
Ottawa, ON K1A 1G6
CANADA
Phone: 613/941-8709
FAX: 613/941-8706
Web: <http://w3.pwgsc.gc.ca/cgsb/>

Compressed Gas Association (CGA)
1725 Jefferson Davis Highway 1004 Suite 1004
Arlington, VA 22202-4102
Phone: 703/412-0900
FAX: 703/412-0128
e-mail: compressgasassoc@msn.com
Web: <http://www.cganet.com>

Construction Specification Institute (CSI)
601 Madison Street
Alexandria, VA 22314-1791
Phone: 703/684-0300
FAX: 703/684-0465
e-mail: csimail@csi.net.org
Web: <http://www.csinet.org>

Deutsches Institut für Normung e. V. (DIN)
Burggrafenstraße 4-10
1000 Berlin 30
West Germany
Telephone: + 49 30 26011
Fax: + 49 30 26011
Web: <http://www.din.de/frames/Welcome.html>

Environmental Protection Agency (EPA)
401 M Street SW
Washington, DC 20460
Phone: 202/260-2090
Web: <http://www.epa.gov>

European Committee for Standardization (CEN)
Rue de Stassart 36
Bruxelles, Belgium 1050
Phone: 010 32 251 968 11
FAX 010 32 251 968 19
e-mail: cen@cencibel.be

US Federal Aviation Administration (FAA)
800 Independence Avenue SW
Washington, DC 20591
Phone: 202/366-4000
Web: <http://www.faa.gov>

US Federal Highway Administration (FHWA)
400 Seventh Street, SW
Washington, DC 20590
Phone: 202/366-4000
Web: <http://www.dot.gov>

Federation of Societies for Coatings Technology (FSCT)
492 Norristown Road
Blue Bell, PA 19422-2350
Phone: 610/940-0777
FAX: 610/940-0292
Web: <http://www.coatingstech.org/coatingstech>

Food and Drug Administration (FDA)
5600 Fishers Lane
Rockville, MD 20857
Phone: 301/827-2410
FAX: 301/443-3100
Web: <http://www.fda.gov>

International Concrete Repair Institute (ICRI)
1323 Shepard Drive, Suite D
Sterling, VA 20164-4428
Phone: 703/450-0116
FAX: 703/450-0119
e-mail: concrepair@aol.com

International Organization for Standardization (ISO)
American National Standards Institute
11 W. 42nd St.
13th Floor
New York, NY 10036
Phone: 212/642-4900
FAX: 212/302-1286
Web: <http://www.iso.ch>

Military Specifications (MILSPEC)
Naval Publications and Forms Center
Attn: NPODS
5801 Tabor Avenue
Philadelphia, PA 19120-5099
Phone: 215/697-2000
FAX: 215/697-5914

NACE International (NACE)
P.O. Box 218340
Houston, TX 77218-8340
Phone: 713/492-0535
FAX: 713/492-8254
Web: <http://www.nace.org>

National Association of Pipe Coating Applicators
Commercial National Bank Building
Suite 717, 333 Texas Street
Shreveport, LA 71101-3666
Phone: 318/227-2769
FAX: 318/222-0482

National Fire Protection Association (NFPA)
P O Box 9101
1 Batterymarch Park
Quincy, MA 02269-9101
Phone: 617/770-3000
FAX: 617/770-0700
Web: <http://www.wpi.edu/Academics/Depts/Fire/Nfpa>

National Institute for Occupational Safety and Health (NIOSH)
200 Independence Avenue, SW
HHH Building, Room 715-H
Washington, DC 20201
Phone: 202/401-6997
FAX: 202/260-1898
Web: <http://www.cdc.gov/niosh/homepage.html>

National Institute of Standards and Technology (NIST)
Gaithersburg, MD 20899-0001
Phone: 301/975-2000
FAX: 301/926-4751
e-mail: inquiries@nist.gov
Web: <http://www.nist.gov>
NOTE: NIST is part of the Dept. of Commerce

NSF International (NSF)
P.O. Box 130140
Ann Arbor, MI 48113-0140
Phone: 313/769-8010
FAX: 313/769-0109
e-mail: info@nsf.org
Web: <http://www.nsf.org/index1.html>

Nuclear Regulatory Commission (NRC)
11555 Rockville Pike
Rockville, MD 20852
Phone: 301/415-7000
FAX: 301/415-7010 or 7020
Web: <http://www.nrc.gov>

Occupational Safety and Health Administration (OSHA)
200 Constitution Avenue, NW
Washington, DC 20210
Phone: 202/219-8151
FAX: 202/219-5986
Web: <http://www.osha.gov/>

