Coating Inspector Program
Level 1
Student Manual

July 2011

Your CIP Level 1 Instructors are:

_____

_____

_____

IMPORTANT NOTICE:

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Policy on Use of Laptop Computers and Camera Phones

In order to be pro-active and provide students with the best opportunity for them to be as fully prepared for the course as possible; NACE has recently implemented a new policy of sending a CD-ROM of the student manual to each student when they register for a CIP course. We are hoping that this process will provide students the opportunity to review and (hopefully) study the manual prior to arriving at the class.

As a result, we have started experiencing students arriving at class with their CD-ROM and a laptop computer. In order to bring ourselves into the 21st Century, the CIP Committee has made the decision to allow students to use their laptops to follow along electronically versus working from their student manual and to also use their laptop to take notes of the class lecture.

In order to make this work, the following guidelines have been put into place:

1. Students are not allowed to be on the internet or connect with the outside world through their computer.
2. Students are not allowed to record any portion of the classroom/lab activities (including lectures)
3. All laptops must be kept in “silent” mode so as not to disturb others in the class.
4. Laptops cannot be used while quizzes or exams are taking place.
5. Laptops cannot be used during the Peer Review

In addition, with the use of more and more camera cell phones, students are forbidden to use their cell phone to take pictures while in the class.

Thank you,

NACE CIP Committee

Acknowledgements

The time and expertise of a many members of NACE International have gone into the development of this course. Their dedication and efforts are greatly appreciated by the authors and by those who have assisted in making this work possible.

The scope, desired learning outcomes and performance criteria of this course, were developed by the NACE Coating Inspector Program (CIP) Subcommittee under the auspices of the NACE Education Administrative Committee in cooperation with the NACE Certification Administrative Committee.

On behalf of NACE, we would like to thank the CIP subcommittee for its work. Their efforts were extraordinary and their goal was in the best interest of public service — to develop and provide a much needed training program that would help improve corrosion control efforts industry-wide. We also wish to thank their employers for being generously supportive of the substantial work and personal time that the members dedicated to this program. Finally, we wish to recognize the significant contributions of member companies who have contributed useful training assets including images, video, equipment, and materials. These companies include:

Elcometer, Inc
1893 Rochester Industrial Dr.
Rochester Hills
Michigan 48309 USA

DeFelsko Corporation
802 Proctor Avenue
Ogdensburg, NY 13669 USA

Fischer Technology, Inc.
750 Marshall Phelps Rd.
Windsor, CT 06095 USA

NACE COATINGS NETWORK (NCN)

NACE has established the NACE Coatings Network, an electronic list serve that is free to the public. It facilitates communications among professionals who work in all facets of corrosion prevention and control.

If you subscribe to the NACE Coatings Network, you will be part of an E-Mail driven open discussion forum on topics A-Z in the coatings industry. Got a question? *Just ask!* Got the answer? *Share it!* The discussions sometimes will be one-time questions, and sometimes there will be debates.

What do you need to join? An E-Mail address. *That's all!* Then:

1. To subscribe, send a blank email to:

Join-coatings@nacecorrosionnetwork.com

2. To unsubscribe, send a blank email to:

Leave-coatings@nacecorrosionnetwork.com

3. You're done! You'll get an email back telling you how to participate, but it's so easy that you'll figure it out without any help!

