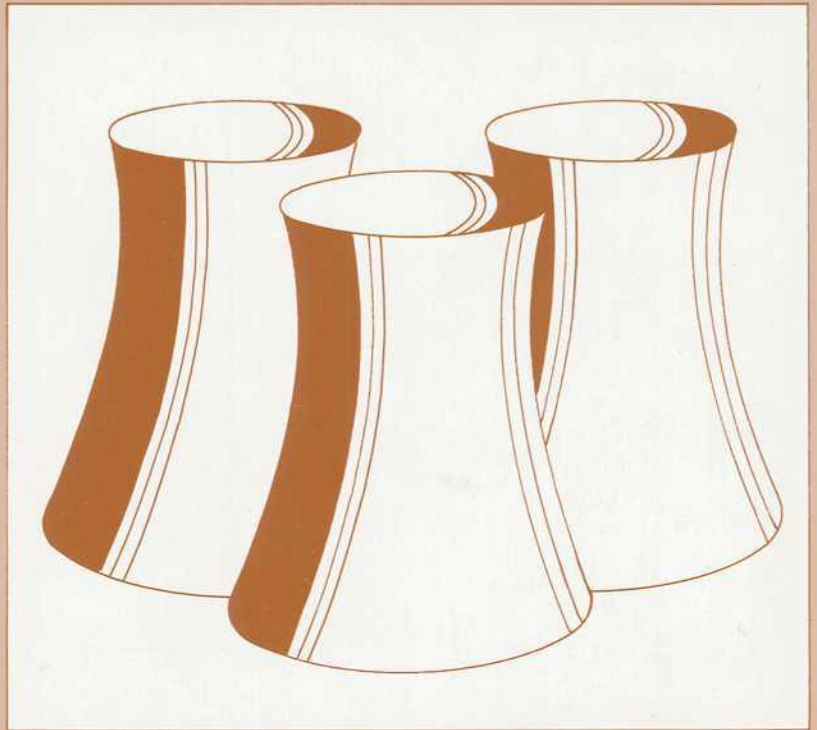


MANUAL ON



**MAINTENANCE
COATINGS
FOR NUCLEAR
POWER PLANTS**



Manual on Maintenance Coatings for Nuclear Power Plants

**Compiled by
ASTM SUBCOMMITTEE D33.10
ON PROTECTIVE COATINGS
MAINTENANCE WORK FOR POWER
GENERATION FACILITIES**

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Dedication



Mendel A. Puschel
1932–1990

MENDEL A. PUSCHEL was one of a small but active group in the early history of ASTM Committee D33 on Protective Coating and Lining Work for Power Generation Facilities, known in the early years as ASTM Subcommittee D01.43. Mendel served in a variety of roles, giving input to various task groups from quality assurance of coating application to the advisory aspects of the power utilities. However, his main goal was to establish maintenance coating procedures for nuclear power plants, for which this manual is intended.

He gained first hand experience in his work interests at Consumers Power Company of Jackson, Michigan. There he served, at the time of his early retirement, as staff engineer of projects, Engineering and Construction.

Mendel graduated in 1957 from Michigan Technical Institute with a Bachelor of Science in Engineering and began working for Consumers Power Co. two years later. In 1989 he received the Engineer of the Year Award from the Jackson Chapter of the Michigan Society of Professional Engineers.

At the time of Mendel's death he was the chairman of Subcommittee D33.10 on Protective Coatings Maintenance Work for Power Generation Facilities. We of ASTM D33 dedicate this manual to his memory. He was our friend, associate, and fellow engineer.

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Foreword

THIS PUBLICATION WAS sponsored by ASTM Committee D33 on Protective Coating and Lining Work for Power Generation Facilities. Its creation and maintenance is the responsibility of Subcommittee D33.10 on Protective Coatings Maintenance Work for Power Generation Facilities. This subcommittee is composed of representatives from various organizations involved with corrosion control by use of protective coatings. Subcommittee members include individuals from utilities, architect-engineer-constructors, coating inspection services, and other interested parties. The information presented herein reflects a consensus of the subcommittee (the list of contributors is on the facing page, members of D33.10 as of 5 Feb. 1990).

This manual was prepared to address a need perceived by ASTM Committee D33 for guidance in selecting and applying maintenance coatings in nuclear plants but is not to be considered a standard. In addition to servicing as that source, this document has the equally necessary role of acting as a focal point for a rapidly changing technology. While the subcommittee considers the information contained in this manual to be state of the art, the book offers limited historical data upon which to establish detailed requirements or methodologies. Accordingly, the user will find this edition rather general.

The procedures described herein may involve hazardous materials, operations, and equipment. This manual does not purport to address all the safety problems associated with their use. It is the responsibility of the user of this manual to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

Mendel A. Puschel

Acronyms

3M	Minnesota Mining and Manufacturing
ACI	American Concrete Institute
ALARA	As low as reasonably achievable
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BWR	Boiling water reactor
CFR	Code of Federal Regulations
DBA	Design basis accident
DWV	Drain, waste, and vent
ECCS	Emergency core cooling system
EPA	Environmental Protection Agency
ESS	Engineered safety system
FSAR	Final safety analysis report
HEPA	High efficiency particulate air
HVAC	Heating, ventilation, and air conditioning
LOCA	Loss of coolant accident
MSHA	Mine Safety and Health Administration
NACE	National Association of Corrosion Engineers
NBS	National Bureau of Standards
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Act
PWR	Pressurized water reactor
QA/QC	Quality assurance/quality control
QC	Quality control
RHR	Residual heat removal
Reg. Guide	Regulatory Guide
SAR	Safety analysis report
SSPC	Steel Structure Painting Council
SSPC-SPII	Steel Structures Painting Council—Surface Preparation
UT	Ultrasonic test

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Protecting Surfaces in a Nuclear Plant

by Don Hill

THIS CHAPTER ACQUAINTS the user of this manual with background information so that a better understanding of the complexities of regulations and their need in the maintenance of the nuclear power facility is achieved. The following subjects will be briefly discussed:

1. The reasons for the initial coating work, including that done in the primary containment structure.
2. The relationship between the coating work accomplished during the construction phase and the concerns of the emergency coolant system/engineered safety systems of light water nuclear power plants.

THE CONTAINMENT ENVIRONMENT

The *primary containment structure* is a very large building which contains the nuclear reactor and associated equipment. During operations, the containment interior may experience varied humidity conditions as high as 100%. Equipment, walls, and appurtenances can be constantly subjected to condensation, radiation, and contamination by radioactive particles.

PURPOSE FOR COATING THE PRIMARY CONTAINMENT STRUCTURE

The Nuclear Regulatory Commission (NRC) does not require an item or surface in a nuclear plant to be coated. However, it would be impractical to allow corrosion to occur if it can be prevented by the application of an acceptable coating or coating system. If a coating or a coating system is used, it must remain on the surface for operating conditions as well as accident conditions.

The critical requirement of coating work in the primary containment relates to the engineered safety systems (ESS) in that the coating system during a design basis accident (DBA) does not impact the orderly and safe shutdown of the plant.

Corrosion protection of carbon steel containment pressure vessels and of carbon steel liners with a coating or coating system may be a direct safety-related function. Impairment of this protection is of vital concern since operational and outage surveillance may be quite difficult. Corrosion protection of other facilities, not related to the primary containment (mechanical and electrical equipment), is also of

major concern, but operational maintenance of these facilities will ordinarily detect corrosion in early stages and thus materially decrease safety-related concerns. A protective coating/coating system used in the primary containment structure is designed to protect surfaces from corrosion and to improve decontaminability of exposure to radioactive nuclides.

During the course of construction, many small “off-the-shelf” items coated with an unqualified coating system will be placed within the primary containment structure. Such surfaces are of particular concern for several reasons—first, the unqualified coating may not be capable of withstanding the environment of the containment for more than a year or two, and, secondly, if allowed in excess of the allowable quantity established during the construction phase, the safe shutdown of the facility could be affected. (NUREG 0800, Section 6.1.2 requires all unqualified coatings be considered to form solid debris under DBA conditions.)

COATING REQUIREMENTS

Only qualified protective coating systems may be used to protect surfaces inside the primary containment in pressure water reactors (PWRs) and boiling water reactors (BWRs). Many of these coating systems, not all, meet the criteria found in ANSI N101.2 and ANSI N5.12 and the relevant ASTM replacements for those ANSI standards. The important criteria include but are not limited to:

1. Pass a design basis accident (DBA) test at either 307°F (153°C) or 340°F (171°C) curve that envelopes the individual plant's curve [ASTM Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Loss of Coolant Accident (LOCA) Conditions (D 3911)].
2. Have a high decontamination factor [ASTM Test Method for Determination of the Decontaminability of Coatings Used in Light-Water Nuclear Power Plants (D 4256)].
3. Have radiation resistance to 10^9 rad or the individual plant's requirements [ASTM Specification for Vapor-Degreasing Grade Trichloroethylene (D 4080)].
4. Meet a flame spread rating below 25 per ASTM Test Method for Surface Burning Characteristics of Building Materials (E 84).
5. Meet pull-off adhesion of greater than 200 psi (1379 kPa) [ASTM Method for Pull-Off Strength of Coatings Using Portable Adhesion-Testers (D 4541)].

DISCLOSURE

These same requirements are applicable to coatings for maintenance painting. In some instances, the original manufacturer's coating (paint) is used for coating repairs, and in those cases the manufacturers must have documented evidence that the performance of their repair coating systems meets these original criteria. When another manufacturer's products are used, it is necessary to perform DBA testing to simulate the repairs intended involving the surface preparation and using the coatings from the two manufacturers.

TYPES OF COMMERCIALY OPERATED BWR AND PWR NUCLEAR REACTORS

The PWR concept (Fig. 1) utilizes a closed coolant loop to circulate high-pressure liquid water at more than 2200 psi (15 160 kPa) 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.

The BWR concept (Fig. 1) utilizes a high-pressure water feed to produce steam within the reactor vessel at about 1000 psi (6895 kPa) and 550°F (288°C). This steam is then piped directly to the turbine generator to produce electric power. The steam condensate from the turbine is piped to

a processing facility for decontamination and impurity cleanup prior to recirculation in the main coolant loop.

RELATIONSHIP OF COATING WORK TO THE ENGINEERED SAFETY SYSTEMS

It is suggested that the following guidelines, adhered to by most architects/engineers/constructors during the construction phase, be implemented during the maintenance of a nuclear power plant. If the item cannot be removed and is not insulated, the item must be coated with a qualified coating system, i.e., liner plate, structural steel, polar crane, tanks, etc. If the item is small and can be detached, an unqualified coating system may be considered, i.e., a motor, pump, panel, etc.

The function of an item being coated must be considered, i.e., is it a safety-related item, does the item receive frequent decontamination, etc. In the primary containment structure, the critical relationship of the coating system to the engineered safety system is that the coating system remains in place and intact in the event of a DBA in order not to compromise the function of the ESS. This critical relationship exists during and after the time required for the ESS to stabilize and maintain cooling of the nuclear fuel core.

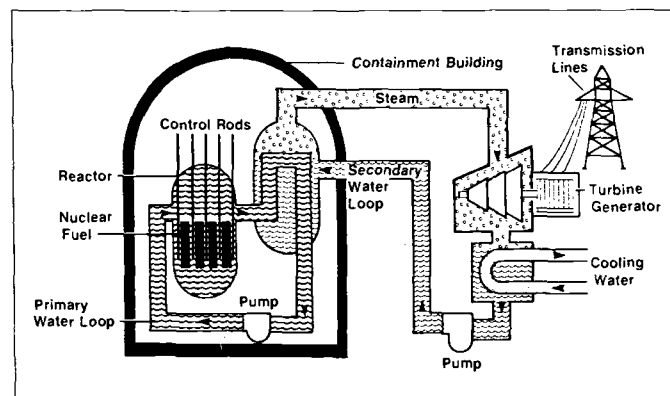
There are three principal ways in which the failure of a coating system can affect the ESS following a DBA:

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 iodine removal effectiveness of the containment spray system. This could result in undue risk to both health and safety of the public.
2. By-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.
3. There has been concern over a coating generating hydrogen gas during contact with steam (particularly inorganic zinc-rich coating systems during a DBA). The concern may be satisfied with the use of hydrogen recombiners. However, this should not give license to undue use of coating materials or reactive metal that would generate gases which could produce explosive mixtures within the primary containment structure.

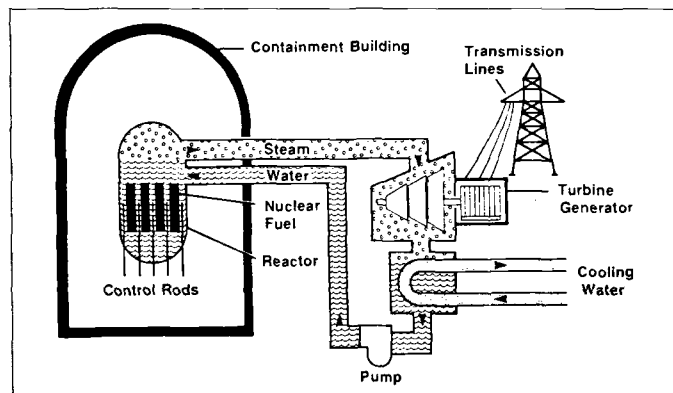
SUMMARY

This chapter has introduced coating concerns in a nuclear plant, and those responsible for coating work should:

1. Know the type of coating(s) used in the facility for all major items located within the primary containment structure.
2. Be able to locate documentation of the coating systems used during the construction phase.
3. Know the allowable limit of unqualified material for the particular plant.
4. Know what items are coated with unqualified materials.



Pressurized water reactor.



Boiling water reactor.

FIG. 1—Diagrams of a pressurized water reactor (above) and a boiling water reactor (below).

The Significance of Maintenance Coating

by Mendel Puschel and John Cavallo

IN THE NUCLEAR utility industry, maintenance painting is performed for one or more of the following purposes:

1. Corrosion mitigation and prevention (life extension).
2. Facilitate decontamination.
3. Regulatory commitment.
4. System color coding.
5. Human factor considerations (aesthetics, lighting, identification, etc.)
6. Facilitate housekeeping.

CORROSION MITIGATION AND PREVENTION

The increasing costs associated with replacement of capital equipment have made corrosion mitigation or life extension much more important in nuclear power plant maintenance.

Modern protective coatings utilize three fundamental methods to mitigate corrosion: barrier protection, sacrificial, and inhibition.

1. *Barrier Protection*: A relatively impermeable barrier between the environment and the substrate. Among the coatings which function in this manner are coal tar epoxies, chlorinated rubbers, epoxies, epoxyphenolics, and urethanes. Epoxy coatings are the predominant choice for use in containment.
2. *Sacrificial*: Metallic zinc, for instance, is less noble than a carbon steel substrate on a galvanic scale. As such, zinc can act as a sacrificial anode when coupled with carbon steel and thereby protects the substrate. Zinc-filled coatings are available in both organic and inorganic binder versions.
3. *Inhibition*: Passivating primers incorporating anticorrosive pigments inhibit corrosion formation. No coating will provide protection against all types of corrosive media.

However, it is possible to protect against a wide variety of corrosive agents by using "defense in depth." This is accomplished by applying a coating system which uses multiple coats of the same (generic) composition. Multiple coats of different coatings must be compatible with the existing substrate. This does not imply that unlimited thickness of coating material can be applied to a given surface. The coating manufacturer designs his product to an optimal thickness and thus must be consulted for advice on the system thickness. Most importantly, design of coating systems for maintenance work respects a different set of selection

parameters than those systems used in new construction. These selected parameters are explained in more detail elsewhere.

DECONTAMINATION

The word *contamination* as used in the nuclear utility industry means "radioactive nuclides in an unplanned or undesirable location." *Decontamination*, conversely, is the removal of the contamination product. Two major types of contamination are of interest: radioactive and chemical.

The selection of protective coatings to control contamination is the same for both types of contamination: a coating should be selected which will not be damaged by a given type of contamination or its removal and will not allow contamination to become affixed to the protected substrate. Concrete surfaces, for instance, are easily contaminated by radionuclides and are normally more difficult to decontaminate; therefore, a carefully selected coating should fill all voids and smooth the surface, which would aid in the decontamination effort.

Typical areas in utility plants which should receive careful attention regarding contamination control are nuclear containment structures, waste treatment buildings, fuel buildings, water treatment areas, and chemical addition rooms.

REGULATORY COMMITMENT

The NRC requires that a plant meet its final safety analysis report (FSAR) commitment for required protective coatings and coating systems acceptable in the plant. Changes to the plant "FSAR" will require concurrence of the Nuclear Regulatory Commission (NRC) prior to making that change.

SYSTEM COLOR CODING

Many insurance carriers, as well as NFPA and Occupational Safety and Health Act (OSHA) requirements, dictate the use of distinctive or contrasting colors for identification of safety components within utility facilities. The most commonly used colors are "safety yellow" for handrails, toe plates, etc., red for fire protection system components, and yellow and magenta for radioactive areas.

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Color codes are also used in many facilities to assist in plant operations. Operator training is also made easier by color coding of process equipment (piping, valves, switchgear, etc). Color coating is also used in two unit plants to differentiate between each unit.

HUMAN FACTOR CONSIDERATIONS (AESTHETICS)

Plants that have selected protective coatings for appearance as well as protection provide an attractive appearance and a functional purpose. As a result, plant operations and maintenance personnel are motivated to keep the facility attractive, resulting in an overall upgrading of plant performance.

Another benefit of careful selection of protective coatings is that the efficiency of the plant lighting system is improved. Lighter colored topcoats which perform well significantly brighten the plant environment without requiring an increase in the size of the lighting system. The increase in lighting system performance decreases lighting system costs (less lighting system power required) and provides increased personnel safety.

HOUSEKEEPING

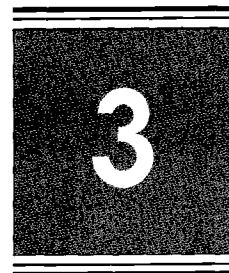
Smooth, hard surfaces are much easier to decontaminate and keep clean than rough surfaces. Lighter surfaces show

dirt and surface defects more readily. Most protective coatings provide this easily cleanable surface. Zinc coatings and some primers have a rougher texture which is more readily conducive to retaining oil and dirt products and which is thus more difficult to decontaminate. Noncoated surfaces are usually more difficult to keep clean than coated surfaces.