Society of Naval Architects and Marine Engineers (SNAME)

601 Pavonia Avenue
Suite 400
Jersey City, NJ 07306
Phone: 201/798-4800
FAX: 201/798-4975
Web: <http://www.sname.org>

SSPC: The Society for Protective Coatings (SSPC)

40 24th Street, 6th Floor
Pittsburgh, PA 15222
Phone: 412/281-2331
FAX: 412/281-9992
e-mail: Research@sspc.org
Web: <http://www.sspc.org>

Swedish Standards Institution (SIS)

Box 3295
S-103 66 Stockholm
SWEDEN
Phone: (46) 8230400
FAX: (46) 8117035
Web: <http://www.sis.se>

Underwriters Laboratories (UL)

333 Pfingsten Road
Northbrook, IL 60062
Phone: 847/272-8800
FAX: 847/272-8129
Web: <http://www.ul.com>

United States Army Corps of Engineers, Headquarters

20 Massachusetts Ave. NW
Washington, DC 20314-1000
Phone: 202/761-0001
FAX: 202/761-1683
Web: <http://www.usace.army.mil>

United States Dept. of Agriculture (USDA)

1400 Independence Ave. SW
Rm. 507-A, J.L. Whitten Bldg.
Washington, DC 20250
Phone: 202/720-2791
Web: <http://www.usda.gov>

United States Dept of Commerce

14th Street and Constitution Ave., NW
Washington, DC 20230
Phone: 202/482-2000
Web: <http://www.doc.gov>

United States Government Printing Office (GPO)

Superintendent of Documents
Mail Stop: SSOP
Washington, DC 20402-9328
Phone: 202/512-1800
FAX: 202/512-2250 (24 hour request fax line)
Hours M-F 7:30 am to 4:30 pm EST)
Web: <http://www.access.gpo.gov>

Appendix F

Inspection Equipment

	STANDARDS	EQUIPMENT	EXAMPLES
I. AMBIENT CONDITIONS			
A. HUMIDITY/DEW POINT	ASTM E 337	Sling psychrometer, with spare thermometers, distilled or deionized water (for wetting wet bulb), psychrometric tables	• Bacharach Sling Psychrometer • Taylor Sling Psychrometer • US Weather Bureau Psychrometric Tables
		Battery operated psychrometer	• Vista Scientific Psychrometer • Psychro-Dyne • Psychron 566
		Electronic hygro-thermometer (measures relative humidity, temperature, and dew point)	• Elcometer 217 Electronic Hygro-Thermometer • Dew Check • Dickson Model TH550
B. AIR TEMPERATURE		Digital thermometer	• Atkins Digital Thermometer • PTC Min/Max Gage
		Temperature recorder	
C. WIND		Wind meter, pipe cleaners (for cleaning meter)	• Turbo-Meter
II. SURFACE CONDITIONS			
A. SURFACE TEMPERATURE		Magnetic contact surface temperature thermometer	• PTC Surface Thermometer • Atkins Digital Thermometer • Raytek Raynger Non-Contact
B. MOISTURE IN CONCRETE	ASTM D 4263	Plastic sheet, duct tape	

Note 1: ASTM is presently developing a standard for this method.

Note 2: This method is included in a draft Technology Update on Soluble Salts Detection, in preparation at SSPC.

Note 3: A visual standard for steel surfaces cleaned by water jetting is in preparation by SSPC and NACE International.

	STANDARDS	EQUIPMENT	EXAMPLES
B. MOISTURE IN CONCRETE (CONTINUED)	Note 1	Equipment for dome test (plastic dish filled with anhydrous calcium chloride, plastic dome, balance capable of weighing to nearest 0.1 g, sealant tape)	
		Moisture meter, drill, nails	• Delmhorst Moisture Indicator • Tramex Non-Destructive Moisture Encounter
C. SURFACE pH	ASTM D 4262	pH paper/litmus paper, distilled or deionized water, beaker or other vessel to collect rinse water	
		Digital pH meter, distilled or deionized water, beaker or other vessel to collect rinse water	
D. SOLUBLE SALT EXTRACTION	ISO 8502-6	Bresle cell, distilled or deionized water, syringe	
	Note 2	Limpet (Soltz) cell, distilled or deionized water, syringe	
	Note 2	Equipment for swabbing (ruler, pencil, cotton balls, latex gloves, forceps, graduated cylinder, beaker), distilled or deionized water	
E. ANALYSIS OF TOTAL SALTS	ISO 8502-9 Note 2	Digital conductivity tester	• DIST 3 ATC Dissolved Solids Tester
F. ANALYSIS OF CHLORIDE ION	Note 2	Test strips	• Quantab strips
	Note 2	Vacuum ampule test kit	• Chemetrics Co. kit
	ISO 8502-2	Direct titration	• Hana Instruments chloride test kit • Hatch Digital Titration
	ISO 8502-5	Chloride ion detection tube	
G. ANALYSIS OF FERROUS ION	ISO 8502-1	Test strips, ascorbic acid (required by some types of test strips)	
H. ANALYSIS OF SULFATE	Note 2	Test kit	• Hach SulfaVer 4 Method
I. GREASE OR OIL CONTAMINATION		Black light (long or short wavelength), black cloth	• Spectroline BIB-150 B Black Light Lamp