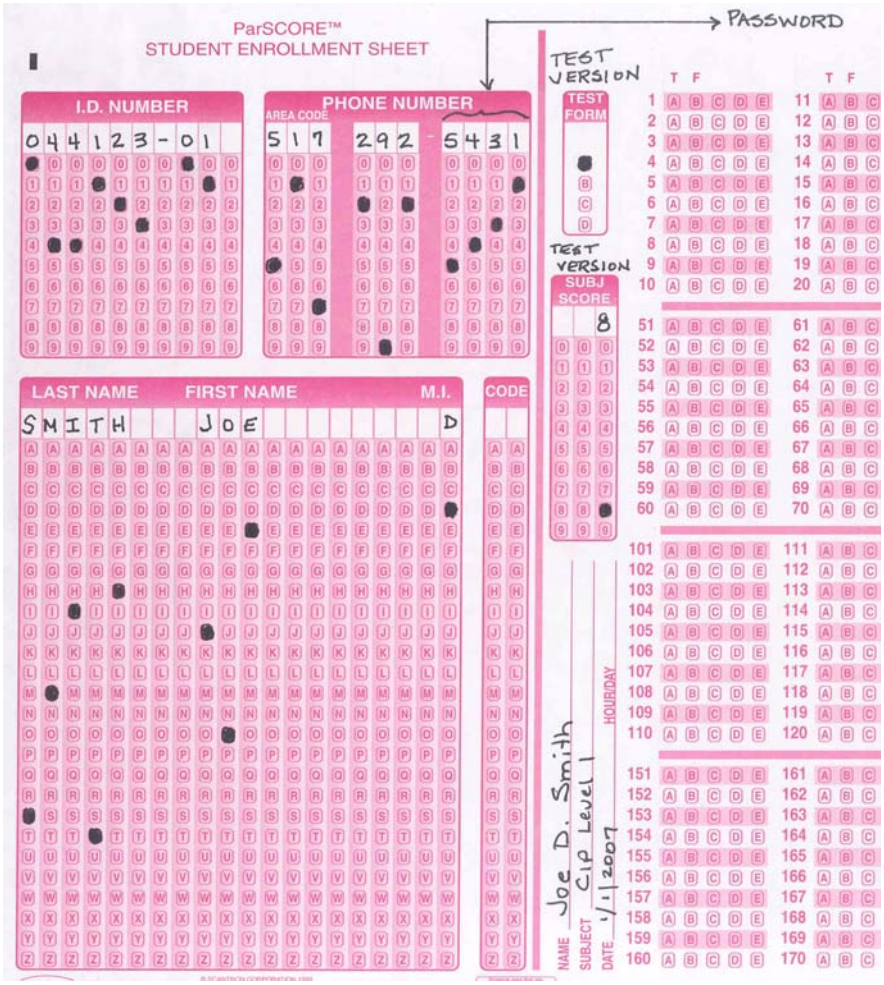
Instructions for Completing the ParSCORE™ Student Enrollment/Score Sheet

1. Use a Number 2 (or dark lead) pencil.

2. Fill in **all** of the following information **and** the corresponding bubbles for each category:

√	ID Number:	Student ID, NACE ID or Temporary ID provided
√	PHONE:	Your phone number. **The last four digits of this number will be your password for accessing your grades on-line.** *(for Privacy issues, you may choose a different four-digit number in this space)*
√	LAST NAME:	Your last name (surname)
√	FIRST NAME:	Your first name (given name)
√	M.I.:	Middle initial (if applicable)
√	TEST FORM:	This is the version of the exam you are taking
√	SUBJ SCORE:	This is the version of the exam you are taking
√	NAME:	_____ (fill in your entire name)
√	SUBJECT:	_____ (fill in the type of exam you are taking,e.g., CIP Level 1)
√	DATE:	_____ (date you are taking exam)

3. The next section of the form (1 to 200) is for the answers to your exam questions.
   - **All answers MUST be bubbled in on the ParSCORE™ Score Sheet .** Answers recorded on the actual exam will NOT be counted.
   - If changing an answer on the ParSCORE™ sheet, be sure to **erase completely**.
   - Bubble only **one** answer per question and do not fill in more answers than the exam contains.



EXAMINATION RESULTS POLICY AND PROCEDURES

It is NACE policy to not disclose student grades via the telephone, e-mail, or fax. Students will receive a grade letter, by regular mail or through a company representative, in approximately 6 to 8 weeks after the completion of the course. However, in most cases, within 7 to 10 business days following receipt of exams at NACE Headquarters, students may access their grades via the NACE Web site.