SUMMARY

Maintenance painting will not only delay the deterioration of the surface and thus prolong the useful life of the equipment, but may also reduce the amount of graffiti often found on the walls of plants. Properly selected, a coating can reduce the electrical energy used to illuminate given areas. Color coding can be used to identify mechanical or electrical system functions. Meeting as low as reasonably achievable (ALARA) (Reg. Guide 8.8) requirements can readily be achieved by selecting and applying a coating system which has a high decontamination factor. By providing a maintenance coating program which maintains and/or increases human factor considerations, housekeeping by station personnel becomes commonplace.

An added benefit to coating is that it may help when the plant is decommissioned. Since coatings facilitate decontamination, decommissioning operations can be less cumbersome and can reduce radioactive waste volume and radiation exposure. (See Reg. Guide 8.8.)



Surveillance Plan for In-Service Coatings

by Mendel Puschel and Timothy Shugart

THIS CHAPTER REVIEWS plant operating and maintenance department requirements associated with in-service coating inspection and covers guidelines for monitoring coating performance in an operating nuclear power plant. Establishment of an in-service coatings surveillance plan permits planning and prioritization of coatings maintenance work to maintain coating integrity and performance in all coating systems, and Service Level I coating systems in particular. It also enables identification and detection of potential problems in coating systems known in advance to be suspect or deficient for some reason and assists in recommendations for follow-up procedures to resolve any significant deficiency relative to coating work. A surveillance plan may also be required to fulfill technical specifications and safety analysis report commitments, if any, for Service Level I coating work.

The responsible organization or department in a plant establishes the requirements and procedures for in-service coatings surveillance. The plant may, however, delegate this responsibility to other qualified coatings inspection organizations. It is a good practice to perform in-service surveillance inspections during each refueling outage or during other major maintenance outages. During surveillance, particular attention must be given to the areas and equipment close to the containment emergency core cooling system (ECCS) screens and strainers and emergency spray pumps. The coating performance determined during surveillance inspection is reported to responsible personnel in the plant. The coating integrity should be verified to determine that it will not affect the safety of the emergency core cooling system, protection of the substrate, or the projected life of the coating system.

Coating performance will depend on the operating conditions experienced by the coating systems. Records of these conditions are normally maintained by the plant operating personnel. These may include, but not be limited to, ambient conditions; upset temperatures; humidity; chemical exposure such as immersion, splash, and spillage; abrasion; and physical abuse. All past history pertaining to the coating systems must be available for review during the surveillance inspection. This may include:

1. Copies of coating specifications and application procedures used for the existing coatings.
2. Quality control documentation for the existing coating application.
3. Copies of previous inspection or monitoring reports.
4. Documentation pertaining to any maintenance work performed on existing coating systems.

5. Radiation-related data and decontamination procedures followed.

Personnel performing surveillance inspections are subject to all station access procedures, including those pertaining to escorted or unescorted security clearance, health physics clearance, health physics classroom training, issuance of film badges and dosimeters, radiation work permits, anti-contamination clothing suit-up requirements, radiation control, and disposal of contaminated clothing at authorized work areas.

Prior to conducting a surveillance inspection of the coating systems, the plant shall ensure that all support services and equipment are provided. These may include one or more of the following:

1. Sufficient temporary lighting to provide adequate illumination for all areas to be inspected, plus localized high-intensity lights for thorough visual observations or photography.
2. Mobile ladders, scaffolding, and other temporary rigging for access to areas beyond the reach of fixed ladders and platforms normally provided in primary containment. This would include temporary rigging on or from the polar crane for PWR containment.
3. Services of a marine diver, who is also certified as a coatings inspector, inflatable rubber rafts or rigid boats, and underwater lights or TV cameras for the suppression pool of BWR containment.
4. Services for cleaning deposits or buildup from some coated surfaces selected by the inspector/inspection team.
5. Provisions for adequate ventilation during coating inspection.

The responsible department or organization involved in the in-service coatings surveillance inspection must ensure that only those personnel within their organization who meet the minimum requirements for qualifications and training are permitted to perform the inspection activities. It is recommended that a qualified coatings professional with an engineering, chemical, or coatings technology background be responsible for supervising the surveillance inspection activities, data collection, and documentation, and assuring that inspection personnel are adequately trained and instructed. Inspection personnel should at least meet the requirements for qualification of Level I capability in accordance with ANSI N45.2.6, "Qualification of Inspection, Examination and Testing Personnel for Nuclear Power Plants," or ASTM Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear

Facilities (D 4537-86). Inspection personnel shall also be trained in the specific tests to be performed. Inspection teams may be formed with two or more inspectors in each team, and each team may be assigned a specific area inside the containment for inspection. A preinspection briefing shall be conducted to familiarize all inspection personnel with objectives of the inspections, procedures to be followed, and precautions to be taken.

A surveillance plan would consist of a general visual inspection on all accessible coated surfaces during a general walk-through to determine the general condition of the coating, noting areas evidencing coating deterioration (for example, rusting, blistering, delamination, and cracking) or other coating deficiencies. Thorough visual inspections and close examination shall be carried out on areas deemed to be suspect prior to, or during, the general walk-through. Areas of deterioration should be marked and mapped, and location, direction, and orientation charts should be kept for either future surveillance or immediate repair. Photographic documentation of coatings inspection areas should be made with special attention to defects and failures. The process of documentation standardized by the power plant to the past and present appearances of coating surfaces is recommended. Defects can be compared by a standardized reproducible method. One method to get consistent, comparable, close-up photographs is provided in ASTM Practice for Photographic Documentation of Coating and Lining Failures and Defects (D 4121). If additional data are required to make an analysis of the coating failure, a coatings professional may decide to perform one or more of the specific physical tests, such as dry film thickness measurements, sampling, and measurement of size of defective pattern, adhesion/cohesion testing, hardness testing, and continuity testing. The relevant ASTM or Steel Structures Painting Council (SSPC) standards shall be used for these tests.

The following instruments and equipment are recommended for each of the following tests:

1. For general and thorough visual inspections—flashlight, spotlight, measuring tape, X5 or X10 magnifier, and X7 or X8 35mm binoculars.
2. For sampling—polyethylene sample bags, 6 by 10 in. (15.24 to 25.4 cm); identification tags; and pocket knife.
3. For general photography—camera with good flash equipment and 50 mm or larger lens. Record make and lens size so that a similarly equipped camera can be used on subsequent inspections. (For permanent records, instant-type cameras are not recommended.) Use of equipment described in ASTM D 4121 simplifies this standardization.
4. For dry film thickness measurements—calibrated magnetic film thickness gauge and NBS calibration standards, and dial calipers with 0.001-in. (0.00254-cm) graduations (Fig. 2).



FIG. 2—Calibrating a dry film thickness gauge (courtesy of Stone & Webster Engineering Corp.).

Additional equipment may include laboratory spatulas, depth gauges, templates for marking areas for subsequent reinspection, permanent ink-type markers, and premade legends to identify plant, unit, and location for photographic records.

The following ASTM standards may be used for evaluation of visual defects, such as blistering, cracking, flaking or peeling, and rusting.

- *Blistering*—ASTM D 714 (Method for Evaluating Degree of Blister of Paints).
- *Flaking/Peeling*—ASTM D 772 [Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints].
- *Rusting*—ASTM D 610 (Method for Evaluating Degree of Rusting on Painted Steel Surfaces).

Inspection reports for submittal to responsible personnel should be prepared after inspections and should include at least the following information:

1. A summary of findings and recommendations for future surveillance or repair—this would include an analysis of the reasons or suspected reasons for failure. The repair work should be prioritized into major and minor defective areas. A recommended corrective plan of action must be provided for the major defective areas so that the plant can repair these areas during the same or next outage.
2. A list and location of all areas evidencing minor deterioration, the repair of which can be postponed to future outages and which will be kept under surveillance in the interim.
3. Inspection data sheets.

Preparing for Maintenance Painting

by Timothy Shugart

THE FIRST STEP in developing a maintenance coating program for an operating nuclear plant is that the painting schedules, materials, and application procedures used during construction be turned over to the Operating Department. This turnover, however, does not happen in all plants. The plant engineer has to survey each area, then develop a program that best fits into the plant's coating maintenance program.

While a plant is being constructed, a number of different coating systems may be used. However, the logistics of using this many systems in an operating plant may be more difficult. The plant, many times, will be using their own personnel to do repair and touch-up of the coating. The fewer coating systems they have to contend with, the easier it will be to control.

An operating plant is faced with coating much smaller areas where only a few gallons may be used at any one time and the painters doing the work may change from one assignment to the next.

The plant owner must select the system to be used. This may actually involve testing the application of new coatings over existing systems to determine the compatibility of the two materials. Meeting the exposure intent of the original applied system is a must. The same consideration regarding decontamination, ability to withstand plant normal operating conditions, and emergency situations have to be addressed.

It is essential to have a quality assurance/quality control documentation program for all materials used. This program includes a letter of compliance from the manufacturer stating that the material being supplied is in fact the same formula, using the same quality materials, and made under the same quality as was the original approved for use at the plant. This may mean the operating plant will have to do additional work or testing to assure that this is, in fact, true.

To accomplish this, the plant could consider a receipt testing program for the small quantity of materials received and used. This could include such quality tests as (1) weight per gallon, (2) viscosity of material, and (3) infrared red (IR) (Fig. 4) or gas chromatograph (GC) (Fig. 3) printouts of the materials being received. Comparing this information to previously received values from the manufacturer would give the user a basis for acceptance of the materials.

An in-plant training and qualification program will be necessary to qualify painters and inspectors regardless of whether they consist of plant personnel or personnel from an outside agency. A plan must be ready for implementation before the need for maintenance coatings becomes acute.

After this is completed, a program should be developed to address generically the areas to be coated and to specify the coatings to be used for typical substrates. Another approach is to develop a specific definitive specification/procedure as the need arises for coating work.

The rest of this chapter will be devoted to preplanning for a specific coating job.

Before any coating work begins, whether inside containment, in contaminated areas outside of containment, or in the remainder of the plant, preplanning of the work is important and is becoming more important as years pass and the cost of maintenance labor and materials increases.

All aspects of the specific job have to be considered. To ensure all considerations being covered, a checklist of items to address is advisable. The check list should include:

1. *The scope of work being contemplated*, i.e., what is to be coated, what are the anticipated desired results, what is the projected completion date, and what personnel will be utilized.
2. *Who will do the work*, i.e., will the job be done with unskilled plant laborers from the plant, journeyman painters on the plant staff, or an outside contractor? Applicators shall be qualified by a formal qualification/certification procedure if coating work is to be performed inside containment.
3. *A list of plant restrictions*:
 - a. Administrative plant procedures for initiating coating work, i.e., technical requirements, purchasing procedures, quality assurance/quality control (QA/QC) requirement, etc.
 - b. What are the atmospheric conditions in the area where the coating must be applied?
 - c. Will the coating work be done in the summer (when there is a chance of hot, humid weather or hot, dry weather) or will it be done in the winter (when low temperatures might be a problem or other adverse weather conditions might exist)?
 - d. Is the work going to be done outside the plant or inside the plant where it can be protected from the elements?
 - e. What are the time restrictions imposed for the coating work?
 - f. Is the "time window" to complete the work and cure the coatings large enough after all preparations and material applications specified have been scheduled? If not, modifications for doing the work will have to be found.
 - g. The coating work may interfere with other plant operations while setting up. The scaffolding and painting



FIG. 3—Gas chromatograph used to generate chromatogram (courtesy of KTA-Tator, Inc.).

equipment (Figs. 5 and 6), covering of equipment adjacent to the work area, and the odor created with most types of paint materials may create problems for the coatings engineer.

- h. Will the coating be used for decorative purposes, for chemical resistance, for heat resistance, for contamination control, or for other purposes?
- i. What precautionary measures must be implemented to protect areas of the plant that are serviced by engineered safety feature atmospheric clean-up system high efficiency particulate air (HEPA) filters and charcoal absorption heating, ventilating, air conditioning (HVAC) systems (Figs. 7 and 8) during surface preparation and

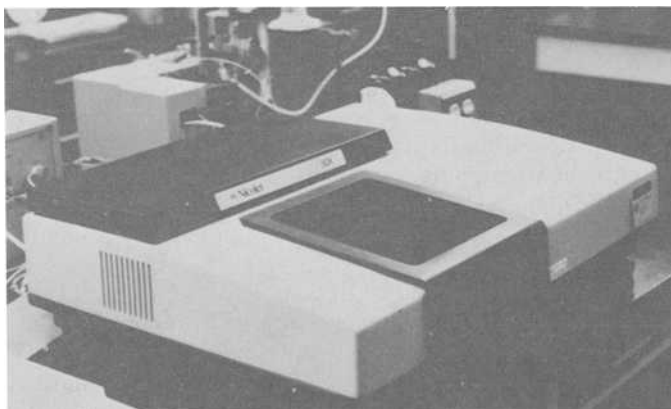


FIG. 4—Fourier transform infrared spectrometer (FT-IR) used to generate infrared spectra (courtesy of KTA-Tator, Inc.).



FIG. 5—Torus coating ventilation ducting (courtesy of Iowa Electric Light and Power Co.).

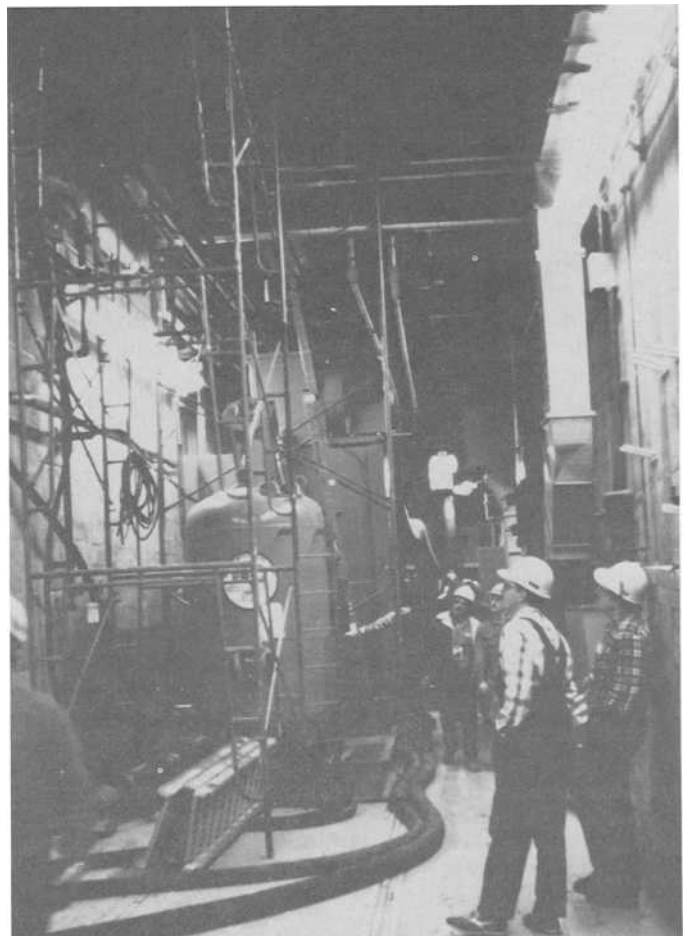


FIG. 6—Vacuum blast equipment (courtesy of Stone & Webster Engineering Corp.).

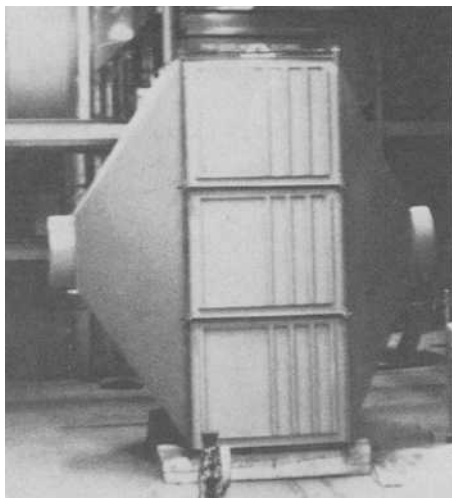


FIG. 7—High efficiency particulate air filter (HEPA) (courtesy of Iowa Electric Light and Power Co.).

coating operations? See U.S. Regulatory Guide 1.52 and 1.140 for guidance.

- j. Will special ventilation equipment be needed (Fig. 9)?
- k. Will the coating be done in a fire-protected area?

All of the preceding factors affect both the selection of a coating system and its ability to be applied under the conditions set down by the plant.

Make a list of the coating systems which might be applicable for the job intended, taking into consideration not only the items listed above, but whether the coating being recommended is compatible with any previous coating on the surface if that previous coating is not going to be completely removed. List the advantages and disadvantages for each of the coating systems being considered. Weigh these with the conditions under which work is to be done, the exposure to which the coatings are to be subjected, and the required life of the coatings.

Coating considerations have to be made with the methods of surface preparation in mind. Would the creation of dust

or airborne contamination be a problem? Are there engineered safety feature atmosphere clean-up systems, HEPA filters, and absorption units (Figs. 7, 8, and 9) the area which would be affected by the coating and its solvent systems? Is there a restriction on the amount of water that could be used in the cleaning of the surfaces? Can the water used be allowed to enter the plant drainage system?

Consider the disposables that are generated by the coating process. Is the cost of processing these disposables factored into the total job?

Many different types of hazardous wastes can be generated during maintenance coating work. These unwanted substances include:

1. Coating chips and flakes.
2. Nonradiologically contaminated spent abrasives.
3. Heavy metals (lead, chromium).
4. Spent solvents.
5. Unused coating materials.
6. Asbestos.

These waste materials can be found alone or in conjunction with other hazardous substances in coating work debris and must be handled and disposed of in accordance with federal, state, and local regulations. Containment and disposal of coating hazardous wastes are significant logistical, schedule, and cost factors to be considered during the planning of coating work projects.

Prior to commencing coating maintenance work, the responsible engineer should investigate the existing coating materials which will be removed as part of the work as well as the new coating materials to be applied. This investigation should identify all hazardous substances which will be contained in the coating work waste and the information obtained should then be factored into the coating work specification, the job plan, and the project cost estimate.

In nuclear plant coating work, coating wastes which are hazardous as defined by 40 CFR 261, "Identification and Listing of Hazardous Wastes," can become contaminated with contaminated radioactive materials, creating a condition called "mixed waste." Currently, the Nuclear Regulatory Commission (NRC) is working with the Environmental Protection Agency (EPA) to develop coordinated



FIG. 8—Portable efficiency particulate air filter (courtesy of Iowa Electric Light and Power Co.).