Note 1: ASTM is presently developing a standard for this method.

Note 2: This method is included in a draft Technology Update on Soluble Salts Detection, in preparation at SSPC.

Note 3: A visual standard for steel surfaces cleaned by water jetting is in preparation by SSPC and NACE International.

	STANDARDS	EQUIPMENT	EXAMPLES
I. GREASE OR OIL CONTAMINATION (CONTINUED)		Water spray bottle (for "water break test")	
J. DUST	ISO 8502-3	Clear tape, contrasting color display board, pictorial references Clean cloth	
K. WELD PREPARATION	NACE RP0178-89	Weld replicas	• NACE Surface Finish Weld Replica
III. SURFACE PREPARATION			
A. SURFACE CLEANLINESS - STEEL	SSPC-Vis 1 SSPC-Vis 3 ISO 8501 Note 3	Visual standards (photographic surface preparation standards)	• SSPC Visual Standards • ISO/Swedish Standards • NACE Visual Comparators • International Paint reference photographs (for water-jet cleaned steel)
B. SURFACE PROFILE - STEEL	ASTM D 4417, Method C NACE RP0287-87	Replica tape, burnishing tool, spring micrometer	• TESTEX Press-O-Film • TESTEX Spring Micrometer
	ASTM D 4417, Method A	Surface profile comparator disc, 5X magnifier	• Keane-Tator Surface Profile Comparator • ISO Surface Comparator • Elcometer Roughness Gage • Clemtex Anchor Pattern Comparator
	ASTM D 4417, Method B	Profile depth gage, smooth glass plate (for zeroing gage)	• Elcometer Surface Profile Gage
C. PIT DEPTH - STEEL		Pit gage	• Pipe-Pit Gage • Starrett Dial Depth (Pit) Gage
D. SURFACE TENSILE STRENGTH - CONCRETE	ASTM D 4541	Adhesion tester, loading fixture (pull stub), adhesive, equipment for mixing/applying adhesive, solvent for cleaning surface, sandpaper for roughening surface	

Note 1: ASTM is presently developing a standard for this method.

Note 2: This method is included in a draft Technology Update on Soluble Salts Detection, in preparation at SSPC.

Note 3: A visual standard for steel surfaces cleaned by water jetting is in preparation by SSPC and NACE International.

	STANDARDS	EQUIPMENT	EXAMPLES
D. SURFACE TENSILE STRENGTH - CONCRETE (CONTINUED)	ACI 503R, Appendix A	Dillon dynamometer, pipe cap, adhesive, equipment for mixing/applying adhesive	
E. SURFACE PROFILE - CONCRETE	ICRI Technical Guideline No. 03732	Molded replicates	ICRI molded replicates
IV. OTHER ITEMS FOR SURFACE PREPARATION			
A. COMPRESSED AIR CLEANLINESS	ASTM D 4285	Blotter paper, rigid backing (to place behind blotter paper)	
B. SIEVE SIZE	ASTM C 136	Sieves of various sizes	
C. ABRASIVE CLEANLINESS	SSPC-AB 1 ASTM D 4940	Jar/vial, distilled or deionized water, filter, equipment for measuring ion content of water (e.g., conductivity meter, ion test kits, pH paper)	
D. RECYCLED ABRASIVE CLEANLINESS	SSPC-AB 2 ASTM D 3335 ASTM D 4940 ASTM E 11	Balance, 203 mm (8 inch) sieve, magnet with plastic sheath or cylinder, two weighing vessels	
E. BLAST NOZZLE WEAR		Blast nozzle orifice gage	Clemtex Pressure Blast Analyzer Gage
F. BLASTING PRESSURE		Hypodermic needle pressure gage, spare needles	
V. PAINT CONDITIONS			
A. PAINT TEMPERATURE		Paint thermometer	Taylor Paint Thermometer
B. VISCOSITY (DIP CUP)	ASTM D 4212	Viscosity cup, stopwatch, and thermometers for measuring air and paint temperatures	- Zahn Viscosity Cup - EZ Viscosity Cup (equivalent to the Zahn cup)
VI. WET FILM THICKNESS			
A. NOTCH GAGE	ASTM D 4414	Notch wet film thickness gage, rag (to wipe gage between tests)	- Nordson Wet Film Gage - Aluminum Wet Film Gage - Disposable Plastic Wet Film Gages