WEB Instructions for accessing student grades on-line:

Go to: **www.nace.org**

Choose:**Education**
Grades
Access Scores Online

Find your **Course ID Number** (Example 07C44222 or 42407002) in the drop down menu.
Type in your **Student ID or Temporary Student ID** (Example 123456 or 4240700217)*****.
Type in your **4-digit Password** (the last four digits of the telephone number entered on your Scantron exam form)
Click on **Search**

Use the spaces provided below to document your access information:

STUDENT ID_____COURSE CODE_____
PASSWORD (Only Four Digits) _____

*Note that the Student ID number for NACE members will be the same as their NACE membership number unless a Temporary Student ID number is issued at the course. For those who register through NACE Headquarters, the Student ID will appear on their course confirmation form, student roster provided to the instructor, and/or students' name badges.

For In-House, Licensee, and Section-Registered courses, a Temporary ID number will be assigned at the course for the purposes of accessing scores online only.

For In-House courses, this information may not be posted until payment has been received from the hosting company.

Information regarding the current shipment status of grade letters is available upon the web upon completion of the course. Processing begins at the receipt of the paperwork at NACE headquarters. When the letters for the course are being processed, the "Status" column will indicate "Processing". Once the letters are mailed, the status will be updated to say "Mailed" and the date mailed will be entered in the last column. Courses are listed in date order. ***Grade letter shipment status can be found at the following link:***

http://web.nace.org/Departments/Education/Grades/GradeStatus.aspx

If you have not received your grade letter within 2-3 weeks after the posted "Mailed date" (6 weeks for International locations), or if you have trouble accessing your scores on-line, you may contact us at GradeQuestions@nace.org

DAILY SCHEDULE	
DAY ONE	
Chapter 1	Introduction and Team Formation
Chapter 2	Corrosion
Lunch	
Chapter 3	Team Building Exercise
Chapter 4	The Role of the Inspector
Chapter 5	Environmental Testing
Chapter 6	Environmental Testing - Practice Lab
Review Practice Lab	
DAY TWO	
Chapter 7	Coating Fundamentals
Chapter 8	Coating Types and Curing Mechanisms
Chapter 9	Coating Project Specification
Chapter 10	Surface Preparation
Lunch	
	Surface Preparation (continued)
Chapter 11	Surface Preparation Instrumentation
Chapter 12	Surface Preparation Instrumentation - Practice Lab
Review Practice Lab	
DAY THREE	
Chapter 13	Pre-Job Conference
Chapter 14	Inspection Project Documentation
Chapter 15	Coating Application
Lunch	
Chapter 16	Dry Film Thickness Measurement Instrumentation

DAILY SCHEDULE	
Chapter 17	Coating Film Thickness Measurement Instrumentation - Practice Lab
Review Practice Lab	
Chapter 18	Product Technical Data Sheets and Material Safety Data Sheets
Chapter 19	Lab Day Specification
DAY FOUR	
Lab Day	
Lunch	
Lab Day (continued)	
Review Lab Day	
Review	Test Instrument / Course Material Review as Required and Time Allows
DAY FIVE	
Chapter 20	Coating Defects
Panel Inspection	
Lunch	
Chapter 21	High Voltage and Low Voltage Holiday Testing Instrumentation
Chapter 22	High Voltage and Low Voltage Holiday Testing Instrumentation - Practice Lab
Review Hands On	
Chapter 23	Standards
Chapter 24	Safety
Chapter 25	The Coating Inspector’s Job
DAY SIX	
Course Review	
Course Exam	

Paul Knobloch Scholarship

Background

The Coating Inspector Program (CIP) Task Group (formerly ETC-40 Subcommittee and later the NICITCP Task Group) of PDC voted to establish an annual honoree scholarship entitled "The Paul Knobloch Scholarship".

The subcommittee chairman appointed a Scholarship Committee (now to be known as Scholarship Task Group) to develop recommendations related to such a scholarship. They are as follows:

Purpose

The Paul Knobloch Scholarship is a discretionary scholarship awarded on merit by the CIP Task Group in honor of one of their founding members, Mr. Paul Knobloch. Paul was generous with his time throughout the development of the CIP, and was a member of the committee that implemented the program. He was particularly interested in training development for individuals with a practical hands-on background.

Resolution

Be it hereby resolved that the Coating Inspector Program Task Group may offer an annual scholarship entitled "The Paul Knobloch Scholarship". A maximum of two (2) scholarships may be granted each calendar year solely at the discretion of the CIP Task Group. It is understood that the scholarship is not an official award of NACE International, but is offered in order to honor the efforts of Paul Knobloch on behalf of the Coating Inspector Program. Granting of such a scholarship shall be subject to the following rules.