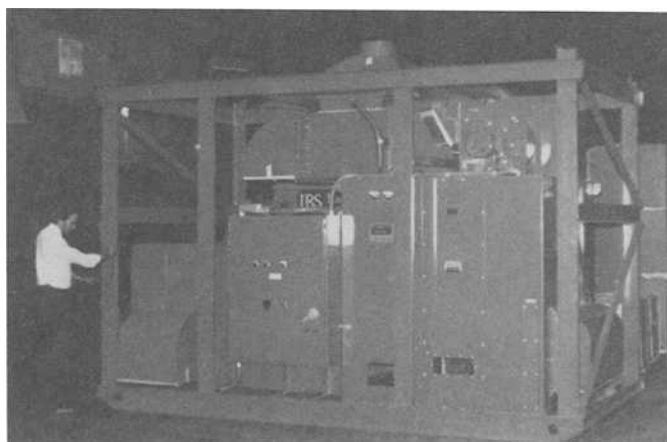


FIG. 9—Dehumidification unit (courtesy of Iowa Electric Light and Power Co.).

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regulations and guidelines for handling and disposal of "mixed waste." The existing regulations do not allow for the legal disposal of many forms of "mixed waste."

ASTM Subcommittee D33.14, Hazardous Waste in Utility Protective Coating and Lining Work, was established to provide information to the utility industry and to develop written guidelines. This subcommittee had its first formal meeting in October of 1988.

Consider the types of equipment used for the coating work. Equipment may have to be used under limiting conditions.

Has the coating system selected been tested under conditions for which it is to be applied and used? Has this testing included DBA, if applicable? If not, time may be required to make these evaluations.

A systematic approach for maintenance painting in a nuclear plant is to have a "check-off" list. This list can help assure that all aspects of a coating job have been addressed. The check list (see the appendix to this chapter) is an example and can be used as is or modified to fit a specific situation. Questions which can be answered with a yes, no, or a check mark also give a quick easy reference document for record.

After all the above considerations have been made, select the coating system which best fits the condition and limitations of the area to be coated. Then verify that the material selected is compatible with the surface preparation and the previous coating. Proceed to write a specific specification/procedure.

APPENDIX—COATING WORK CHECKLIST

Accessibility

Yes/No

1. Is the area accessible for the coating operation? _____
2. Is equipment required to perform the coating work accessible to the work area? _____
3. Is the removal of interferences such as insulation, equipment, piping, etc., required? _____
4. Does the area have enough accessibility to permit the specified surface preparation and/or coating application technique? _____
5. Is scaffolding equipment required for the coating work? (Ensure proper safety for workers.) _____
6. Is any special personnel breathing equipment needed to support work? (Refer to OSHA, radiation control or government requirements.) _____

Design Requirements and Configuration of the Surface(s) To Be Coated

1. Is the surface to be coated:
 - (a) Flat? _____
 - (b) Smooth? _____
 - (c) Contain weld seams? _____
 - (d) Vertical? _____
 - (e) Horizontal? _____
 - (f) Contain welded attachments? _____
 - (g) Is the weld surface smooth? (Check weld spatter.) _____
2. Service level of equipment or components? (Refer to ASTM D 3843, Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities.) _____
3. Quality assurance requirements? (Refer to ASTM D 3843.) _____
4. Quality control and testing requirements? _____
5. Reason for coating:
 - (a) Corrosion protection? _____
 - (b) Decontaminability? _____
 - (c) Aesthetics? _____
 - (d) Cleanliness? _____
 - (e) Combination of above? _____

Material (Substrate) To Be Coated

1. Carbon steel? _____
2. Stainless steel? _____
3. Alloys? _____
4. Plastic? _____

5. Concrete? _____

6. Other nonferrous materials? _____

7. Other? _____

Is the coating material approved for the substrate? _____

Historical coating information available? _____

Is the coating material recommended by the coating manufacturer for the substrate and service? _____

Previously Coated Substrate

1. Investigate existing coating's historical performance. _____
2. Investigate possible failure mode and cause. _____
3. Can existing coating materials still be certified as qualified coatings? _____
4. Based on the above, could the present coating material continue to be used? _____
5. Do present coatings contain hazardous waste material, i.e., lead, asbestos, coal, tar, etc.? _____
6. Based on the above, should a new coating material be selected to prevent future failures? _____
7. Inadequate coating process:
 - (a) Improper surface preparation? _____
 - (b) Improper coating application? _____
 - (c) Inadequate testing? _____
 - (d) Inadequate training of application personnel? _____
 - (e) Inadequate training of preparation personnel? _____
 - (f) Inadequate training of inspection personnel? _____
 - (g) Inadequate procedures? _____

Present Substrate Corrosion Condition

1. Is the substrate presently corroded? _____
2. Extent of corrosion, % (ASTM D 610) _____
3. Type of corrosion:
 - (a) General? _____
 - (b) Pitting? _____
 - (c) Stress corrosion? _____
 - (d) Intergranular? _____
 - (e) Other? _____
4. Are repairs to the substrate required prior to coating? _____
5. Can the substrate be repaired? _____
6. Are procedures required for the repair? _____
7. Are repair procedures available? _____

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Plant Operational Conditions

1. Do any of the following operating conditions affect the coating work or ability to work? _____
 - (a) High radiation levels? _____
 - (b) Area security requirements? _____
 - (c) Area temperature restrictions? _____
 - (d) Material and substrate temperatures? _____
 - (e) Accessibility (including confined space entry)? _____
 - (f) Ventilation requirements? _____
 - (g) Fire control restrictions? _____
 - (h) Protection required for plant's engineered safety feature atmospheric clean-up system HEPA filters and absorption units? _____

Radiation Levels

1. Is the substrate radioactively contaminated? _____
2. Is the substrate radioactive? _____
3. Are the general area radiation levels within acceptable limits? [Verify with Plant Health Physics (HP) Department.] _____
4. Is there airborne contamination? (Verify with Plant Health Physics Department.) _____
5. Will surface preparation generate airborne contamination? _____
6. Type of breathing apparatus and clothing required? (Verify with Plant Health Physics Department and OSHA requirements.) _____
7. Is decontamination practical? _____
8. Should decontaminability be considered in the future? _____
9. If decontamination is not practical, can the contamination be sealed to the substrate? _____
10. Will special ventilation and filtration equipment be required? _____
11. Are special procedures required for the ventilation equipment operation? _____
12. Are special and additional arrangements required for contaminated material disposal? _____

In-Service Inspection Requirements

1. Does the substrate require inspection as a part of an in-service inspection program? _____
2. Can the substrate remain uncoated to facilitate inspection? _____

Time Constraints

1. Can the coating work be completed at one time? _____

2. Should the coating work be divided into phases? _____
3. If the work is completed in phases, is the material/equipment to remain onsite? _____
4. Has the remobilization of workers been negotiated? _____

Weather/Climatic Conditions

1. Is the work area susceptible to adverse climatic conditions? _____
2. Can the work area be protected from the adverse conditions? _____
3. Are there temperature and humidity requirements for the coating material? _____
4. Have provisions been made for controlling temperature and humidity? _____
5. Can work area cleanliness be maintained? _____
6. Equipment placement and protection evaluated? _____
7. Equipment operation evaluated? _____
8. Material storage requirements considered (i.e., heating and ventilation requirements)? _____
9. Personnel considerations? _____

Material/Waste Disposal

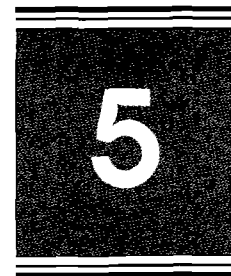
1. Disposal requirements for the coating material waste checked? _____
2. Disposal requirements for the surface preparation material checked? _____
3. Disposal of radioactively contaminated material arranged? _____

Ventilation Requirements

1. Humidity control required? (Refer to coating data sheets.) _____
2. Temperature control required? (Refer to coating data sheets.) _____
3. Particulate filtration required? (Refer to OSHA requirements.) _____
4. Confined entry precautions? _____
5. Explosive concentrations to be monitored? _____
6. Air changes per hour calculated and adequate? _____

Safety Requirements

1. Personnel safety requirements checked? (Refer to Health Physics, OSHA, Mine Safety and Health Administration (MSHA), NIOSH, EPA, NRC, company and plant requirements.) _____



Planning and Scheduling Maintenance Coating Work

by Ralph Trallo

THIS CHAPTER is closely related to Chapter 4. However, this chapter goes into more detail as to the specific area being coated.

PERFORM AN INSPECTION SURVEY

One of the best ways to begin a protective coatings maintenance program is to *perform a thorough inspection survey* of the coated and uncoated surfaces in the plant to be coated to determine the locations and extent and degree of damage and/or deficiencies in the protective coating systems.

1. The emphasis of the coating surveillance work should primarily be within the containment structure and, secondly, all other areas of the plant subject to contamination (i.e., Coating Service Levels I and II areas as identified in the controlling documents).
2. The results of the survey should be reported in written form and retained as a permanent plant record. These records should be kept in the plant by the maintenance organization. The file should be reviewed annually and updated as coating work is performed.
3. The survey should identify areas which are damaged, delaminated, cracked, excessively worn, and radioactive contaminated, and/or having other coating flaws.
4. Coated surfaces generally require the capability of being readily decontaminated.
5. The surface characteristics of the previously coated surface should be considered.
6. Photographing or video taping the areas needing remedial work are useful ways for describing and recording the affected areas. They may also be used as a means of mapping the locations.
7. Survey personnel shall meet the qualifications detailed in Chapter 3.

PREPARE MAINTENANCE PLAN

The next major step in a protective coating maintenance program is to *prepare a maintenance plan* for the restoration of the damaged or deficient coating systems revealed from the survey.

1. The plan should address both a short-term and long-term program typically spanning as much as five years.
2. Determine what areas should be coated first, second, etc. (prioritize coating work with regard to availability of equipment, room/area, etc. to be coated). Take into con-

sideration the level of radiation present in the area. An ALARA plan may have to be developed for the work.

3. The plan should include an accurate description of the surfaces to be restored, the time frame for the restoration, and the related labor and material cost estimates.
4. The schedules for future outages and other major projects which would affect and/or control the coating maintenance work should be closely reviewed with the project planning coordinator and Maintenance Department representatives.
5. The type of equipment necessary to perform the upcoming work should be determined and arrangements made to have the equipment on site.
6. Determine what potential impacts the coating work will have on the plant's operation (e.g., how will the engineered safety feature atmospheric clean-up systems HEPA filters and absorption units be protected or affected by the painting program).

Seek management approval of the coating maintenance program. See that the necessary funds are budgeted for the performance of the work planned for the upcoming projects. Ensure that the coating maintenance plan is communicated to all involved parties. Determine the best way to economically handle the project (i.e., lump-sum contract, cost plus contract, use of onsite personnel).

For contracted work:

1. Prepare commercial/technical documents.
2. Competitively bid the work.
3. Analyze bids, i.e., review for approval, qualifications, application procedures, work plan, etc.
4. Award contract, or, for projects involving onsite personnel:
5. Prepare manhour estimates.
6. Obtain approval to proceed with work.

SCHEDULING

Generally, protective coating maintenance work within the primary containment structure must be performed during an outage.

Outages are normally periods of high maintenance activity with many crafts competing for time and space to accomplish their maintenance projects. Typically, all activities during an outage are scheduled and planned well in advance to assure a productive outage. For this reason, it is necessary to know the entire scope of work required for a specific coating activity before the activity is scheduled so that ade-

quate time and support is available to perform the desired application.

Protective coatings maintenance work may have to be performed on second or third shift or in limited specified locations. It is very important to incorporate cure times and recoat intervals into the schedule of activities.

Night shifts may also be required when floors, handrail, or other traffic areas require recoating.

The following steps should be considered in the formulation of a maintenance painting schedule:

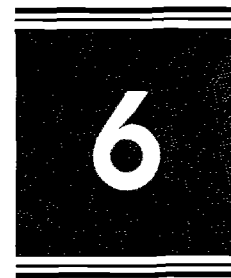
1. Determine and clearly identify the scope of work for the particular project under consideration. It is often useful to divide the work into individual parts which are readily handled at one time (i.e., a floor at a specific location and elevation, or an area of liner plate within given quadrants and elevations).
2. Be sure that the protective coating specifications and/or procedures are updated and appropriate for maintenance work. If specifications are not suitable for maintenance painting, refer to later chapters of these guidelines for guidance.
3. Depending upon how the provision of labor, supervision, and inspection personnel will be handled, whether by outside contractor or by other means, the arrangements for labor, supervision, and inspection personnel should be finalized at least three months prior to the start of the project. The requirements for personnel access (an in-depth background investigation, a psychological evaluation, and fitness for duty evaluation may require two weeks or more). In addition, employees will have to undergo nuclear general employment training and/or site specific training. In some cases, prospective employees may have to have a medical examination.
4. Determine whether adequate coating materials (i.e., coatings, thinners, solvents for surface preparation and clean-up) are on hand. If not, the materials must be ordered sufficiently in advance of the intended usage and be received with the required documentation. However, care must be taken to ensure that the material will not exceed its "shelf life" as specified by the manufacturer when ordering material in advance.
5. Obtain necessary permits such as radiation work permits. It may be necessary to discuss potential problems relating to generation of airborne contamination or the prospects of working in highly contaminated areas with health physics personnel. The site person responsible for the coating project should be aware of clearance requirements for systems and equipment and the need for any special permits required at the particular site.
6. Establish a priority list for the items of work to be undertaken during the subject project. The priorities should be reviewed with the plant management, the Maintenance Department, and other involved parties. Preproject meeting with engineers, foremen, craft, health physics, station personnel, safety, QC, and others as necessary who may interface directly or indirectly with the project.
7. A line schedule may be a useful tool for maintaining priorities and for monitoring the progress of the work. The schedule should include time for:
 - a. Setup of scaffolding and/or other rigging.
 - b. Gathering of materials.
 - c. Entrance and exit time.
 - d. Mobilization/demobilization for intermittent outages.
 - e. Surface preparation.
 - f. Cleanup following surface preparation.
 - g. Primer application (touch-up or complete coat).
 - h. Cure/recoat time interval.
 - i. Finish application (sometimes multicoat).
 - j. Final cure time.
 - k. Removal of scaffolding and equipment.

Major equipment (blast equipment, ventilation, filtration, etc.) may require structural analysis to ensure that during an accident event (earthquake) the equipment will not fall on or in any way impair the plant's structural integrity or safe shutdown of the plant. This may mean that additional support and/or anchoring may be required. This analysis may be required whether the plant is in an operating or shutdown condition.

Proper attention given to the considerations stated above should provide reasonable basis for a well-planned and scheduled maintenance painting project.

Qualification of Nuclear Grade Maintenance Coatings

by S. J. Oechsle



PREPARATION OF CONCRETE TEST BLOCKS FOR EVALUATION OF COATING PERFORMANCE UNDER DESIGN BASIS ACCIDENT CONDITIONS

Purpose

The purpose of preparing concrete test blocks is to use these samples for application of coatings which represent coating systems found in Service Level I nuclear facilities. These samples are then subjected to radiation and DBA conditions found in that particular facility¹ (Fig. 10).

Preparation of Concrete

The concrete shall be composed of the following:

Cement, ASTM C 150 ² , Type II, low alkali	21.2 lb ³
Gravel, ASTM C 33 ⁴ , Size 3/8 in. ⁵	54.4 lb
Sand, ASTM C 33	60.7 lb
Water-reducing admixture, ASTM C 494 ⁶	13.9 g
Air-entraining admixture, ASTM C 260 ⁷	4.22 g
Pozzolans, ASTM C 618 ⁸	3.2 lb
Demineralized water	12.0 lb ⁹

Procedure

Forms are constructed with pine sides and plywood base. The test blocks are 2 by 2 by 4 in. (5.08 by 5.08 by 10.16 cm). Before assembly, the forms are coated with clear epoxy curing compound to prevent absorption of water into the wood. Stainless steel hooks are imbedded into the wood at one end of each form section. These hooks will remain imbedded in the top of one end of each block. This will be used to hold the block while testing.

¹Throughout this document, reference has been made to ASTM standards which have been proposed to replace ANSI N101.2, N101.4, and N512. It is suggested that users of this manual refer to their license commitment, which addresses the owner's position to Regulatory Guide 1.54.

²Specification for portland cement.

³1 lb = 0.45 kg.

⁴Specification for concrete aggregates.

⁵1 in. = 2.54 cm.

⁶Specification for Chemical Admixtures for Concrete.

⁷Specification for Air-Entraining Admixtures for Concrete.

⁸Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete.

⁹Enough water to produce a 3-in. (7.62-cm) slump.

Mixing of the concrete is done either by hand or electric mixer depending upon batch size. All components are weighed on scales appropriate to the amount being measured. The pour is made. Prior to setting, the surface will be given a broom finish. Therefore, one side of the test block will evaluate floor coatings.

The concrete is made in accordance with ASTM Test Method of Making and Curing Concrete Test Specimens in the Laboratory (C 192). Curing of the concrete test specimens is in accordance with ACI 301, Specifications for Structural Concrete for Buildings.

Method of concrete cure type varies with the requirements set up for each test situation. Curing is done in accordance with ACI 301 for a minimum of 28 days.

Coatings Over Concrete Surfaces

Preparing of test blocks for maintenance service using the procedure for design basis accident testing, ASTM Specification for Drain, Waste, and Vent (DWV) Plastic Fittings Patterns (D 3311).

Conditioning of Test Blocks

After the existing coatings have been applied and allowed to cure 14 days, place them in a control oven set at 150°F (65.55°C). Allow the test coupons to cure seven days at 150°F (65.55°C). This will simulate an extended service life. The panels are now ready to be damaged prior to application of the repair coating system per the following procedures.

Floor Coatings

In an effort to simulate the floor condition after several years of service, the block is damaged. The upper one third of one face of the block will be used to simulate repaired broken floor areas. To accomplish, drill a 1/2-in. (1.27-cm) hole through the coating to bare concrete. This portion will be labeled 1A.

The lower one half of this face will represent worn areas of floor coating. On this one half, use 3M Co. "Clean 'N Strip" disc or laminated discs to remove only the finish coat of paint, leaving the sealer and as much surfacer as possible. A sander may also be used. Place each block in a rubber-padded vise to enable uniformity in coating removal. Padding is needed so as not to damage the other coated surfaces. This portion will be labeled 1B.