Note 1: ASTM is presently developing a standard for this method.

Note 2: This method is included in a draft Technology Update on Soluble Salts Detection, in preparation at SSPC.

Note 3: A visual standard for steel surfaces cleaned by water jetting is in preparation by SSPC and NACE International.

	STANDARDS	EQUIPMENT	EXAMPLES
B. OTHER TYPES OF GAGES		Pfund wet film thickness gage	
		Interchemical roller wet film thickness gage	
		Needle micrometer wet film thickness gage	
VII. DRY FILM THICKNESS			
A. NON-DESTRUCTIVE DRY FILM THICKNESS	SSPC-PA 2, Type 1 ASTM D 1186	Magnetic pull-off dry film thickness gage, calibration standards	• Elcometer 211 • Elcometer Inspector • Elcometer Pull-Off • Mikrotest III • Mikrotest IV • Pentest • PosiPen • PosiTest • Pro-Gauge • NIST (NBS) Calibration Standards • MIKROTEST Calibration Standards
	SSPC-PA 2, Type 2	Magnetic constant pressure probe dry film thickness gage, plastic calibration shims (needed for some Type 2 gages)	• Elcometer 145 • Elcometer 256 • Elcometer 300 • Elcometer 345 • Elcometer 355 • Elcometer Thickness Gage • ETG • Minitest 100/300 • Minitest 1001, 3001, 4000 • PosiTector 6000 • PosiTest 1000 • QuaNix 1500 • QuaNix 2200 • QuaNix 7200/7300

Note 1: ASTM is presently developing a standard for this method.

Note 2: This method is included in a draft Technology Update on Soluble Salts Detection, in preparation at SSPC.

Note 3: A visual standard for steel surfaces cleaned by water jetting is in preparation by SSPC and NACE International.

	STANDARDS	EQUIPMENT	EXAMPLES
	ASTM D 1400	Eddy current gage, plastic calibration shims	• QuaNix 2300
	Note 1	Ultrasonic gage, couplant, plastic calibration shims	• PosiTector
B. DESTRUCTIVE DRY FILM THICKNESS	ASTM D 4138	Destructive dry film thickness gage, cutting tips, 50X calibrated microscope	• Tooke Gage - Mark III • Tooke Gage - Mark IV • Saberg Drill
C. FILM THICKNESS OF PRE-FABRICATED COATINGS AND LININGS	ASTM D 1005	Stationary or hand-held micrometer	
VIII. FILM PROPERTIES			
A. VISUAL INSPECTION		Magnifying glass/inspection microscope	• 30X and 100X Economy Microscopes • PTC Precision Hand Lens • Macroscope 25 and Zoom Inspection Microscope
		Inspection mirrors (with extension handles)	
		Inspection flashlight	• Mini Mag Flashlight
B. HOLIDAY DETECTION	ASTM D 5162 - steel ASTM D 4787 - concrete NACE RP0188-90	Low-voltage holiday detector, distilled or deionized water, wetting agent, non-wax marker for marking defects	• Elcometer Pinhole Detector • K-D Bird Dog (low voltage) • Tinker & Razor M-1 Low Voltage Holiday Detector
	ASTM D 5162 NACE RP0188-90	High-voltage holiday detector, non-wax marker for marking defects	• DE Stearns 14/20 High Voltage Holiday Detector (for thick coatings) • Elcometer High Voltage Pinhole Detector • Spy High Voltage Holiday Detector • Tinker & Razor AP-W High Voltage Holiday Detector

Note 1: ASTM is presently developing a standard for this method.

Note 2: This method is included in a draft Technology Update on Soluble Salts Detection, in preparation at SSPC.

Note 3: A visual standard for steel surfaces cleaned by water jetting is in preparation by SSPC and NACE International.