Eligibility

- People who have successfully completed Level 1 of the Coating Inspector Program shall be eligible for the scholarship.

- Successful completion of each subsequent course (i.e., CIP Level 2) shall be the criterion for the continuation of the scholarship. Failure to achieve a passing grade in any examination shall terminate the scholarship award.

Scholarship Committee

Each year at the NACE Annual Conference, the Chairman of the CIP Task Group shall appoint a Scholarship Task Group. The Scholarship Task Group shall consist of three members with one being designated as Chairman. All three members must be CIP Task Group members.

Nominations

At the time the Scholarship Task Group is formed (NACE Annual Conference), nominations shall be considered for the scholarship. Nominations must be made in writing on the proper Nomination Form (example attached) and shall be submitted to the CIP Scholarship Task Group Chairman (c/o NACE Education Division).

The Scholarship Chairman shall maintain a list of nominations received.

The Scholarship Task Group shall review nominations for complete and accurate data. The Scholarship Task Group will not consider incomplete or inaccurate nominations.

The Scholarship Task Group will only consider information provided in writing on the proper forms. Information provided to the Task Group will not be disclosed to any third party, and shall remain confidential.

The Scholarship Task Group will consider all valid nominations, and will make their decision based on the criteria stated below. All decisions of the Task Group are final, and reasons for the selection will not be disclosed.

The Scholarship Task Group will submit the name of the recipient(s) to NACE and the CIP Committee within 30 days of the closing of nominations, unless otherwise determined by the chairman of the CIP Committee.

Criteria for Nomination

In making its decision, the Scholarship Task Group shall consider the following criteria:

- Financial need
- Leadership potential
- Technical knowledge
- Examination results in CIP Level 1. Successful completion of Level 1 is a mandatory requirement. The examination results achieved will be a contributory factor to any successful application.

Who May Nominate

Nominations must be jointly submitted by two persons, each of whom must be associated with the Coating Inspector Program, i.e., individuals currently holding NACE Coating Inspector-Level 3 Certification.

The Scholarship

The scholarship program shall consist of the following:

1. **Letter of Notification:** The recipient shall be officially notified of the receipt of the scholarship by letter from the CIP Committee Chairman.

2. **Certificate:** A certificate for the scholarship will be awarded to the recipient.

3. **Tuition:** The recipient shall be granted a scholarship to attend one (1) or two (2) eligible training courses as defined in item 4 below. The value of the scholarship shall consist of course registration fees only, at actual cost.

4. **Eligible Training Courses:** The scholarship may be applied to registration fees for any or all of the following, provided the candidate has not already successfully completed them:

    - Level 2
    - Peer Review

5. **Payment of Tuition Costs:** Registration fees shall be paid to NACE International, and not paid directly to recipient.

6. **Scholarship Tuition Fee Payment/Registration:** The scholarship recipient shall notify the NACE Education Division at least thirty (30) days in advance of the course offering which the recipient wishes to attend. The recipient shall be added to the class roster provided that the class is not fully booked.

    It shall be the responsibility of the recipient to make all other arrangements related to attendance at the course. These arrangements include, but are not limited to, transportation, lodging and meals.

Time Limit

The recipient shall make use of the provisions of the scholarship within two (2) calendar years of award of scholarship. Should recipient fail to make use of the scholarship within two years, the CIP Task Group may, at its own discretion, vote to extend the benefit period, or the recipient will be declared ineligible for further use of the scholarship.

If a scholarship recipient is unable to use the scholarship due to circumstances such as their work schedule, illness or lack of company support that might not permit its full use, they may make application to the CIP Task Group to postpone the award of scholarship. In such circumstances, the CIP Task Group may, at its own discretion, agree to extend the benefit period.

NOMINATION FORM FOR PAUL KNOBLOCH SCHOLARSHIP

Nomination guidelines and required information:

1. In order for a person to be eligible, a written nomination form and required documents must be submitted to the CIP Scholarship Task Group, c/o NACE Education Division.