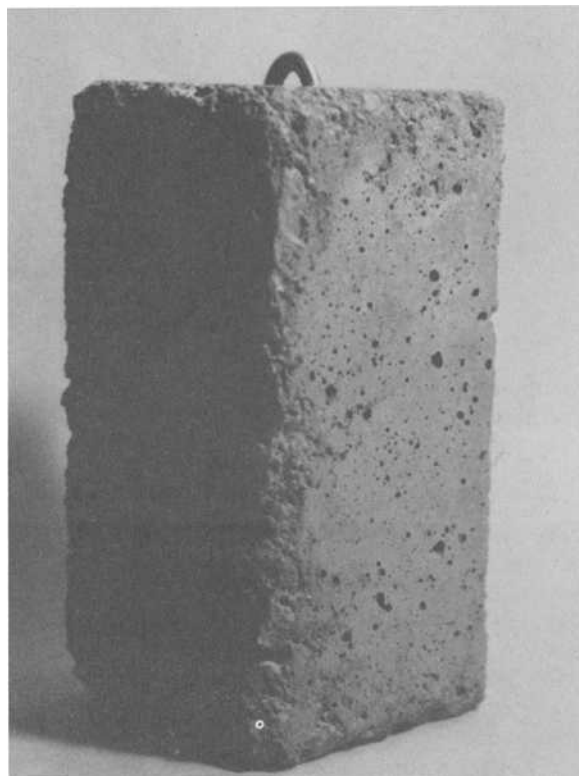


FIG. 10—Concrete test block with embedded stainless steel hook (courtesy of KTA-Tator, Inc.).

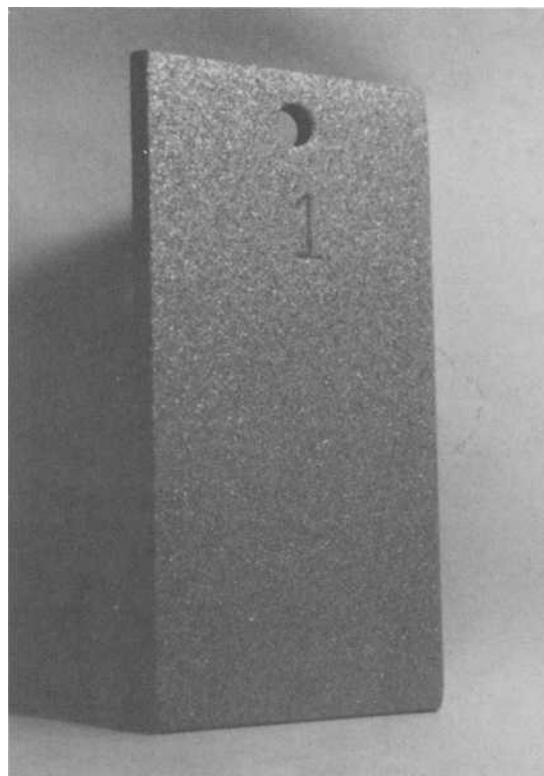


FIG. 11—Abrasive blast-cleaned steel test panel (courtesy of KTA-Tator, Inc.).

The Concrete Wall Coating

Opposite the floor coating system, Side 3, on the upper one third of the test block, drill a hole into the concrete. This hole should be about 1/2 in. in diameter and leave a flat surface. This will represent areas where other damage has occurred.

The lower half of Side 3 should be abraded to remove some of the finish coat. It is not necessary to remove all the finish. This will represent a worn surface. Accomplish this with a rotary peening machine if possible.

Cure the repair coatings according to the manufacturer's instructions. Place the newly coated panels in a control oven seven days at 150°F (65.55°C). This will simulate an extended service life of the repair coatings. Panels are now ready for test.

PREPARATION OF STEEL COUPONS FOR EVALUATION OF COATING PERFORMANCE UNDER DESIGN BASIS ACCIDENT CONDITIONS

Purpose

The purpose of preparing steel panels is to represent existing conditions where coatings have been damaged and the steel surface needs to be protected from corrosion in Service Level I nuclear facilities.

Steel panels, Type A36, carbon steel 2 by 4 by 1/4-in. (5.08 by 10.16 by 0.635 cm) are used. The panels are blast cleaned

and coated with the existing coating system per manufacturer's instructions or the specifications on all sides (Fig. 11).

Conditioning of Steel Test Coupons

After coating the steel test coupons in accordance with the specification, allow the coating to cure 14 days. Place the coupons in a control oven at 150°F (65.55°C) for seven days (Fig. 12).

On Side 1, drill a hole through the coating about 1/2-in. (1.27 cm) in diameter in the upper one third of the panel down to the steel surface.

On the lower one half of Side 1, remove the coating down to bare steel, partially leaving some existing primer and partially showing about one fourth of the surface as bare steel.

On Side 2, leave the upper one half intact. Partially remove some of the existing finish coat leaving the primer, using 3M Co. "Clean 'N Strip" abrasive discs or laminated discs on the lower one half of Side 2.

Damage the coupons per the above procedure. Place the damaged coupons in a 100°F (37.77°C) Cleveland humidity chamber for 14 days. Allow rust to form (Fig. 13).

Application of Repair Coatings

Surface Preparation

Remove rust according to the specification or with power tools per SSPC SP-11, Power Tool Cleaning to Bare Metal.

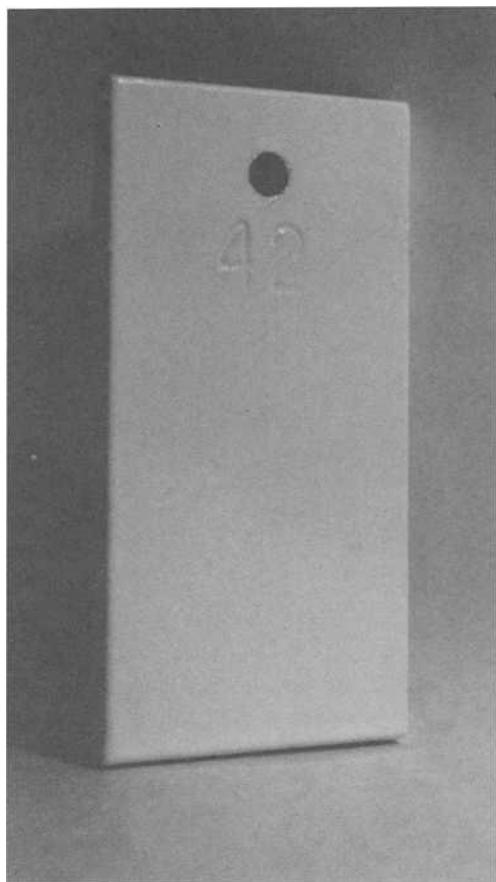


FIG. 12—Coated steel test panel (courtesy of KTA-Tator, Inc.).

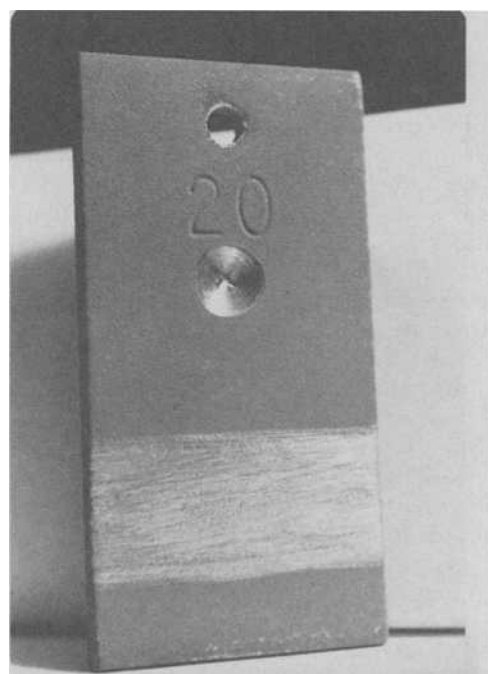


FIG. 13—Intentional “damaging” of coated steel test panel (courtesy of KTA-Tator, Inc.).

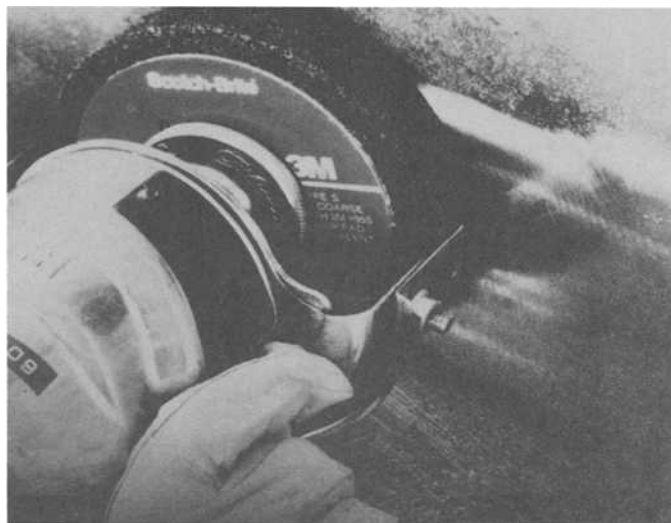


FIG. 14—3M Clean-N-Strip Cup Wheel (courtesy of KTA-Tator, Inc.).

Use 3M Co. “Clean ’N Strip” discs or laminated discs, needle gun, or other tools as appropriate (Figs. 14 and 15).

Coating Application

Apply the primer as needed over bare steel surfaces in accordance with manufacturer’s instructions or the specifications.

Apply the finish coat or self-priming coating per manufacturer’s instructions over the entire panel including the undamaged section. Some surface preparation is permitted such as light sanding prior to coating over the undamaged area.

Allow all coatings to cure in accordance with the manufacturer’s recommendations.

Design Basis Accident Testing

The repaired test blocks or steel coupons are subjected to design basis accident testing per the Facility Final Safety Analysis Report (FSAR) and evaluated per ASTM D 3911.

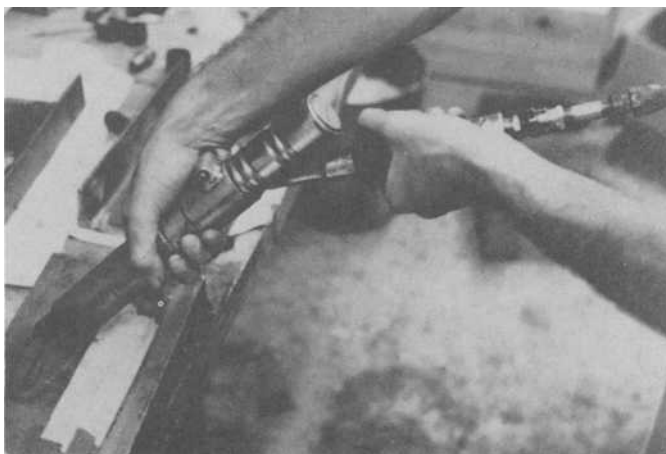
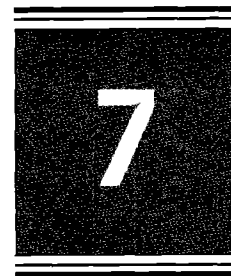


FIG. 15—Needle gun (courtesy of KTA-Tator, Inc.).



Coating Materials

by Michael Masciale

THE SELECTION OF coatings for use in nuclear power plants is based upon requirements for normal operations as well as established accident requirements. Coating manufacturers evaluate materials in accordance with current standards to determine radiation resistance, decontamination properties, and service ability under design basis accident conditions [1]. Other criteria for the testing, selection, and application of coatings in nuclear power plants are defined in ANSI and ASTM documents (references to be given).

The subject of "protective coating maintenance work for power generating facilities" is specific to maintenance coatings applied over existing substrates. Areas of concern that are not necessarily considered in a new construction phase include:

1. *Downtime*—A determination has to be made as to the amount of time allowable to accomplish coating work due to constraints of a plant shutdown period, or coating repair work that must be accomplished during plant operation.
2. *Environmental Conditions*—It may not be possible to control temperature, relative humidity, air movement and ventilation, and other application factors.
3. *Existing Substrates*—Coatings may have to be applied over existing substrates, i.e., previously applied coatings or previously prepared substrates. Special surface preparation techniques such as scarifying and methods described in Power Tool Cleaning to Bare Metal, SSPC-SP11, would have to be considered since it may not always be possible or desirable to remove coatings and prepare substrates in accordance with original new construction specifications.
4. *Personnel Safety*—Rapid coating application may be necessary where minimal personnel exposure can be tolerated due to existing levels of radiation in the workplace. Innovative application techniques may have to be developed.
5. *Inaccessibility*—Unusual methods of application may be necessary due to physical constraints such as inaccessible areas for normal coating application methods, blockage caused by equipment, instruments, piping, walkways, etc. Coating materials would have to be compatible with such application techniques as brushing, rolling, troweling, squeegeeing, and innovative spray methods.

Once these parameters are defined, then and only then can coating materials be selected so that they are compatible with given conditions of application, environment, and substrate preparation procedures.

Protective coatings are used extensively in nuclear power plants for corrosion protection, for maintaining appearance,

and to aid in the removal of radionuclide soils (contamination). Normally, the corrosive atmosphere near any power plant is considered mild since most facilities are located in rural or suburban areas. However, when facilities are located adjacent to oceans, bays, or general saltwater corrosive atmosphere, atmospheric corrosion is a significant factor in the selection of coating systems. Coatings are used significantly in nuclear plants for protection of steel, concrete surfaces, and nonferrous surfaces from: (a) contamination by radioactive nuclides and subsequent decontamination processes; (b) ionizing radiation, chemical, and water sprays; (c) high temperature and high pressure steam, and (d) abrasion [1]. Some typical conditions of nuclear, chemical, and physical exposure are described by Watson and West [2] as follows:

Radiation—For severe or moderate exposures to radiation, a coating is usually selected on the basis of its radiation-resistant properties. Obviously, film integrity must be maintained, otherwise the coating cannot function properly as an anticontamination and anticorrosion medium. To evaluate these and other properties, accelerated radiation exposure tests are necessary and are defined in applicable ANSI and ASTM standards (Fig. 16).

Organic materials, including coatings, dissipate the energy of gamma radiation and energetic particles through ionization and electronic excitation. Both modes of energy dissipation lead to broken valence bonds in the form of an electrically charged site or unpaired electron. Both species are quite reactive and chemical reaction products can be expected in a variety of types and yields. Under radiation exposure a coating may crack, blister, soften, chalk, discolor, become brittle, or exhibit a combination of these phenomena. Additives such as pigments, plasticizers, and other coating ingredients, as well as types of surfaces on which the coatings are applied, influence the radiation stability of the coatings. Coatings that are highly pigmented are generally more resistant to radiation than similar gloss coatings containing lesser amounts of pigments.

The color of a pigment cannot be related by present-day empirical tests to its resistance to radiation. All colors studied are darkened or discolored by exposure to radiation. Initially, the surface discolors and, as the exposure increases, the depth of discoloration in the film also increases. White pigmented epoxies and modified epoxies turn yellow after exposure of about 5×10^8 rads and progressively darken to brown after exposure of about 2×10^9 rads.

Studies indicate that for many coating materials, the effect of radiation is essentially a curing process characterized by

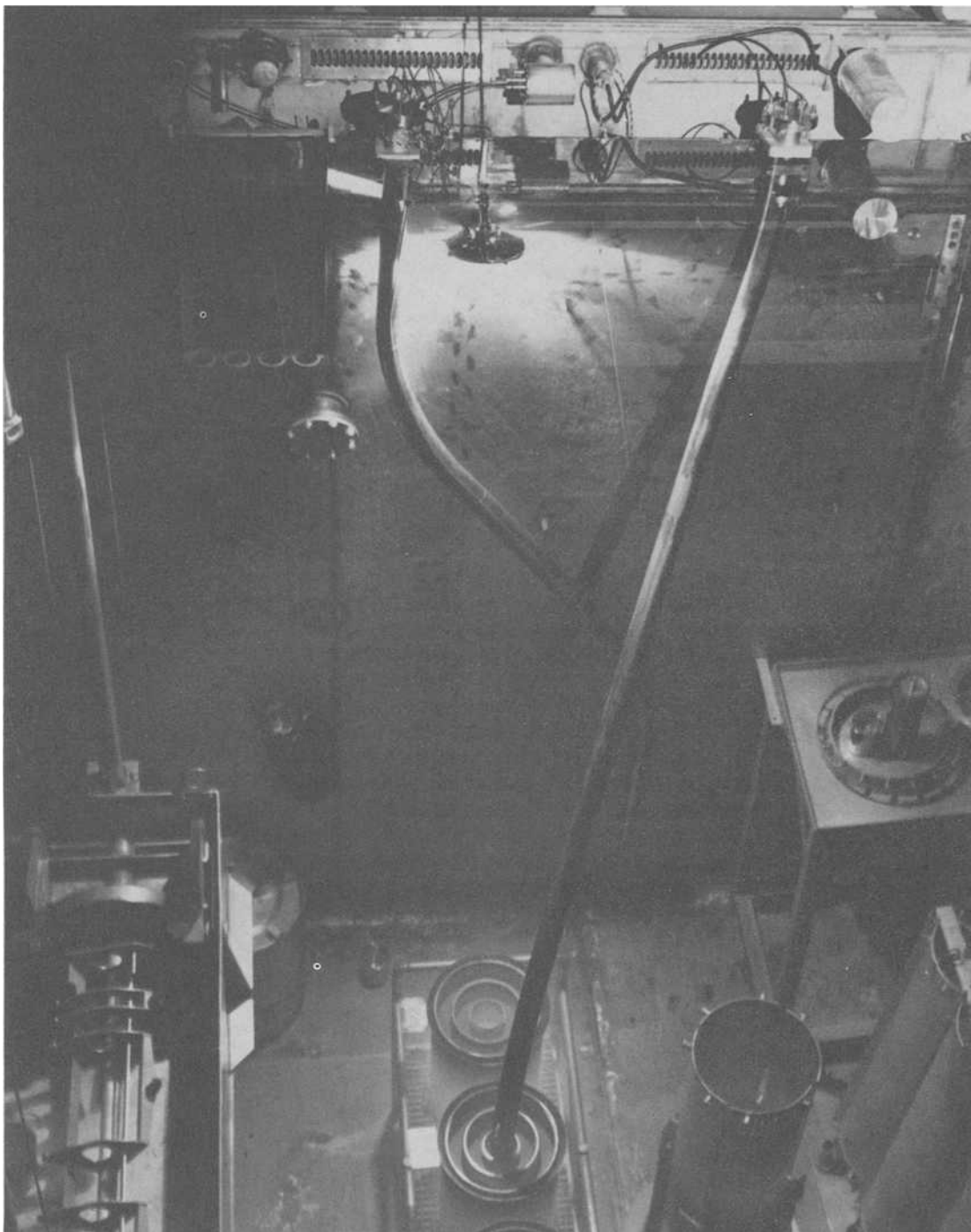


FIG. 16—Irradiation test facilities (courtesy of Oak Ridge National Laboratory).

an increase in hardness, a decrease in solubility, and sometimes, initially, by an increase in strength. The eventual stability of polymer depends on its chemical structure. Epoxies and modified epoxies show a great deal of stability in a radiation field. Epoxy resins, when cured, are generally hard, extremely tough, and chemically inert. These resins are above average in radiation resistance, very likely because of their rigidity and aromatic content.