	STANDARDS	EQUIPMENT	EXAMPLES
IX. ADHESION			
A. ADHESION TESTING USING TAPE TEST	ASTM D 3359	Cutting guides or straight-edge, utility knife or razor blade, pencil with eraser, tape	• KTA Cross-Cut Guide • GARDCO Paint Adhesion Test Kit • Permacel 99 (tape for cross-cut method)
B. MECHANICAL ADHESION TESTING	ASTM D 4541	Adhesion tester, loading fixture (pull stub), adhesive, equipment for mixing/applying adhesive, solvent for cleaning surface, sandpaper for roughening surface	• Elcometer Adhesion Tester (mechanically operated, "pull-off" method; up to 4000 psi [28 MPa]) • SEMicro PATTI Pneumatic Adhesion Test Instrument (up to 10,000 psi [69 MPa]) • HATE Mark VII Hydraulic Adhesion Test Instrument (up to 3000 psi [21 MPa])
X. HARDNESS			
A. PENCIL TESTING	ASTM D 3363	Set of pencil leads, fine sandpaper or emery cloth	
B. REBOUND NUMBER OF CONCRETE	ASTM C 805	Schmidt hammer	
C. DUROMETER HARDNESS	ASTM D 2240	Shore A or Shore D Durometer	• PTC Durometer
D. INDENTATION HARDNESS	ASTM D 2583	Barcol Impressor, calibration disk	• Barber Coleman Impressor
XI. CURE			
A. SOLVENT RUB	ASTM D 4752	MEK, clean cloth (for solvent rub test)	
B. COIN RUB		Coin (for coin rub test)	
C. COLOR CHANGE		Color comparator	

Note 1: ASTM is presently developing a standard for this method.

Note 2: This method is included in a draft Technology Update on Soluble Salts Detection, in preparation at SSPC.

Note 3: A visual standard for steel surfaces cleaned by water jetting is in preparation by SSPC and NACE International.

Appendix G

Inspection Equipment Suppliers

KEY TO INSPECTION EQUIPMENT

- 1 Adhesion Tester, Laboratory
- 2 Adhesion Tester, Tensile
- 3 Adhesion Tester, Cross-Hatch
- 4 Dry Film Thickness Gage, Destructive
- 5 Dry Film Thickness Gage, Eddy Current
- 6 Dry Film Thickness Gage, Magnetic
- 7 Dry Film Thickness Gage, Ultrasonic
- 8 Hardness Tester
- 9 Holiday Detector, High Voltage
- 10 Holiday Detector, Low Voltage
- 11 Microscope, Field
- 12 Nozzle Orifice Gage
- 13 Pit Gage
- 14 Pressure Gage, Needle
- 15 Profile Comparator
- 16 Profilometer
- 17 Psychrometer
- 18 Replica Tape
- 19 Test Kits for Soluble Salt Contaminants (e.g., sulfates, chlorides, iron salts)
- 20 Thermometer, Surface Temperature
- 21 Wet Film Thickness Gage
- 22 Viscosity Cup
- 23 Visual Standards/Reference Photographs

LIST OF SUPPLIERS

Note: This list does not necessarily cover each supplier's full product line. For information about equipment not on this list, please contact the suppliers directly.

ABC's Co. American Blast Cleaning Supply Co.

1920 Olive Drive
Santa Maria, CA 93454
Phone: 805/928-8400
FAX: 805/349-2450
Inspection Equipment: 12, 14, 16

Airblast B.V.

P.O. Box 1075
1700 BB Heerhugowaard
THE NETHERLANDS
Phone: 31 7 25718002
FAX: 31 7 25714340
Inspection Equipment: 3, 4, 5, 6, 9, 10, 12, 14, 15, 17, 18, 20, 21, 23

American Environmental Enterprises

1311 West Chester Pike
West Chester, PA 19382
Phone: 610/344-0637
FAX: 610/436-4983
Inspection Equipment: 4, 5, 6

Appendix G

Inspection Equipment Suppliers

KEY TO INSPECTION EQUIPMENT

- 1 Adhesion Tester, Laboratory
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- 6 Dry Film Thickness Gage, Magnetic
- 7 Dry Film Thickness Gage, Ultrasonic
- 8 Hardness Tester
- 9 Holiday Detector, High Voltage
- 10 Holiday Detector, Low Voltage
- 11 Microscope, Field
- 12 Nozzle Orifice Gage
- 13 Pit Gage
- 14 Pressure Gage, Needle
- 15 Profile Comparator
- 16 Profilometer
- 17 Psychrometer
- 18 Replica Tape
- 19 Test Kits for Soluble Salt Contaminants (e.g., sulfates, chlorides, iron salts)
- 20 Thermometer, Surface Temperature
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ABC's Co. American Blast Cleaning Supply Co.
1920 Olive Drive
Santa Maria, CA 93454
Phone: 805/928-8400
FAX: 805/349-2450
Inspection Equipment: 12, 14, 16