2. Nominee must have successfully completed NACE International Coating Inspector Program Level 1.

3. A resume of work experience and education must accompany the nomination package. The Scholarship Task Group Chairman will verify Work experience.

This nomination requires that two (2) people complete the attached forms. They must both be associated with the Coating Inspector Program (subcommittee member, peer, instructor, or person holding NACE Coating Inspector Certification).

Please use the Submission CheckList to make certain that your nomination package is complete.

We hereby nominate the following person for consideration for the Paul Knobloch Scholarship as a result of outstanding performance in Level 1 of the NACE International Coating Inspector Program:

Nominee Name: _____

Address: _____

City, State, Country, and ZIP: _____

Telephone Number: _____

Fax Number: _____

E-mail Address: _____

Nomination Form for the Paul Knobloch Scholarship:

Submitted by:

Signature: _____

Date: _____

NACE Certified Coating Inspector-Level 3 Certification Number: _____

Signature: _____

Date: _____

NACE Certified Coating Inspector-Level 3 Certification Number: _____

Mail to:

CIP Knobloch Scholarship
Task Group
c/o NACE Education Division
1440 South Creek Drive
Houston, TX 77084-4906

For HQ Use Only

Level 1 Date: _____ Work Experience Verified:_____
Written Exam Grade:_____
Practical Exam Grade:_____
Logbook Grade: _____ _____
Level 2 Date: _____ Scholarship Task Group Chairman
Written Exam Grade:_____
Practical Exam Grade:_____

KNOBLOCH SCHOLARSHIP NOMINATION SUBMISSION CHECK LIST

Please use this form to be certain that you are forwarding a complete information package. Incomplete submissions will be returned to the nominators with a request that all items be submitted in one package.

_____ Nomination Form

_____ Information Form #1

_____ Information Form #2

_____ Scholarship Nominee Form

_____ Resume

INFORMATION FORM #1

Please answer the following based upon your knowledge of, or personal experience with the nominee, _____ (nominee's name):

1. The nominee's completion of Coating Inspection Certification will further the integrity or enhance the Coating Inspection Program because of the following reasons:

   A.

   B.

   C.

2. How would the Knobloch Scholarship aid this individual in receiving his/her certification:

Nominator #1:

Signature: _____

Date: _____

NACE Certified Coating Inspector-Level 3 Certification Number: _____

Telephone No.: _____ Fax Number: _____

E-mail Address:_____

Address: _____

City, State, Country, ZIP Code _____

INFORMATION FORM #2

Please answer the following based upon your knowledge of, or personal experience with the nominee, _____ (nominee's name):

1. The nominee's completion of Coating Inspection Certification will further the integrity or enhance the Coating Inspection Program because of the following reasons:

   A.

   B.

   C.

2. How would the Knobloch Scholarship aid this individual in receiving his certification:

Nominator #2:

Signature: _____

Date: _____

NACE Certified Coating Inspector-Level 3 Certification Number: _____

Telephone No.: _____ Fax Number: _____

E-mail Address:_____

Address: _____

City, State, Country, ZIP Code _____

FOR THE KNOBLOCH SCHOLARSHIP NOMINEE

Please give this page to the nominee. It must be completed and returned with the complete scholarship nomination package.

To the Knobloch Scholarship nominee:

If you were awarded the Knobloch Scholarship, how would this benefit you as an individual?

How will you use this scholarship to enhance the coatings industry as a whole?

Nominee Signature: _____

Print Name: _____

Address: _____

City, State, Country, Zip: _____

Phone/Fax: _____

E-mail address: _____

CIP Peer Review

Work Experience Assessment Procedure and Documentation

1. Two years of coatings-related work experience is required in order to take peer review. Completed work experience forms **must** be received at NACE Headquarters at least two months in advance of the date of peer review for verification and approval purposes. If you plan to take the peer review in the next year, it is to your benefit to complete and send the forms to NACE Headquarters as soon as possible.
2. At this time, there is no waiting period between CIP Level 1 and Level 2 courses. This means that:
   a. No matter how much or how little experience you have in the coatings industry, you can take CIP Level 1 and CIP Level 2 with no waiting period in between.
   b. You do not have to complete any work experience forms in order to attend the CIP Level 1 or Level 2 training courses.
3. Thirty-six (36) field-related work experience points are strongly recommended before you attempt to take the Peer Review to achieve Certification under the CIP. Peer Review is significantly more difficult without the field experience of 36 points.