The resistance of organic coatings to radiation can be

predicted to some degree from data available from polymers and plastics. However, because of the complicating factors introduced by pigments, plasticizers, and other coating ingredients, coatings resistance to radiation should be obtained only by empirical testing.

Epoxy coatings are exceeded in radiation resistance by inorganic zinc coatings. The ranking of zinc coatings in resistance to radiation is sometimes negated in practice because of marginal resistance to chemical and poorer

decontamination properties. However, inorganic zinc primers are often used in conjunction with epoxy or modified epoxy topcoats in high radiation areas.

DECONTAMINATION

Contamination by radioactive substances is believed to occur through chemisorption, by ion exchange with free surface ions, by physical adhesion, or by migration of the radioactive nuclides into cracks and crevices. Generally, decontamination can be defined as a highly effective cleaning process. It is the practice or art of removing radioactive materials from surfaces. The purpose of decontamination is to render the affected areas harmless to unprotected workers and the biological environment, and to salvage costly equipment in work areas.

In nuclear installations, ferrous and nonferrous surfaces in various areas should be protected from radiation deposits. Suitable coatings applied over ferrous, nonferrous, and concrete surfaces allow for decontamination and provide resistance to radiation as well as abrasion resistance. It is, therefore, imperative that all areas where radioactive contamination is possible be protected with suitable coatings. As a case in point, if a bare concrete surface is contaminated, there is no practical way to decontaminate the surface except to remove the contaminated concrete.

Decontamination testing (Fig. 17) provides methods for the quantitative evaluation of the ease and degree of decontamination of protective coatings. Essentially, decontamination testing measures the ratio of original beta-gamma activity versus the activity after decontamination. Currently, the ANSI and ASTM test procedures to determine a decontamination factor are relative tests to compare the relative ease of decontamination of coatings using a laboratory procedure. The test methods are not intended to be directly related to decontamination methods used in practice. To achieve a high degree of decontamination, both chemical and physical methods are usually used. In the contamination/decontamination cycle, coatings serve not only as a barrier, but also as a sacrificial surface.

In the past, a variety of coatings were used in nuclear facilities because of their acceptable decontamination properties. Currently, epoxies or modified epoxy coatings have replaced other generic types because they provide satisfactory decontamination properties as well as superior abrasion resistance, elevated temperature service, solvent and radiation resistance. Chloride-bearing coating materials are prohibited from coming in contact with stainless steel components and, consequently, vinyl and chlorinated rubber coating applications are restricted in critical areas of nuclear power plants.

Design Basis Accident

In the design and operation of light water moderated nuclear power plants, consideration must be given to a design basis accident (DBA), as the subsequent events might lead to a fractional release or expulsion of a fraction of the fission product inventory of the core to the primary containment facility. Engineered safety features, principally a primary

containment facility, are provided to prevent a release of fission products to the biological environment during and after this improbable event. Large areas of the primary containment facility are coated with a protective coating for the purpose of corrosion protection as well as ease of decontamination. If severe peeling, flaking, or chalking cause significant portions of the coating to be discharged into a common water reservoir, the performance of the safety systems could be seriously compromised by the plugging of strainer, flow lines, pumps, spray nozzles, and core coolant channels. If coating failure occurred during DBA, the performance of the safety systems could be seriously compromised. Therefore, it is important that coatings withstand the harsh DBA conditions as well as meet the other stated criteria that are unique to nuclear plant operations [3].

Test results have shown that two-component epoxy or two-component modified epoxy systems and inorganic zinc coatings are the best of the air-dried systems tested. Blistering and peeling caused by heat and chemical attack is the principal cause of failure of coatings. Suitable DBA test programs are essential to develop valid empirical data to reinforce the choice of coating systems used. The results of DBA testing (Fig. 18) have demonstrated that technology currently exists to produce acceptable coatings to meet DBA conditions specified in various plant safety analysis reports (SAR). Coatings applied under maintenance conditions to

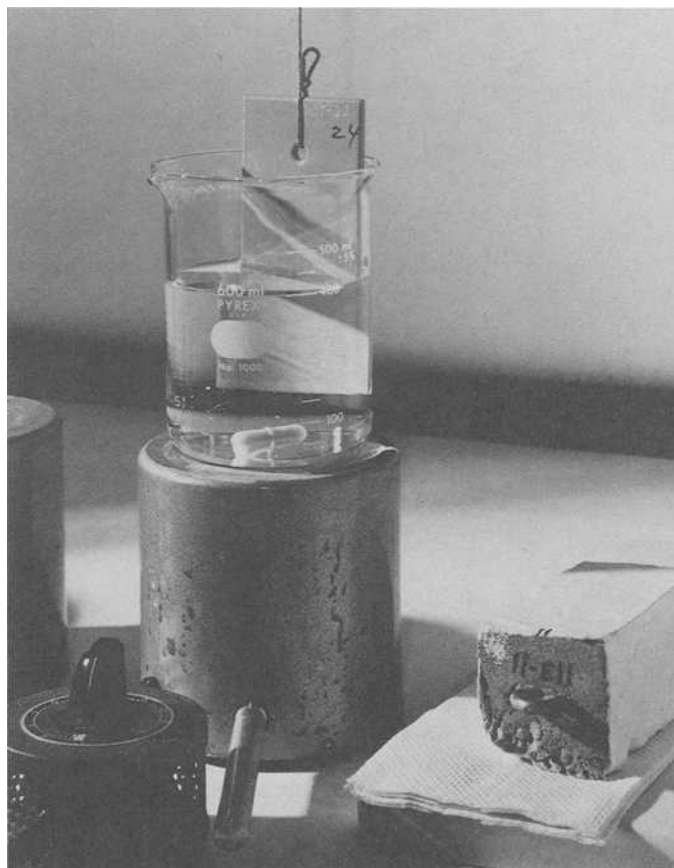


FIG. 17—Decontamination testing (courtesy of Oak Ridge National Laboratory).

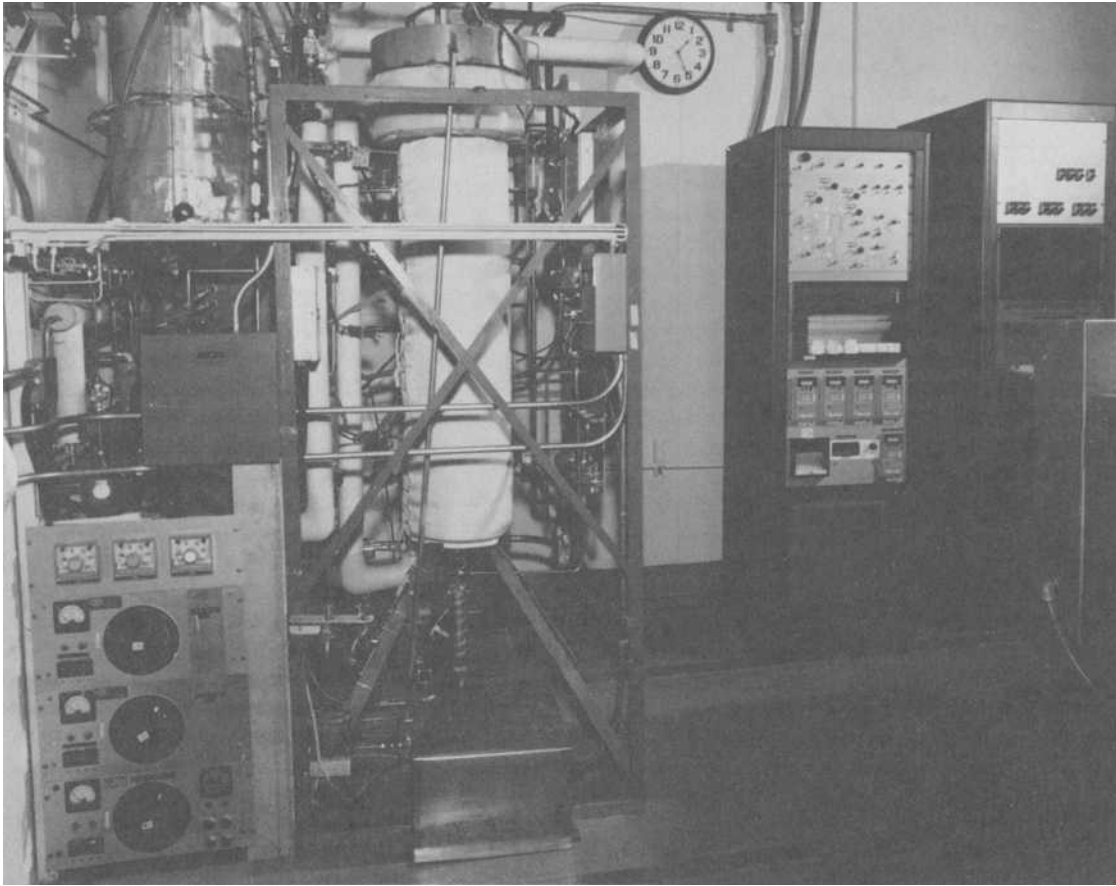


FIG. 18—Design Basis Accident (DBA) test facilities (courtesy of Oak Ridge National Laboratory).

existing substrates should meet the SAR criteria and, in some cases, the volatile organic compounds (VOC) regulation(s) of the state in which the plant is located, where required.

CONSIDERATIONS FOR COATING SELECTION

The major requirements for coating in nuclear power plants have been described. Although there are many specific requirements for coatings, the more general requirements can be listed as follows:

- a. Radiation resistance.
- b. Decontamination.
- c. Design basis accident.
- d. Resistance to continuous immersion in deionized water (as required).
- e. Physical properties.
- f. Chemical resistance.

There are many generic types of coatings being used in nuclear power plants today, the most common of which are:

- a. Inorganic zinc-rich coatings.
- b. Epoxy and modified epoxy coatings.
- c. Conventional alkyds, latex, and specialty coatings for noncritical areas.

A brief description of these generic types follows.

INORGANIC ZINC-RICH PRIMERS

A zinc-rich coating is characterized by a very high degree of pigmentation, normally above 75% of metallic zinc in the dried paint film. One essential property is that the paint film is electrically conductive and that it is in electrical contact with the steel substrate. These properties are obtained when a high portion of metallic zinc particles are in electrical contact with each other in the paint film and with the steel. An inorganic zinc-rich primer has properties similar to that of a galvanized coating. When it is applied on an electrically conductive media, the zinc-rich coating will provide electrochemical protection.

The inorganic binder is essentially a solution of silicates. The inorganic zinc-rich primer is unaffected by most organic solvents, is nonflammable, provides good sacrificial release of zinc to provide cathodic protection, has relatively high heat resistance [in excess of 400°F (204.4°C)], and is resistant to thermal shock cycles. The inorganic zinc coatings are normally applied by spray techniques. (Spray applications might not be permitted inside containment without elaborate over-spray controls.) They adhere well to properly prepared steel and give excellent protection against corrosion throughout the normal life of a nuclear plant.

In a nuclear facility, inorganic zinc-rich coatings are usually topcoated in areas requiring high decontaminability.

Organic topcoats are usually applied, since they are more easily decontaminated.

EPOXY AND MODIFIED EPOXY COATINGS

The catalyzed epoxy coatings are composed of an epoxy resin and suitable catalyst (activator, hardener, or curing agent). Epoxy resins most commonly used in room-temperature-cured coatings are the reaction products of various proportions of bisphenol A and epichlorohydrin. Many resins are formed by this chemical reaction and they vary in degree of polymerization, solubility in various solvents, and physical form.

The modified epoxy (epoxy-phenolic) is another variety of an epoxy coating in which phenolic groups are introduced into the backbone of the resulting polymer. The amine adduct epoxy and the modified epoxy (epoxy-phenolic) perform similarly when tested under nuclear environments. Each is capable of being formulated to meet specific requirements. Generally, the unmodified epoxy coatings have application advantages over the modified (epoxy-phenolic) coatings in that they are more tolerant to adverse field painting conditions of high humidity, varying temperatures, and prolonged drying periods between coats.

The cured epoxy or modified epoxy resin is a hard thermoset material in which the epoxy resin molecules are joined in a three-dimensional network of linkages and cross linkages. It is no wonder that these materials are primarily used in nuclear plants for their excellent resistance to radiation, decontamination properties, and abrasion resistance. It is important to note that epoxy or modified epoxy coatings can vary significantly due to formulation differences. Therefore, certain epoxy coating formulation must be tested to determine whether they meet the criteria for the particular service intended.

Alkyd Modified Alkyd Primers and Topcoats

Alkyd resins are polymeric esters prepared by the reaction of polyhydric alcohols and polybasic acids or their anhydrides. The trade often refers to short-oil or long-oil alkyds. Long-oil alkyds contain a relatively high percentage of oil, while short-oil alkyds contain a relatively small percentage of oil. The long-oil alkyds are softer, more flexible, and slower drying, while the short-oil alkyds are harder, fast drying, and more brittle. Coating manufacturers often use a blend of different types of alkyds to achieve desired properties.

The alkyds, as a group, offer a durable film with good weather resistance. A high-quality alkyd will offer moderate resistance to radiation in air and will seal a substrate from radioactive particles at ambient conditions. Alkyds do not have good resistance to strong chemicals and solvents and consequently are not normally used where frequent decontamination procedures are anticipated.

Alkyd coatings can be used for most noncritical area within a nuclear facility due to their ease of application, overall good durability, and aesthetic properties. Alkyds are capable of being modified with silicone resins which provide

added durability and are often used on turbines and other showplace areas. These coatings can easily be cleaned.

LATEX PAINTS

In general, when latex emulsion paints are compared with solvent-based resinous paints of the same type, they have many advantages: faster drying, easier application, improved cleanup of application tools with tap water, no fire hazard, improved resistance to mild alkali, resistance to fats and oils, and less color change. Latex paints do have disadvantages in that they are subject to freezing and may be damaged by the freeze-thaw process. They should not be applied below 10°C. At these temperatures poor film formation can be expected due to poor coalescing action.

Many variations of latex coatings can be formulated. They are generally of three chemical compositions: (1) styrene-butadiene, (2) polyvinyl acetate, and (3) acrylic. Many variations of these basic types can be formulated, and they can be plasticized with different plasticizers to give a variety of properties, such as flexibility, stability, etc.

Latex coatings will normally be used in noncritical areas. Latex concrete block fillers are used commonly on much of the concrete surfaces to fill small voids prior to topcoating with latex or alkyd finish coats.

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- [2] Watson, D. C. and West, G. A., "Protective Coatings (Paints)," *Decontamination of Nuclear Reactors and Equipment*, J. A. Ayres, Ed., Ronald Press, New York, 1970.
- [3] Watson, C. D., Griess, J. C., Row, T. H., and West, G. A., *Protective Coatings for PWR & BWR Reactor Containment Facilities*, ANS National Meeting, invited persons, Los Angeles, CA, 28 June–2 July 1970.

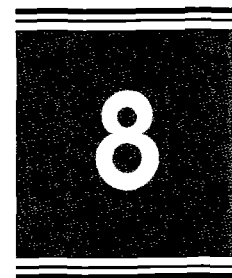
OTHER APPLICABLE REFERENCES

ASTM's *Manual of Coating Work for Light-Water Nuclear Power Plant Primary Containment and Other Safety-Related Facilities*, 1979, Chapt. 3, "Coating System Selection," and Chapt. 12, "Topcoating of Cured Coatings," provide a guide to pertinent information necessary for the selection of suitable coating systems for the primary containment and other safety-related facilities of nuclear power plants. The chapters describe recommended procedures for topcoating intact cured coating systems, or primed coats, for nuclear plant facilities that have been exposed for extended periods of time after fabrication or during plant construction and prior to plant operation. These chapters should serve as ready references prior to selection of coating systems for maintenance purposes.

In addition, the NACE technical committee report "Combating Adhesion Problems When Applying New Onto Existing Finish Coats of Paint" should serve as another ready reference prior to commencing any refurbishing and maintenance work.

Practical Methods of Surface Preparation for Maintenance Painting

by John Cavallo



INTRODUCTION

Surface preparation is the most important part of any painting project. Historical analysis of failures of industrial painting systems indicates that up to 75% of all coating system failures are the result of inadequate surface preparation.

Surface preparation for maintenance painting is far more difficult than in new construction work for a number of reasons, including:

1. The proximity of painting work to plant equipment.
2. The radioactive and chemical contamination of paint films and substrates.
3. Restricted work area access.

In this chapter, the surface preparation methods which have been used successfully in maintenance painting work are discussed. These methods can be used singly or in conjunction with others, depending upon the maintenance paint system to be applied. Table 1 (general production rates for blast cleaning) contains information to assist in surface preparation scheduling.

The selected surface preparation methods are:

- A. Solvent cleaning.
- B. Hand tool cleaning.
- C. Power tool cleaning.
- D. Power tool cleaning to bare metal.
- E. Abrasive blasting.
- F. Water washing.

SOLVENT CLEANING

Solvent cleaning is one method for removing grease, oil, soot, and other hydrocarbon contaminants from existing paint films and substrates. Contaminants may be visible or invisible to the naked eye, but they will cause premature failure of applied maintenance paint films if not completely removed. Thorough removal of contaminants must be performed prior to subsequent surface preparation efforts.

Nonflammable detergents and emulsifiers have proven efficient when used by hand or with water washing equipment (Fig. 19).

The industry standard for solvent cleaning is Steel Structures Painting Council document SSPC SP-1, "Surface Preparation Specification 1—Solvent Cleaning."

Production rates for solvent cleaning will vary significantly with the degree of contamination present. Normally, manual solvent cleaning rates are found to be approxi-

mately 500 ft² (46.45 m²) per working hour per man. Solvent cleaning with volatile materials is not permitted in Coating Service Level I areas unless proper ventilation is provided to avoid contamination of charcoal filters.