Airblast B.V.
P.O. Box 1075
1700 BB Heerhugowaard
THE NETHERLANDS
Phone: 31 7 25718002
FAX: 31 7 25714340
Inspection Equipment: 3, 4, 5, 6, 9, 10, 12, 14, 15, 17, 18, 20, 21, 23

American Environmental Enterprises
1311 West Chester Pike
West Chester, PA 19382
Phone: 610/344-0637
FAX: 610/436-4983
Inspection Equipment: 4, 5, 6

Apollo Sprayers--Texas

3314 Greenbriar
Houston, TX 77098
Phone: 713/526-5601
FAX: 713/526-5601
Inspection Equipment: 22

Atkins Technical Inc.

3401 S.W. 40th Blvd.
Gainesville, FL 32608
Phone: 352/378-5555
FAX: 352/335-6736
Inspection Equipment: 20

Atlas Electric Devices Co.

4114 N. Ravenswood Avenue
Chicago, IL 60613
Phone: 312/327-4520
FAX: 312/327-5787
Inspection Equipment: 1

Automation USA

P.O. Box 563
Westminster, MD 21158
Phone: 800/678-4370
FAX: 410/857-3818
Inspection Equipment: 5, 6

Blastmaster Industries

P.O. Box 3532
Davenport, IA 52808-3532
Phone: 800/US-BLAST
FAX: 319/324-1531
Inspection Equipment: 14

T.F. Campbell Company, Inc. Bacharach Products

1521 Saw Mill Run Blvd.
Pittsburgh, PA 15210
Phone: 412/881-8006
FAX: 412/881-0437
e-mail: campbellco@aol.com
Web: <http://www.aol.com/campbellco>
Inspection Equipment: 14, 17, 20

Cascade Associates, Inc.

6911-13 Market Street
Youngstown, OH 44512
Phone: 330/758-6649
FAX: 330/758-5075
Inspection Equipment: 9, 10, 17

CHEMetrics, Inc.

Route 28
Calverton, VA 20138
Phone: 540/788-9026
FAX: 540/788-4856
e-mail: techinfo@chemetrics.com
Web: <http://www.chemetrics.com>
Inspection Equipment: 19

Clemco Industries Corp.

One Cable Car Drive
Washington, MO 63090
Phone: 314/239-0300
FAX: 314/239-0999
Inspection Equipment: 14, 15

Clemtex Inc.

P.O. Box 15214
Houston, TX 77220-5214
Phone: 713/672-8251
FAX: 713/672-6336
Inspection Equipment: 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23

CMI

945 Busse Road
Elk Grove Village, IL 60007
Phone: 847/439-4404
FAX: 847/439-4425
e-mail: cmi.int@ix.netcom.com
Inspection Equipment: 5, 6

Cole-Parmer Instrument Co.

625 East Bunker Ct.
Vernon Hills, IL 60061-1844
Phone: 800/323-4340 or 847/549-7600
FAX: 847/549-7676
e-mail: info@coleparmer.com
Web: <http://www.coleparmer.com>
Inspection Equipment: 1, 6, 7, 8, 11, 14, 17, 19, 20, 22

Control Analytics Inc.

106 Laird Street
Greensburg, PA 15601
Phone: 412/837-3417
FAX: 412/837-3418
Inspection Equipment: 9, 10

CRM Inspection Equipment

471 Casey Lane
Strawberry Plains, TN 37871
Phone: 800/898-2764
FAX: 423/933-5953
Inspection Equipment: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23

Cygnus Instruments Inc.

P.O. Box 6417
Annapolis, MD 21401
Phone: 410/267-9771
FAX: 410/268-2013
cygnusus@ix.netcom.com
Web: <http://www.cygnus-instruments.co.uk>
Inspection Equipment: 13

DeFelsko Corporation

802 Proctor Avenue
P.O. Box 676
Ogdensburg, NY 13669
Phone: 800/448-3835
FAX: 315/393-8471
e-mail: techsale@defelsko.com
Web: <http://www.defelsko.com>
Inspection Equipment: 2, 4, 5, 6, 7, 9, 10, 20, 21, 22, 23

D Tex Corp.

5687 W. Touhy Avenue
Niles, IL 60714
Phone: 312/631-4253
Inspection Equipment: 19

Elcometer Inc.