HAND TOOL CLEANING

Hand tool cleaning is widely used for surface preparation of small areas or areas not readily accessible. The tools used are scrapers, chippers, slag hammers, chisels, sandpaper, and abrasive pads. This surface preparation method will not effectively remove tight mill scale or rust and is not appropriate for high-performance protective coating systems which require a high degree of surface cleanliness and profile (Fig. 20).

A widely used standard for hand tool cleaning is Steel Structures Painting Council document SSPC SP-2, "Surface Preparation Specification 2—Hand Tool Cleaning."

Production rates for this surface preparation method are usually 50 to 100 ft² (4.64 to 9.29 m²) per work hour per man.

POWER TOOL CLEANING

Many technical improvements have been made in power tools and attachments in recent years, resulting in both higher quality and production rates in surface preparation. If used properly, power tool cleaning can produce surface preparation quality appropriate for subsequent application of high performance coating materials.

There are three major categories of power tools:

1. *Impact cleaning tools* (Figs. 21 and 22)—These tools include needle guns, chipping hammers, and power chisels. They are useful for preparing small areas and/or areas not readily accessible, such as nuts and bolts, rivets, hatch covers, etc. However, they often do not uniformly clean the entire surface, except that needle guns using sharpened 2-mm-diameter needles can produce a uniformly clean surface with a profile *similar* to shot-blasted steel.
2. *Rotary cleaning tools* (Fig. 23)—For surface preparation work, semiflexible captive abrasive wheel and disc products, constructed of nonwoven synthetic fiber web material of continuous filament impregnated with an abrasive grit, such as 3M "Clean 'N Strip" discs, are recommended. In addition, coated abrasive discs (sanding pads, coated abrasive flap wheels, etc.) per SSPC SP-11 are also

TABLE 1—General production rates for blast cleaning.

Title	NACE Spec No	SSPC Spec No	Approximate Production Rates/Man ¹
Brush-off blast	4	SP 7	2400 ft ² /day
Commercial blast	3	SP 6	800 ft ² /day
Near-white blast	2	SP 10	400 ft ² /day
White metal blast	1	SP 5	400 ft ² /day

NOTE: 1 ft² = 0.093 m².¹All production rates vary greatly depending on overall size of surface, accessibility, intricacies of detail, contamination factors, environmental factors, etc.

acceptable in many instances. These new types of rotary tools produce both uniform and high degrees of surface cleanliness, and, unlike wire wheels, do not burnish surfaces to be coated while leaving a surface profile.

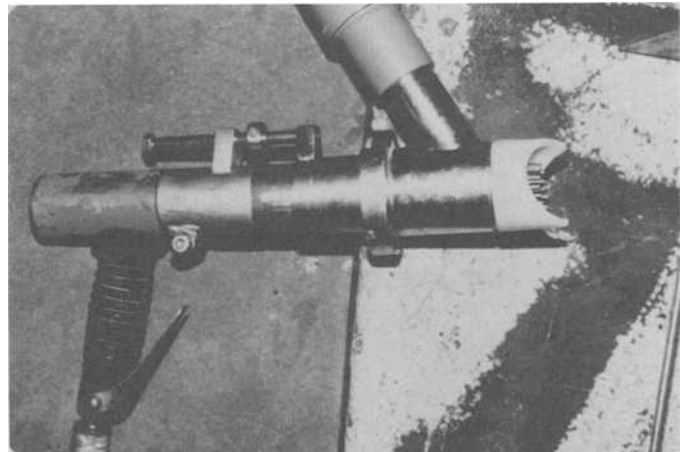
Double-action (DA) sanders are recommended for feather-edging sound coating materials adjacent to repair areas.

Operator training is mandatory for personnel who will be operating these high-performance power tools to prevent injury of personnel and damage to equipment or sound coatings.

3. *Rotary impact cleaning tools* (Figs. 24 and 25)—This category of power tools is new to the painting industry. Properly used, this type of equipment will remove heavy layers of existing coatings, mill scale, and tightly adherent rust, producing a controlled surface profile.

For preparation of metallic and concrete surfaces, rotary nylon flaps tipped with tungsten carbide buttons are manufactured by the 3M Company under the brand name "Heavy Duty Roto-Peen." For preparation of concrete, rotary knife scarifiers are produced by the Desco Manufacturing Company.

Both types of tools produce a very high degree of surface preparation if operated properly. The drive equipment and expendable flaps and cutters are quite expensive and can cause rapid-wear damage to equipment and injury to personnel when not properly adjusted and operated.

**FIG. 19**—Solvent cleaning (courtesy of Stone & Webster Engineering Corp.).**FIG. 20**—Hand tool cleaning (sandpaper) (courtesy of Stone & Webster Corp.).**FIG. 21**—Needle gun (courtesy of KTA-Tator, Inc.).**FIG. 22**—Needle gun operation.

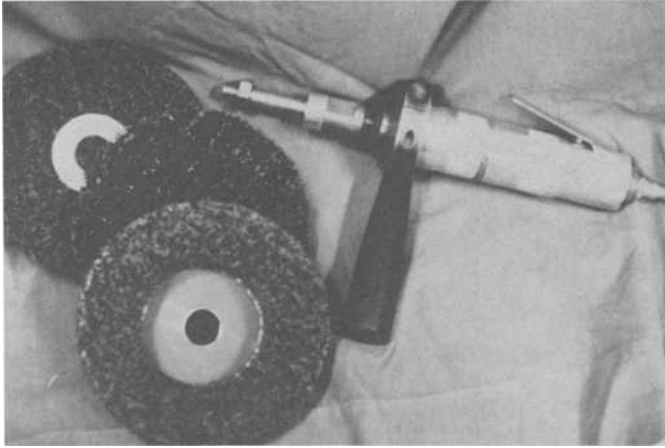


FIG. 23—3M Clean-N-Strip discs (courtesy of KTA-Tator, Inc.).



FIG. 24—3M Heavy Duty Roto-Peen (courtesy of KTA-Tator, Inc.).



FIG. 25—Rotary impact tool operation (courtesy of Stone & Webster Corp.).

Thus, operator training is mandatory. This equipment is also available with vacuum attachment.

Power tool surface preparation rates will vary from 20 to 100 ft² (1.86 to 9.29 m²) per work hour per man depending upon job conditions.

Steel Structures Painting Council Document SSPC SP-11, Surface Preparation Specification, "Power Tool Cleaning to Bare Metal," provides good guidance.

ABRASIVE BLASTING

Abrasive blasting is usually employed to prepare flat surfaces in maintenance painting work. High production rates are obtainable, but containment of spent coatings and abrasives is a definite problem.

In open blasting, approximately 100 lb (45.36 kg) of abrasive is required to prepare between 10 and 17 ft² (0.92 to 7.71 m²) of surface, depending upon the degree of cleanliness required. Disposal of large quantities of waste is a definite concern.

Isolation of the blast area from all other areas in the facility must also be accomplished to protect both personnel and equipment. In an operating facility, this may prove very costly or impossible.

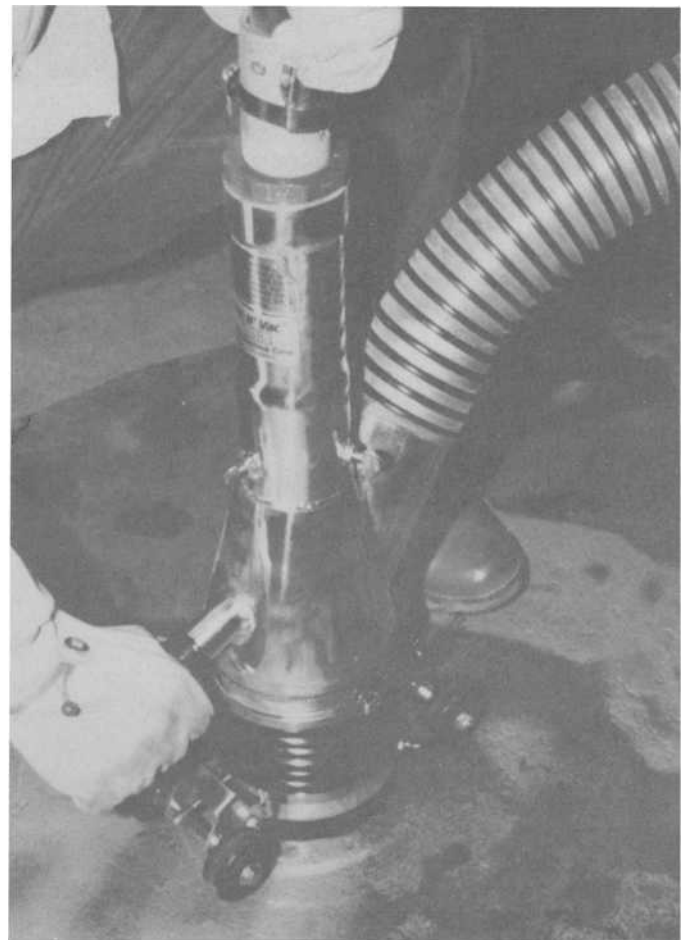


FIG. 26—Vacuum blast equipment (courtesy of KTA-Tator, Inc.).



FIG. 27—Vacuum blast operation (courtesy of Stone & Webster Corp.).

A technique called vacuum blasting partially mitigates the problems associated with open blasting. The blast nozzle is surrounded by a vacuum head, which removes spent abrasive and coatings at the work. Usually, contaminants are removed away from the work area, and the reclaimed abrasive is reused unless it is contaminated. Vacuum blasting (Figs. 26 and 27) is of limited use on complex shapes, since



FIG. 28—ADMAC high-pressure water blasting equipment (courtesy of KTA-Tator, Inc.).



FIG. 29—ADMAC high-pressure water blasting equipment (courtesy of KTA-Tator, Inc.).

the vacuum head cannot contour itself to fully capture the propelled abrasive from the nozzle.

Several Steel Structures Painting Council (SSPC) and comparable National Association of Corrosion Engineers (NACE) specifications cover abrasive blasting. These specifications are listed below in conjunction with approximate production rates.

Power Water Washing/Water Blasting

With modern power water washing/blasting equipment, nozzle pressures vary from several hundred psi to over 30 000 psi (206 850 kpa). With some units, solid abrasives can be injected into the fluid stream (Figs. 28 and 29).

If detergents and surfactants are utilized in the fluid stream, manual solvent cleaning of surfaces to be painted may be unnecessary. Preparation of noncorrosion-resistant surfaces by power water washing or blasting will probably require the addition of inhibitors to prevent rusting. Use of detergents, surfactants, or inhibitors may affect adhesion of the coating unless special precautions are used. Manufacturer's recommendations must be followed.

Typical power water washing and blasting production rates are approximately 3500 ft² (325.15 m²)/day/man.

When using water blasting near electrical or electronic equipment, appropriate safety precautions must be utilized. A new SSPC specification is being developed.



Practical Methods of Coating Application

by Robert Ikenberry and W. C. Bates

THIS CHAPTER OUTLINES the methods and tools in common use for application of maintenance coatings at power generating facilities. In most cases, a liquid material is applied in a uniform manner to the surface to be protected. The liquid will then cure to the desired state (rigid, elastomer, etc.) by solvent evaporation, oxidation, catalyzation, or a combination of methods.

1. *Coating material*—Some materials, due to viscosity, solvents, or other physical characteristics, do not lend themselves to certain application methods.
2. *Skill of applicator*—The more sophisticated spray equipment requires greater skill in application.
3. *Size of item and schedule*—The selection of application methods may be affected by size and configuration of the work areas or short schedules.
4. *Accessibility*—The degree of difficulty in getting men and equipment to the work location and the amount of area available to work will have an impact on the selection of application techniques.
5. *Adjacent surfaces*—Among items to be considered in selecting an application method are the susceptibility of adjacent items to overspray, dust, solvent vapors, etc.
6. *Other*—Special problems on each particular project must be considered.

PREPARATION

Preparation of the surface, work area, and paint materials are important for a successful coating application. The surface preparation should be checked prior to application of the coating to ensure that no deterioration of the cleaned surface has occurred.

Preparation of the work area involves verifying that all surfaces are accessible and making provisions for access to elevated areas (i.e., scaffolding). When access time to the work area is limited due to plant operation or contamination, a preliminary inspection (with photo documentation, if necessary) and accurate planning are critical. In addition to providing access to all areas, preparation of the work area may include such activities as masking and protecting sensitive equipment or surfaces not to be painted. Temporary enclosures may be needed if the work area is a small part of a large building or if masking is not practical. Carbon filters may have to be removed from the ventilation system and an alternate or auxiliary ventilation system installed. Proper ventilation of the work area is necessary for personnel and fire safety, as well as the proper and timely cure of

the coating material. Material preparation is the step that takes the coating from its storage configuration to an applicable condition. This requires stirring and thoroughly mixing a single component prepackaged container to ensure that all pigments and solids are resuspended to ensure uniform consistency. Multicomponent materials (including most high performance industrial maintenance coatings) require mixing two or more components with a power mixer in strict accordance with manufacturer's instructions and straining the material (unless the coating intentionally contains large particles) into a container and, in some cases, waiting a prescribed induction period. Paint mixing and thinning should be done outside of containment, if possible.

APPLICATION

Most applications of coatings will fall into three broad classes:

1. *Mechanical application*—Such as trowel or squeegee spreading.
2. *Capillary or wicking action applications*—Examples would be use of brushes and rollers.
3. *Direct material projection*—Such as spray application or pouring, typically with no further operator action once the material is on the surface.

MECHANICAL APPLICATION

This method is most commonly used for high viscosity materials applied at relatively high thicknesses (over 40 mils) to flat surfaces. Some low viscosity floor sealers are applied by roller or by pouring the coating onto the surface and spreading to the desired thickness with a rubber-bladed squeegee.

Trowels, in various sizes and configurations, are used for application of filled materials. These materials contain silica, carbon, glass flakes, fibers, or other resistant inerts. They are applied to floors and walls that are subject to acid corrosion, heavy traffic, or other rigorous conditions. Many linings are applied by trowel, as are many fireproofing systems. Advantages include low equipment costs, the ability to get material into small or complex areas, and an attractive finish. Disadvantages include high labor cost (high applicator skill is required), slow application rates, and difficult control of thickness with some materials.

Many materials are most efficiently applied by a combination of methods. An example would be spray application to get the material on the surface and then finishing by trowel or roller to provide a smooth or aesthetically pleasing finish (examples would include glass flake-filled materials which are rolled).

CAPILLARY OR WICKING ACTION APPLICATION

Of course, the most common tool (method) is the paint brush. Brushes come in a myriad of sizes and shapes, with specific designs for specific purposes. When a brush is to be used, it must be compatible with the paint components. Certain solvents such as ketones affect synthetic bristles; therefore, camels hair bristles or other special brushes may be required. Similarly, bristle brushes absorb water and should not be used with water-based coatings. The brush should be designed to hold a reasonable amount of coating commensurate with the thickness of the coating and the area to be coated. Typically, brushes are not the tool of choice for large flat areas. To be successfully brushed, a material must have a low enough viscosity to flow out after it has been applied and not show excessive brush streaks. Generally, thicknesses of more than 3 to 5 mils (0.762 to 1.27 mm) are not practical to apply in a single coat with a brush.

Rollers hold more coating material than brushes and thus provide a more rapid method for coating large flat areas. They do not have the flexibility of a brush for working on complex structures or with coatings that have poor wetting characteristics. Rolling may also entrap air in the film which can cause bubbling and pinholing in some coatings. Brushes and rollers are most commonly used with solvent reduced, single-component, thin film coatings and for minor touch-up of larger items. Both brushes and rollers must be resistant to the typical solvents found in most coatings.

Gloves, mitts, and daubers are special tools that fall into this classification. Gloves and mitts are efficient alternates to brushing or rolling for irregular or small items such as handrails and small diameter piping.

DIRECT MATERIAL PROJECTION

The most common type of equipment for this kind of coating application is the spray unit, consisting of a paint container, a hose, and a spray gun. The two classes of spray

equipment most broadly used today are (1) airless, where the high pressure of the fluid being forced through a small opening atomizes the coatings; and (2) air spray, or conventional, where compressed air is used to atomize the liquid coating. Airless spray is appropriate for a wide range of coatings with a wide range of viscosities and constituents. The airless pumps are constructed of corrosion-resistant materials and can handle most types of solvents and resins. For materials with very short pot lives, plural component machines are used with two or more pumps operating in unison, with the materials only being mixed at the tip immediately prior to being sprayed. Some guns involve an external mix head where the two reacting components are not mixed inside the machine at all. Airless equipment can be coupled with in-line heaters that raise the temperature of the coating to lower the viscosity and allow materials to be sprayed at lower pressures and with faster cure times. Sand-filled or other similar materials generally cannot be pumped.

Air spray application is called conventional spray because it is the original method of spray application and has been in use for many years (most applicators are familiar with the equipment). The speed advantages of spraying over brushing or rolling are dramatic. A typical air spray system includes a compressor, a pressurized paint container (pot), two hoses from the pot, and a spray gun. Because the paint is being atomized by a stream of air, much higher losses due to overspray occur than with airless spraying. Additional protection of applicators and adjacent surfaces are generally required. Most of the benefits and limitations of airless spray apply to air spray. Air spray has the additional limits of relatively short hoses [the paint supply must be within about 50 ft (15.24 m) of the spray gun], and a narrower range of viscosities. The air supply must be kept free of any oil or water from the compressor.

An advantage of air spray over airless is the ability to better disperse large solid particles. A glass flake-filled material cannot be sprayed with airless equipment. A properly configured air spray unit can successfully apply most materials of this type. One final advantage of the air spray gun is the ability to make changes in the size and shape of the pattern without changing tips or stopping the spraying operation. An advantage of airless spray is the ability to atomize higher viscosity material which decreases the amount of thinning necessary, thus reducing the amount of solvent released to the atmosphere. One disadvantage of air spray is the high amount of overspray created in application; therefore, serious consideration should be given to either airless spray or brush/roller application inside containment.

by Don Hill

1. The inspection agency/personnel should be committed exclusively to the inspection of coatings rather than utilizing the same inspectors for a multiple of areas such as welding inspection, cathodic protection, ultrasonic test (UT) examination, etc.
2. The inspector must have knowledge not only in evaluating in-process application, but also in the use of the various instruments that are available for inspection purposes and when they should be used (Figs. 30–33). This is necessary to avoid intimidation by the painter himself.
3. The reputation of the inspection agency and the particular inspector assigned to his project should be evaluated.
4. The inspector should have the ability to climb and do as well on a scaffold as the painters.
5. The attitude of the inspector is of extreme importance. More is achieved by cooperation than by intimidation. His objective should be to help complete the job properly in accordance with specifications rather than being an adversary to the applicator.

The inspector should have adequate training as to areas of a structure which will undoubtedly fail unless properly coated (e.g., corners, welds, edges, back-to-back angles, connecting/fastening of two dissimilar metals, etc.). The knowledge of the inspector need not be of the caliber of a corrosion engineer; however, it is helpful for him to know, for example, that welds will, in almost all cases, be the anode of the corrosion cell and that corrosion will always occur at the anode. In addition, these areas are the most difficult to spray coat—the painter would be anxious to spray apply the material on such areas rather than following the guidelines of the inspector, where brush application would be the preferred method. The inspector, being knowledgeable of the “whys” of inspection, would assist the painting firm. Communication with knowledge is more effective than intimidation.

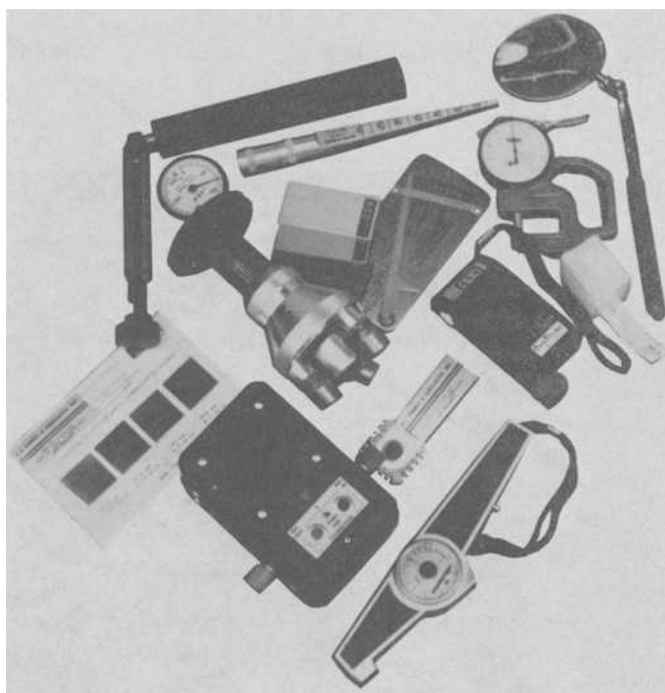


FIG. 30—Quality control coating inspection instrumentation (courtesy of S. G. Pinney Assoc.).



FIG. 31—Magnetic dry film thickness gauge (courtesy of Stone & Webster Corp.).

Another aspect would be that of breaking, i.e., rounding the edges of structural members—pointing out this is necessary to avoid separation of the coating upon application, which would be of benefit to the painting contractor in that he would not be back at the eleventh month warranty inspection redoing much of his work. In summary, the inspector must realize that he is in a position to promote and expedite the proper completion of the work by ensuring it is done properly the first time.

THE PRESTARTUP/PREAWARD MEETING

It is recommended that the inspection personnel and his inspectors be present during the prestartup or preaward meeting. The purpose is to review those areas of the spec-



FIG. 32—Wet film thickness gauge (courtesy of Don Hill).

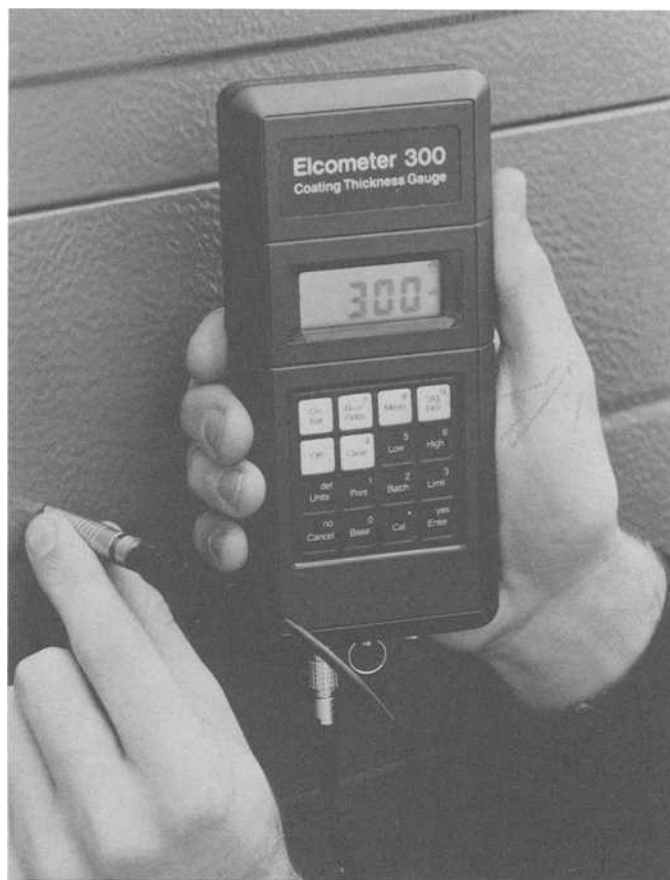


FIG. 33—Magnetic and eddy current coating thickness gauge—digital (courtesy of Elcometer, Inc.).

DAILY REPORT FORM

PROJECT: _____

JOB NO. _____

REPORT NO. _____

DATE: _____

REMARKS:

PREPARED BY: _____

DATE: _____

FIG. 34—Reporting form example.

REPORT FORM

INSPECTOR: _____

DATE: _____

TIME: _____ AM/PM SEQUENCE NUMBER: _____

MORE THAN ONE REPORT FOR TODAY?

☐ YES ☐ NO☐ Additional attached reports (Mixing Sheet, Deviation Report, DFT report)☐ DRAWING ATTACHED SHOWING TODAY'S WORK ACTIVITY

AREA OF WORK: _____

ACTIVITY: ☐ Pre-surface preparation☐ Surface preparation☐ Application of _____ coat☐ Final Inspection

Time taken

Humidity				
Surf. temp.				
Air temp.				

Time taken

Humidity				
Surf. temp.				
Air temp.				

Time taken

Humidity				
Surf. temp.				
Air temp.				

☐ Cleanliness prior to blasting:

ACCEPTABLE NOT ACCEPTABLE

Notes: _____

☐ Blasting to: SSPC-10 Modified.

ACCEPTABLE NOT ACCEPTABLE

Notes: _____

☐ Profile obtained _____
Using DuPont Starblast☐ Application

Using: Tip _____ (Size) Gun _____ (Type)

Airless _____ Conventional _____ A.A. Airless _____

☐ No change from previous report number _____☐ Material Used (Brand Name and Manufacturer)

Color: _____

Amount Used For Today: _____

☐ Time between coats _____ hours.☐ Time interval after surface preparation (blasting) to the application of the first coat _____ hours.☐ Thinner Used _____

Amount per gallon _____ for _____ coat.

Reason for use _____

☐ Problem areas (to be reported to Engineer AS SOON AS POSSIBLE if any of the following occurs):

_____ Sheen not correct.

_____ Dry time not normal.

_____ Blush appears.

_____ Gassing.

_____ Other (Please describe) _____

☐ Viscosity Test

Temperature _____ Time _____

☐ Tape test (ASTM D 3359 "Measuring Adhesion By Tape Test")

Notes: _____

☐ Elcometer Pull-Off Test

Notes: _____

☐ Blotter Test

Notes: _____

Signed By _____

Inspector

NOTE: Reports must be submitted on a daily basis.

FIG. 35—An example of a deviation report.

REPORTING FORM

INSPECTOR: _____

DATE: _____

TIME: _____ SEQUENCE NUMBER: _____

MORE THAN ONE REPORT FOR TODAY?

☐ YES ☐ NO☐ DRAWING ATTACHED SHOWING TODAY'S WORK
ACTIVITY

AREA OF WORK: _____

ACTIVITY: ☐ Pre-surface preparation☐ Surface preparation☐ Application of _____ coat☐ Final Inspection☐ Humidity reading: _____ (To be taken for all activities)

Time Taken: _____

☐ Temperature reading: _____ (Surface temperature)
(For blasting prior to first coating application)

Time Taken: _____

☐ Temperature reading: _____ (Environmental) (to be
taken during all activities).

Time Taken: _____

☐ Cleanliness prior to blasting:

Notes: _____

☐ Blasting to: SSPC SP-5/SSPC SP-7 compared to Vis
Standard:

Meets _____ Does Not Meet _____

Comments: _____

☐ Profile obtained Yes _____ No _____

Using: _____

Application: Wet _____ mils

Using: Tip _____ (Size) Gun _____ (Type)

Airless _____ Conventional _____

☐ No change from previous report number _____☐ Material Used (Brand Name and Manufacturer):

Color: _____

Amount Used for Today: _____

Lot number: _____ Compartment A

Lot number: _____ Compartment B

☐ Time interval after surface preparation (blasting) to the
application of the first coat _____ hours.☐ Time between coats _____ hours.☐ Thinner used _____

Amount per gallon _____ for _____ coat.

Reason for use: _____

☐ Dry film thickness readings:

TOTAL:

Average _____

Magnetic gauge calibrated: (Date) _____

(By using U.S. Bureau of Standards skims.)

☐ Action taken for low readings:

☐ Problem areas (to be reported to management AS SOON
AS POSSIBLE if any of the following occurs):

_____ Sheen not correct.

_____ Dry time not normal.

_____ Blush appears.

_____ Gassing.

_____ Other (Please describe) _____

☐ Holiday check done (high voltage)

Areas found and marked _____

Corrective Action Taken: _____

(If more than 10% of the surface area, ADVISE IMMEDIATELY)

☐ This holiday check was done on:

Intermediate Cost _____ Final Cost _____

☐ Cure test performed after last application:

Comments: _____

SIGNED BY: _____
Inspector

DISTRIBUTION MADE TO:

NOTE: Must be submitted on a daily basis to Art Olson.
And copy sent to Hansen Painting Company on _____ (Date)

*Mark N/A if not applicable.

FIG. 36—The final report.

ification that would be of particular interest to the inspector. In maintenance, photographs of areas of concern are a great asset. Making the contractor aware "up front" will avoid surprises during the course of the job.

THE METHODS AND INSTRUMENTS USED DURING INSPECTION

The methods and instruments used are dependent upon the item being protected and its condition. For example, if we are refurbishing the interior of an oil storage tank, it would be important to determine, after cleaning, if all oils have been removed prior to blasting. The inspector may wish to use a black light to determine these areas prior to the abrasive blasting operation. If the structure has been previously coated and the intention is to leave the previous material intact where performing well, it is necessary to determine the film thickness of the existing coating prior to any start of reapplication.

There are many instruments available for the purposes of inspection. Some of the more common are as follows:

1. Sling psychrometer—such as manufactured by Bacharach or Taylor.
2. U.S. Weather Bureau psychrometric tables.
3. Surface thermometer.
4. Mini/max recording thermometer.
5. Hypodermic needle pressure gauge.
6. Blast nozzle aperture gauge.
7. TESTEX Press-o-Film replica tape with micrometer.
8. Surface profile comparator.
9. SSPC VIS 1-89 standards.
10. Wet film thickness gauge.
11. NIST (NBS) calibration standards.
12. Magnetic coating thickness gauge such as manufactured by Elcometer.
13. Low-voltage holiday detector such as manufactured by Tinker and Razor.
14. High-voltage holiday detector such as manufactured by D. E. Stearns.
15. Cross-hatch adhesion test kit such as manufactured by Gardco.
16. "Pull-off" adhesion tester such as manufactured by Elcometer.
17. Paint inspection (tooke) gauge.
18. Inspection mirrors.
19. Inspection flashlight.

Marking of Areas That Are Found Defective

The most common marking material, which is considered unaffected by subsequent coats, is the Carter's Marks-A-Lot ink marker. There are many others similar to this type. More recently, however, there has been a use of fluorescent ribbons or tapes. These can be seen at a greater distance and are nondestructive to the surface being recoated.

Reporting Deviations or Deficient Areas

The reporting form example is given in Fig. 34. An example of a deviation report is given in Fig. 35. Similar forms are available through the engineering firms or through the inspection agencies. The important aspect of such a report is the follow-through. It is necessary that an effective counter check be accomplished to assure that those areas found are repaired in accordance with the specification.

The final report will indicate all areas have been repaired in accordance with the specifications (Fig. 36) and produce the intended results of the specification.



Safety

by Ralph Trallo

SAFETY IN AN operating nuclear plant is site specific. The information provided in this chapter should be considered when scoping and scheduling coating work and is meant only as a guide.

PLANT SAFETY PROGRAM

Courses in safety, the contents of the program, and times given (daily, weekly) are site specific. The lengths of time to process prospective employees taking courses should be considered so as not to impact coating work scheduling. Successful completion of courses may be a prerequisite for working at the stations. Furthermore, the number of courses taken may/will govern the level of entry for the new employee. Entry into containment, fuel handling building, etc. may require successful completion of all courses in safety, whereas work in the station yard may require the successful completion of only one course. Courses may cover the following areas:

GENERAL EMPLOYEE TRAINING

This course presents the station alarm systems for fire, radiation alert, evacuation; types of fire suppression systems (water, Cardox, etc.); control points; radiation control areas; security system; function of Health Physics; personal hygiene; etc.

RADIATION WORKERS' TRAINING

An in-depth presentation is made of radiation hazards, limits of exposure to radiation, use of protective clothing (PCs) in radiation areas, training in dressing and removing PCs, working permits in hazardous radiation areas, etc.

RESPIRATOR TRAINING

In this course, the trainee is informed of the types of respirators, filtering mediums, etc. that are available; how to put on, use, and remove a respirator; when and where a respirator should be used; and is fitted with a respirator mask. Will fumes from painting render the radiation respirator useless?

BADGING

Badging is nuclear plant (site) specific. Upon successful completion of the number of required courses, the trainee is photographed. The photograph is placed on a color-coded card, a number is assigned, and the card is laminated. The color of the card (badge) will indicate the trainee's level of entry in some plants.

MATERIAL STORAGE SAFETY

Paints, coatings, and solvents should be stored in a building or van away from all plant buildings in accordance with NFPA codes and plant-specific requirements. In addition, most paints and coatings may have specific temperature and humidity requirements while being stored.

HANDLING AND MIXING OF MATERIALS

Generally all handling and mixing of materials are done in accordance with the manufacturers' recommendations. However, nonsparking tools, safety cans for solvents and waste rags, protective clothing (not PCs), gloves, goggles, hard hats, respirators, etc., should be considered for use.

MECHANICAL CLEANING

When hand tool and/or power tool cleaning, goggles, air masks or respirators, hard hats, gloves, forced air ventilation, nonsparking tools, etc., should be considered. Tools should be operated at recommended operating speeds (ROS), not maximum operating speed (MOS), to guard against breakage/disintegration of sanding discs, rotary wire brushes, flapper wheels, and other abrasive media.

BLAST CLEANING

Before blast cleaning is begun, check for worn, frayed, or broken air hoses; worn nozzle tips, worn hose connectors; clean air supply, etc. The use of forced air ventilation, force feed air safety helmets, gloves, protective clothing, etc. should be considered.

SOLVENT CLEANING

Solvent mixes, alkaline cleaners, detergents, wetting agents, etc. may be used in solvent cleaning. Care should be exercised in mixing solvents. The flash point may be altered, which could present an explosion hazard. Protective clothing, gloves, goggles, forced air ventilation, forced feed air safety helmets, etc. should be considered for use. Avoid solvent spills and prevent solvents from entering the drains or waste system of the plant. Provide for lawful and proper disposal of spent solvents.

STEAM CLEANING

Hazards may arise from pressures, temperatures of solutions, cleaning agents, etc. Protective clothing, gloves, goggles, boots, forced air ventilation, and forced feed air safety helmets (if required) should be considered for use. Hoses and connections, thermostats, and related electrical equipment should be checked.

ACID CLEANING

Hot and cold solutions are corrosive to the skin. Their fumes attack the mucous membranes. Forced air ventilation, forced feed air safety helmet (if required), rubber gloves, boots, goggles, protective plastic, or rubber clothing, etc. should be considered for use.

HEPA FILTERS AND ABSORBER SAFETY

Charcoal HEPA filter and absorber efficiency to absorb radioactive iodine and other impurities may be reduced if paint overspray and solvents are absorbed. In addition, the absorption of ketone solvents on charcoal presents a potential fire hazard.

Some suggested methods to prevent charcoal poisoning are to block off vents in the area being coated, isolate the entire charcoal filter system (if required), and use an auxiliary charcoal filter system equipped with HEPA filters. Refer to Regulatory Guides 1.52 and 1.140 for regulatory requirements.

AIR VENTILATION

The ASTM Manual of Coating Work for Light-Water Nuclear Power Plant Primary Containment and Other Safety-Related Facilities (ISBN No. 03-401079-14) contains information on safe "respirable air" requirements for life support and ventilation equipment in Chapter 7, titled "Safety and Environmental Control."

MISCELLANEOUS SAFETY CONSIDERATIONS

- *Toxic Fumes From Fires*—Know where the nearest exit is. If available, use portable air supply.
- *Explosion Hazard*—Use forced air ventilation to dilute solvent fumes. Do not allow welding or other open flames in the painting area. All electrical equipment must be explosionproof.
- *Waste Solvent and Waste Rag Hazard*—Place in safety cans and remove to a designated disposal area at the end of each shift.
- *Explosionproof Lights*—Use during and after completion of coating work.
- *Ladder*—Inspect rungs and sides for broken parts. Does ladder have safety shoes? Wobble? Check for worn pulleys and frayed and worn rope. Ladders should be constructed of a material which is decontaminatable, if possible, and to the requirements of the individual plant.
- *Staging*—Inspect to insure that all staging has been properly assembled and has been tagged "OK" by a member of the plant safety team or responsible person.
- *Scaffolds, Hooks, Block and Falls, Ropes*—Inspect to insure that a scaffold is sound, hooks are not worn, block and falls have good connections and the wheels are free, and that ropes are not frayed and worn. Replace as required.
- *Boatswain's Chair, Lifelines, Lifelines, Lifebelts*—Inspect for frayed and worn ropes, belts, etc. Replace as required.

GENERAL SAFETY REQUIREMENTS

Hazards from volatilized toxic compounds, chromates, cadmium, zinc, etc. may be encountered. Protective clothing, gloves, forced feed air safety helmets, forced air ventilation, etc. should be considered for use.

Steel Structures Painting Council book, Volume 1, entitled "Good Painting Practice," and ASTM "Manual of Coating Work for Light-Water Nuclear Power Plant Primary Containment and Other Safety-Related Facilities" contain many reference sources for safety. It is further suggested that the ASTM Practice for Design and Use of Safety Alert System for Hazardous Work Locations in the Coatings and Lining Industry (Intent to Withdraw) (D 4257) be used to properly post the areas being painted.