1893 Rochester Industrial Drive
Rochester Hills, MI 48309-1728
Phone: 800/521-0635
FAX: 810/650-0501
Inspection Equipment: 2, 3, 4, 5, 6, 7, 9, 10, 11, 13, 15, 17, 18, 20, 21, 23

Electromatic Equipment Co., Inc.

600 Oakland Avenue
Cedarhurst, NY 11516
Phone: 800/645-4330
FAX: 516/295-4399
Web: <http://www.checkline.com>
Inspection Equipment: 5, 6, 7

Elektro-Physik USA Inc.

770 W. Algonquin Road
Arlington Heights, IL 60005
Phone: 800/782-1506
FAX: 847/437-0053
Inspection Equipment: 5, 6, 9, 10, 21

ENG Equipment Inc.

1013 Peninsula Avenue
Tarpon Springs, FL 34689
Phone: 813/942-3868
FAX: 813/942-6723
Inspection Equipment: 4, 5, 15, 17, 21

Fischer Technology Inc.

750 Marshall Phelps Road
Windsor, CT 06095
Phone: 800/243-8417
FAX: 860/688-8496
Inspection Equipment: 4, 5, 6

Paul N. Gardner Co., Inc.

P.O. Box 10688
Pompano Beach, FL 33060
Phone: 954/946-9454
FAX: 954/946-9309 or 9375
e-mail: gardner@gardco.com
Web: <http://www.gardco.com>
Inspection Equipment: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,
13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23

Gordon Sand Company

2201 South Santa Fe Avenue
Compton, CA 90221
Phone: 213/774-7930
FAX: 310/537-2483
Inspection Equipment: 14, 18

Hach Co.

P.O. Box 608
Loveland, CO 80539-0608
Phone: 800/227-4224
FAX: 970/669-2932
Inspection Equipment: 19

HybriVet Systems Inc.

P.O. Box 1210
Framingham, MA 01701
Phone: 508/651-7881
FAX: 508/651-8837
Inspection Equipment: 19

Hydraulic Adhesion Test Equipment Ltd.

629 Inlet Road
North Palm Beach, FL 33408
Phone: 407/863-3564
FAX: 407/863-3564
Inspection Equipment: 1, 2

Inter Mountain Electronix R&D

1515 Elk # 13
Rock Springs, WY 82901
Phone: 307/362-1872
FAX: 307/362-7164
Inspection Equipment: 10

International Paints - Courtaulds Coatings

6001 Antoine Dr.
Houston, TX 77091
Phone: 713/682-1711
FAX: 713/684-1511
Inspection Equipment: 23

IPCO Safety

128 Wharton Road
Bristol, PA 19007
Phone: 800/827-2338
FAX: 800/827-8036
Inspection Equipment: 19

K-D Company

7899 St. Helena Road
Santa Rosa, CA 95404
Phone: 707/539-2286
Inspection Equipment: 10

KTA-Tator Inc.

115 Technology Drive
Pittsburgh, PA 15275-1085
Phone: 412/788-1300
FAX: 412/788-1306
e-mail: info@kta.com
Web: <http://www.kta.com>
Inspection Equipment: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,
13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23

LaMotte Company

P.O. Box 329
Chestertown, MD 21620
Phone: 800/344-3100
FAX: 410/778-6394
Web: <http://www.lamotte.com>
Inspection Equipment: 19

Michael J. Lunardini Inc.

125 Theobald Avenue
Greensburg, PA 15601
Phone: 412/836-2227
FAX: 412/836-0808
Inspection Equipment: 14

Manus Abrasive Systems Inc.

1040-78 Avenue
Edmonton, AB T6P 1L7
CANADA
Phone: 800/661-3842
FAX: 403/465-7317
Inspection Equipment: 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14,
15, 16, 17, 18, 19, 20, 21, 23

Marco®

1044 South Dittmen
Davenport, IA 52802
Phone: 800/252-7848
FAX: 319/324-8504
Inspection Equipment: 14

Metorex Inc.

1900 NE Division Street Suite 204
Bend, OR 97701
Phone: 541/385-6748
FAX: 541/385-6750
e-mail: Product_Info@metorex.com
Inspection Equipment: 4, 19

Micro Metrics Company

2064 Briarcliff Road Suite 112
Atlanta, GA 30329
Phone: 404/325-3243
FAX: 404/320-1668
e-mail: 75124.3075@compuserve.com (company presi-
dent)
Inspection Equipment: 4, 8

NACE International

Membership Services Department
P.O. Box 218340
Houston, TX 77218-8340
Phone: 713/492-0535
FAX: 713/579-6694
e-mail: ginac@mail.nace.org
Web: <http://www.nace.org>
Inspection Equipment: 23

PPS Industries

19 Sweetmans Lane
Manalapan, NJ 07726
Phone: 800/423-7733
FAX: 908/409-1144
Inspection Equipment: 4, 5

S.G. Pinney & Associates, Inc.