BIBLIOGRAPHY

- Good Painting Practice*, Vol. 1, Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA.
- Manual of Coating Work for Light-Water Nuclear Power Plant Primary Containment and Other Safety-Related Facilities*, American Society for Testing and Materials, Philadelphia, 1979.

Appendix A

GLOSSARY OF TERMS COMMONLY USED IN COATING WORK

- abrasion**—wearing away of material in small shreds as a result of friction.
- abrasion resistance**—that property of a surface by which it resists being worn away as a result of friction. This property is not necessarily related to hardness of the surface but is more often correlated with its toughness.
- abrasive**—a substance, such as sand, steel grit, steel shot, metallic oxide particles, etc., used in blast or abrasive cleaning.
- absolute moisture content**—amount of water contained per unit volume.
- absorption**—the process of soaking up, or assimilation of one substance by another.
- acid etch**—a cleaning method that roughens a surface by using an acid.
- activator**—a catalyst or curing agent.
- adhesion**—the bond or attraction of a coat of paint to the underlying material such as a substrate or another coat.
- admixture**—any material other than water, aggregate, and cement, used as an ingredient of concrete; used to modify the properties of concrete to make it more suitable for the work.
- adsorption**—the process of attraction to a surface.
- air dry**—to dry by oxidation or evaporation of volatiles by simple exposure to air without heat or catalyst.
- air void**—a small hole in a coating or on a surface of a coating.
- alkali**—caustic; inorganic compounds that contain hydroxy groups in aqueous media.
- alligatoring**—surface cracking of a paint film having the appearance similar to alligator hide.
- ambient**—an encompassing atmosphere or surrounding environmental condition, such as temperature, relative humidity, and pressure.
- anchor pattern profile**—roughness of a blast-cleaned surface measured by the height from the bottom of the valley to the top of the highest adjacent peak. It depends upon the original condition of the surface and the degree of surface preparation.
- anode**—the electrode of an electrolytic cell at which a net oxidation reaction occurs.
- atmosphere**—a gaseous medium surrounding the working area.
- audit**—an activity to determine through investigation the adequacy of and adherence to established procedures, instructions, specifications, codes and standards or other applicable contractual and licensing requirements and effectiveness of implementation.
- batch adjustment record**—a record of materials added to a paint batch to adjust viscosity, color, or other properties.
- batch record**—a record of all materials and proportions used to produce a batch of paint.
- biological shield**—mass of absorbing material placed around a reactor or radioactive source to reduce ionizing radiation to levels not hazardous to personnel.
- blast cleaning, blasting**—a method of surface preparation using abrasives, propelled through nozzles or by centrifugal wheels, to remove mill scale, rust, rust scale, old paint, laitance, and other foreign containments that would interfere with the adhesion of the subsequent coating.
- blast profile**—See **anchor pattern profile**.
- blistering**—the formation of bubbles in a cured, or a nearly cured, coating (paint) film after exposure, generally in an aqueous environment.
- bond breakers**—coatings applied to concrete surfaces or forms to prevent bonding between the concrete and other materials or forms.
- bubbling**—bubbles appearing on the surface while coating is being applied.
- bughole**—a small void at or near the surface of concrete.
- calibrate**—to determine the indication or output of a measuring device with respect to that of a standard.
- catalyst**—accelerator; curing agent; a component of a multicomponent coating that causes cross-linking and film formation.
- cathode**—the electrode of an electrolytic cell at which a net reduction reaction occurs.
- caulking compound**—a soft plastic material used for sealing joints in buildings and other structures where normal structural movement may occur.
- certification**—confirmation by document under hand or seal as being true or as meeting a standard or as being as represented.
- cfm**—cubic feet per minute.
- chalking**—that phenomena manifested on cured coatings (paints) by the presence of loose, removable powder, evolved from the film itself, at or just beneath the surface, generally caused by ultraviolet exposure and subsequent degradation of the binder. Chalking may be easily detected

- by rubbing the film with a cloth of contrasting color or with the fingertip (ASTM Method D 659).
- checking**—a defect in the coating (paint) that manifests itself by slight breaks in the surface of the films.
- chemical pretreatment**—use of chemicals to prepare a surface prior to application of a coating.
- chlorinated rubber**—a particular film former used as binder, made by chlorination of natural rubber.
- clean air supply**—air relatively free of fumes, vapors, and such, used for working and coating operations.
- coagulation**—the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical.
- coating applicator**—one who applies a protective or decorative coating (paint).
- coatings (paints)**—polymeric materials that, applied in a fluid phase, cure to continuous films.
- coating system**—a multicomponent polymeric protective film usually consisting of prime, intermediate or finish coats, or both.
- coating work**—an all-inclusive term to define all operations required to accomplish a complete coating job; the term shall be construed to include materials, equipment, labor, preparation of surfaces, control of ambient conditions, application of coating systems, inspection, etc.
- commercial blast**—SSPC-SP-6 or NACE No. 3 abrasive cleaning.
- compatible**—suitable to combine with other substances, or to adhere properly to other parts of system; capable of resisting the chemical, physical, and other effects of the intended service condition.
- concrete**—material made from portland cement and inert aggregates, such as sand and gravel, which are mixed with water to a plastic consistency, and placed in forms to harden and gain strength.
- concrete hardener**—an aqueous solution of a chemical, such as magnesium fluosilicate, sodium silicate, etc., which is applied to concrete surfaces to harden the surface and reduce dusting due to traffic.
- containment**—See **reactor containment facility**.
- contaminant**—a foreign substance, inadvertently added to a coating or found on a substrate, that adversely affects the application, adhesion, curing, and/or subsequent performance of the applied coating. Atmospheric moisture and condensation can be considered to be substrate contaminants, as is a solution of mixed fission products or radioactive nuclides.
- contamination**—lack of cleanliness of substrate, adulteration of coating product, also the act of depositing substances containing radioactive nuclides on the surface or within the body of a material. In a strict sense contamination is undesirable in that it constitutes a health hazard to the biological environment or is detrimental to experiments and other operations.
- corrosion**—the deterioration of a material, usually a metal, due to a chemical reaction with its environment.
- cracking**—a break or split in a coating extending from the surface to the substrate.
- cured film**—a hardened film.
- curing**—the changing of the physical properties of a coating by chemical reaction accomplished by the action of heat or an activator, or both.
- curing agent**—See **activator**.
- curing membrane**—a temporary or permanent coating applied to new concrete to retard the loss of water from the mass in order to facilitate its curing.
- curtains**—sags.
- damp**—wet, not dry.
- decontaminate**—to remove reactive nuclides (the contaminant) from a surface.
- decontamination**—the act of decontaminating.
- defective**—subnormal in respect to written specifications.
- degrease**—remove grease and fatty substances from a surface by use of solvents or detergents, or both.
- dehumidify**—to reduce, by any process, the quantity of water vapor within a given space.
- delamination**—separation of one coat or layer from another coat or layer of a paint system.
- demisters**—mechanical means to remove mists, generally water.
- desorb**—removal of volatile materials recovered by absorption and adsorption operations.
- deviation**—completed work that is not in accordance with the specification requirements.
- dew point**—temperature at which moisture condenses.
- documentation**—the assembling and dissemination of written information or records in substantiation of work done or facts quoted.
- dry film thickness (DFT)**—thickness of applied coating when dry, expressed in mils (0.001 in.) or micrometres (1×10^{-4}).
- dry to handle time**—time interval between application and ability to pick up without excessive damage.
- dry to recoat time**—interval between application and ability to receive next coat satisfactorily.
- dry spray**—overspray or bounce back.
- dry to touch**—interval between application and tack-free time.
- drywell**—steel pressure chamber surrounded by reinforced concrete shielding in containment building and used to differentiate from a wet well in BWR containments.
- efflorescence**—deposit of soluble white salts on surface of masonry.
- entrapped air**—air voids in concrete which are usually not produced by the intentional use of an air-entraining agent.
- environment**—the sum of all external conditions (physical, chemical, mechanical, radiation, etc.) in which a material exists, or to which a surface is exposed.
- epoxy resins**—film formers usually made from bisphenol and epichlorohydrin.
- etch**—roughening of a surface by chemical means.
- exemption log**—record of surface area and location of each component coated with uncontrolled coatings.
- expiration date**—that date after which a coating (paint) cannot be used because of possible formula deterioration or expiration of shelf life.
- extender**—an organic material used to augment the polymer in a compound.

- fallout**—paint overspray.
- filler**—an extender or inert pigments.
- film thickness**—thickness of coating above substrate.
- filtration**—purification by removal of small particulates by passing a liquid through a filter.
- final cure**—interval of time necessary for a coating (paint) to achieve a degree of cure to normally permit placing in expected service.
- fish eyes**—formation of holes or visible depressions in a paint film.
- fission products**—atomic nuclei produced by the splitting of heavy-element isotopes; also elements formed from these nuclei.
- flaking (scaling)**—the detachment of small pieces of the coating film. This is usually preceded by cracking, checking, or blistering.
- flame spread rating**—measurement of flame propagation on the surface of materials in accordance with ASTM Method E 84 or equivalent test.
- flash point**—lowest temperature at which a given flammable material will flash if a flame or spark is present.
- flocculation**—the agglomeration of colloidal and finely divided suspended matter, after coagulation, by gentle stirring using mechanical or hydraulic means.
- forced cure**—acceleration of curing by increasing the temperature above ambient temperature accompanied by forced air circulation.
- form release agent**—an oil or plastic coating used on concrete forms to reduce damage to the concrete and to the forms when they are stripped from the hardened concrete.
- form sealers**—coatings applied on concrete forms to facilitate removal after concrete has set.
- fumes**—types of contaminants or particles generated by condensation from a gaseous state.
- galvanized**—plated by dipping a steel surface into a molten zinc.
- generic type**—a particular family of coatings generally referring to a type of resin or binder.
- grout**—a plastic mixture of cementitious materials and water used as a filler for cracks, or other void spaces, in concrete surfaces to be coated.
- hardener**—curing agent, see activator.
- hold point**—the point at which work must be stopped until inspection or testing is performed; upon approval by owner or his representative, process can be continued.
- holiday**—pinhole, skip, discontinuity, or void in a coating film that exposes the substrate.
- honeycomb**—multiple voids in concrete surface.
- humidity**—moisture content of a gas, usually air.
- induction time**—for chemical cured coatings, the time required, after combining and mixing of the components, to render the product ready for use.
- inert particulates**—nonreactive particles in atmospheric air larger than 2.0- μ m diameter.
- inorganic**—containing no carbon atoms.
- inorganic zinc coating**—zinc-rich paint with inorganic binder or vehicle.
- intercoat**—boundary between coats, phases or system, interface.
- irradiation**—exposure to ionizing radiation.
- laitance**—a fine whitish powder on concrete surfaces. Consists of cement particles that are carried by water rising to the surface of freshly placed concrete. The resulting concrete surface is dusty and unsuitable for proper adhesion or bond of subsequent fillers or protective coatings.
- lower explosive limit**—lower limit of explosibility of a gas or vapor at ordinary ambient temperatures expressed in percent of the gas or vapor in air by volume.
- masonry**—built-up construction consisting of building units made of clay, shale, concrete, stone, etc., set in mortar.
- metallizing**—mechanical deposition of one metal on another.
- mill roller flaws**—imperfections on the surface of steel mill-rolled in the mill.
- millscale**—heavy oxide layer formed on hot steel during hot rolling and cooling.
- mists**—small droplets of liquids in the air at normal temperature and pressure.
- mixing ratio**—ratio, expressed by weight or volume, of separately packaged components of a multiple-component coating by which the components are to be combined and mixed to uniform condition before application.
- mud cracking**—irregular cracking that occurs as a coating dries.
- near-white blast**—SSPC-SP-10 or NACE No. 2 abrasion cleaning.
- non-conformance**—deficiency in characteristic, documentation, or procedure that renders quality of item unacceptable or undeterminate.
- oil and moisture trap**—device on air compressors to eliminate most oil and moisture from the incoming air supply.
- oleoresinous**—film former containing oil or alkyd resins.
- orange peel**—dimpled appearance of a dried film.
- overspray**—sprayed paint on adjacent surfaces.
- paint**—See **protective coating**.
- peeling**—separation of one or more coats or layers of a coating system from the substrate.
- pH**—a measure of the degree of acidity or alkalinity of a solution on a scale ranging from 1 (acidic) to 14 (alkaline) with a neutral point at pH 7.
- pickling**—a surface treatment for steel to remove rust and mill scale by immersion in an acid solution which may contain an inhibitor. Pickling is followed by thorough washing and drying before painting.
- pinholes**—minute holes through the entire thickness of coating film; cratering.
- pitting**—formation of small, usually shallow low depressions or cavities.
- porosity**—small interconnected voids which allow fluids to penetrate an otherwise impervious material.
- pot life**—interval after mixing of two component coatings during which the liquid material is usable before gelling.
- primer**—the first complete coat of paint of a coating system

applied to an uncoated surface. The type of primer varies with the surface, its condition, the intended purpose, and the coating system to be used.

profile—the surface roughness resulting from surface preparation, such as abrasive blasting, chemical etching, or other means. It is a measure of the anchor pattern.

profile depth—the average depth between the high and low points of a profile.

proprietary—available on the open market under a brand name.

protective coating—an adherent thin polymeric film applied to a substrate for protection from environmental attack and for esthetic effect.

quality assurance—the verification of the conformance of materials and methods of application to the governing specifications, in order to achieve a desired result.

quality control—administrative and engineering procedures employed to attain the desired level of quality assurance.

rad—the unit of absorbed radiation dose.

radiation buildup—increase in level of radiation.

radiation exposure level—actual radiation rate.

raw material—basic materials used in manufacturing coatings.

reactor-containment facility—containment enclosure provided to protect the environment from the consequences of a nuclear incident.

recoat time—interval required between application of successive coats.

relative humidity—ratio of the actual water vapor pressure of air to the saturated water vapor pressure at a given temperature, usually expressed as a percentage.

respirable air—air satisfactory for life support.

responsible engineer—the owner's or A/E's engineer who is responsible for the coating work.

runs—See **sags**.

sacking—filling air holes, cracks, and other smaller irregularities in concrete surfaces with cement mortar, then rubbing it flush, so as to provide a smooth surface for subsequent coatings application.

sags—the running of paint on a vertical surface due to being applied in too thick a wet film; also curtains.

scrubbers—devices to remove contaminants from air by washing air with liquid.

sedimentation—the process of subsidence and deposition of suspended matter carried in water, waste water, or other liquids by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. It is also called "settling."

shelf life—time period in which a material may normally be stored in usable condition.

silencers—devices to reduce level of noise from equipment.

solids by volume—percentage of total volume occupied by nonvolatiles in a coating; the film-forming part of the coating.

solvent—liquid in which another substance may be dissolved.

snubbers—silencers; also mechanical supports to dampen movement of equipment.

spackling compound—plaster used to fill irregularities and cracks in plaster.

spatter—deposit on or adjacent to weld seams produced by weld metal during electric hand welding operation. It is unacceptable for coating because of the sharp protrusions, and therefore must be removed prior to coating application.

spray tip—an orifice in the spray gun which uniformly meters the coating through the spray cap.

squeegee—flexible bar applicator.

substrate—the uncoated base surface to which the coating is to be applied.

surface defects—the existence in a coating of any of the following conditions which impair its performance for the intended surfaces: (a) fine line cracking, (b) checking, (c) alligatoring, (d) mud-cracking, (e) blisters, (f) pinholes, (g) damaged or abraded areas, or (h) anything that would be a defect in the coating system.

suppression chamber—torus; wet well.

surfacers—a material used to fill and smooth a surface before the finish coats are applied; see **grout** and **spackling compound**.

surface profile—See **profile**.

sweep blast—NACE No. 4 or SSPC-SP-6 Brush-Off Blast Cleaned Surface Finish.

synthetic abrasive—manufactured grit.

thermal conductivity—the rate at which heat passes through a material through a unit area of a surface whose thickness is unity when its opposite faces differ in temperature by 1 deg.

threshold limit values—values for airborne toxic materials that are to be used as guides in control of health hazards and represent time-weighted concentrations to which all workers may be exposed 8 h per day over extended periods of time without adverse effects.

tooth—profile; surface roughness.

torus—suppression chamber; wet well.

uncontrolled coatings—coatings applied that do not meet specified conditions.

vapors—the gaseous phase of matter that normally exists in a liquid or solid state.

viscosity—a measure of fluidity; the internal friction of a fluid that influences its flow.

voids—skips; holes in a film; see **holiday** and **pinholes**.

weathering—natural alteration by either chemical or mechanical processes due to action of constituents of the atmosphere.

weld slag—amorphous deposits formed during welding.

wet film thickness—thickness of liquid film immediately after application.

wet well—torus; suppression chamber.

whip blast—sweep blast, NACE No. 4 Brush Blast, SSPC-SP-7.

white blast—SSPC-SP-5, NACE No. 1.

wrinkling—a surface defect resembling the skin of a prune.

Appendix B

ASTM STANDARDS

ASTM D 610	Method for Evaluating Degree of Rusting on Painted Steel Surfaces
ASTM D 714	Method for Evaluating Degree of Blistering of Paints
ASTM D 1186	Method for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base
ASTM D 1400	Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base
ASTM D 3276	Guide for Paint Inspectors (Metal Substrates)
ASTM D 3359	Method for Measuring Adhesion by Tape Test
ASTM D 3843	Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities
ASTM D 3911	Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Loss of Coolant Accident (LOCA) 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 4121	Practice for Photographic Documentation of Coating and Lining Failures and Defects
ASTM D 4138	Test Method for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means
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 4256	Test Method for Determination of the Decontaminability of Coatings Used in Light-Water Nuclear Power Plants
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 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
ASTM D 4286	Practice for Determining Coating Contractor Qualifications for Nuclear Powered Electric Generation Facilities
ASTM D 4414	Practice for Measurement of Wet Film Thickness by Notched Gages
ASTM D 4417	Test Method for Field Measurement of Surface Profile of Blast Cleaned Steel
ASTM D 4537	Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear Facilities
ASTM D 4538	Definitions of Terms Relating to Protective Coatings and Lining Work for Power-Generation Facilities
ASTM D 4541	Method for Pull-Off Strength of Coatings Using Portable Adhesion-Testers
ASTM E 84	Test Method for Surface Burning Characteristics of Building Materials

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