P.O. Box 9220
Port St. Lucie, FL 34985-9220
Phone: 407/337-3080
FAX: 407/337-0294
Inspection Equipment: 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14,
15, 16, 17, 18, 19, 20, 21, 22, 23

Pipeline Inspection Co. Inc.

1919 Antoine
Houston, TX 77055
Phone: 713/681-5837
FAX: 713/681-4838
Inspection Equipment: 9, 10

PPS Industries

19 Sweetmans Lane
Manalapan, NJ 07726
Phone: 800/423-7733
FAX: 908/409-1144
Inspection Equipment: 4, 5

Protimeter Inc.

P.O. Box 450
Danvers, MA 01923
Phone: 800/321-4878
FAX: 508/777-5033
Inspection Equipment: 17, 20

Reed Minerals

A Harsco Company
8149 C. Kennedy Avenue
Highland, IN 46322
Phone: 219/923-4200
FAX: 219/923-3044
Inspection Equipment: 14

Rentalease Inc.

230 Barrios Street
Lockport, LA 70374
Phone: 504/532-5700
FAX: 504/532-3040
Inspection Equipment: 3, 4, 5, 6, 11, 12, 13, 14, 15, 16, 17,
18, 20, 21, 22, 23

Bob Schmidt, Inc.

6040 Osborn
Houston, TX 77033
Phone: 713/644-2071
FAX: 713/644-9461
Inspection Equipment: 6, 7, 10, 11, 12, 13, 14, 15, 16, 17,
18, 20, 21, 23

SDS Company

P.O. Box 844
Paso Robles, CA 93447
Phone: 805/238-3229
FAX: 805/238-3496
Inspection Equipment: 2

SEMicro, division M.E. Taylor Engineering, Inc.

15817 Crabbs Branch Way
Rockville, MD 20855
Phone: 301/975-9798
FAX: 301/975-9653
e-mail: SEMicro@aol.com
Inspection Equipment: 1, 2, 11

Shelby Jones

8800 West Chester Pike
Upper Darby, PA 19082
Phone: 610/446-6600
FAX: 610/449-7010
e-mail: shelby@p3.net
Web: <http://www.shelbyjones.com> (under construction)
Inspection Equipment: 7, 8, 14, 17, 20

Spray-Quip Inc.

1754 Des Jardines
Houston, TX 77023
Phone: 713/923-2771
FAX: 713/923-7822
e-mail: sq@net1.net
Inspection Equipment: 2, 4, 6, 7, 9, 10, 11, 17, 19, 20, 21,
22, 23

The D.E. Stearns Company

P.O. Box 3456
Shreveport, LA 71133
Phone: 318/635-5351
FAX: 318/636-6969
Inspection Equipment: 9, 10

SSPC: The Society for Protective Coatings

40 24th Street
Pittsburgh, PA 15222
Phone: 412/281-2331
FAX: 412/281-9992
Inspection Equipment: 23

Technitron Labs

555 Briarwood Court
Troy, OH 45373
Phone: 513/335-3139
FAX: 513/335-9828
Inspection Equipment: 22

Teknocom, Inc.

43 Main Street
Potsdam, NY 13676
Phone: 800/724-5265
FAX: 315/265-1536
Inspection Equipment: 4, 5, 7, 6, 9, 10, 21

Testex

P.O. Box 867
Newark, DE 19715
Phone: 302/731-5693
FAX: 302/455-0915
e-mail: testex@interramp.com
Inspection Equipment: 18

Tinker & Rasor

P.O. Box 281
San Gabriel, CA 91778
Phone: 818/287-5259
FAX: 818/287-0132
e-mail: TandR@pacbell.net
Web: <http://www.TandR.com>
Inspection Equipment: 6, 7, 9, 10

United Abrasive Inc.

19100 Industrial Drive
Vulcan, MI 49892
Phone: 800/228-2925
FAX: 906/563-8739
Inspection Equipment: 12, 14, 15, 16, 18, 23

Wonder Makers Inc.

P O Box 50209
Kalamazoo, MI 49005-0209
Phone: 616/382-4154
FAX: 616/382-4161
Inspection Equipment: 19

Appendix H

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