How the Work Experience Assessment Procedure Operates

Your work experience documentation must provide documentation of field-related work experience points. Experience points are calculated on Form 2.

Only **coatings-related field work experience** (defined as coatings-related field work in a place where protective coatings are applied or inspected). Experience points are assigned as follows when the work experience has been uninterrupted:

Type of Coatings-Related Work Experience	Points Awarded Per Month of Uninterrupted Work Experience
Coating Inspection	2.0
Other Field Experience	1.5
Non-Field Experience	1.0

Points are not given for non-field coatings-related experience. The following lists, while neither definitive nor exhaustive, indicate what kinds of experience would and would not be considered **coatings-related field work experience**.

Accepted	Not Accepted
•Coating Inspector	•Laboratory technician without field-related responsibilities
•Paint Crew Foreman	•Specification writing without field-related responsibilities
•Industrial Maintenance Painter	•Protective coatings sales without field-related responsibilities
•Blast cleaning operator	
•Protective coating sales with field-related responsibilities	
•Site manager of coatings operation	

INTERRUPTED EXPERIENCE CALCULATION

When coatings-related work experience has been interrupted for two years or longer, the points awarded for the work experience prior to interruption are reduced, as follows:

Length of Interruption in Continuity of Coatings-Related Work	Factor for Reduced Points Awarded for Coatings-Related Work Prior to Interruption
Up to 2 years	No reduction factor
2 years to 3 years	80%
3 years to 4 years	70%
4 years to 5 years	60%
5 years and more	50%

For example: An applicant worked 24 months as a painter applying industrial maintenance coatings, then worked in a job not at all related to protective coatings for 2 years, then most recently worked 12 months as a coating inspector. The coatings-related total work points awarded are calculated as follows:

24 months x 1.5 points per month x 80%	=	28.8 points for work as a painter
12 months x 2.0 points per month x 100%	=	24.0 points for inspection work
Total Work Points	=	52.8

How to fill out the forms

Disregard of these instructions may seriously delay your application process. NACE cannot be responsible, and accepts no responsibility for delays caused by incomplete, inaccurate, or illegible information.

1. Carefully read these instructions, and look over the sample forms, before proceeding.
2. Read and sign the **attestation and affirmation pages**. These must be included with the work experience forms for them to be considered.
3. **Form 1: Summary of Protective Coatings-Related Work Experience**. This form is a summary, just as it is entitled. Complete, sign and date.
4. **Form 2: Individual Job Documentation**: You should complete one Form 2 for each job listed on the summary page (Form 1). Make as many copies as you need of Form 2 to document the 36 work experience points you need to attend the Peer Review. Write clearly and legibly or type the information. Be sure to include a brief description of the coating related responsibilities for each job at the bottom of each form. Write only on one side of each page. Sign and date each page.

   Notes:

   You must provide complete information. If you are self employed, provide names and addresses of specific individuals at major clients who can verify your work history.

   For the purpose of these forms, job is defined as a position in which you are regularly employed for a period of time. For those who work for a company who provides services to clients, you only need to list the company you are employed by, not the individual clients.
5. Make and keep a copy of the completed forms for your records.
6. Send the completed, signed, and dated forms to:

   NACE International – Education Div.
   Attention: Carol Steele
   1440 South Creek Drive
   Houston, TX 77084-4906 USA

   Phone: 281/228-6244
   FAX: 281/228-6344
   E-Mail: Carol.Steele@nace.org

   Note: Faxed, scanned and e-mailed documents are acceptable with signature. You do not need to return the instructions or sample pages, only your completed forms.
7. If you require assistance, contact NACE at the above address or phone.

Forms must be received at NACE Headquarters not less than 60 days from the first day of the Peer Review you plan to attend to allow time for the verification and approval process to be completed.

S A M P L E

Form 1: Summary of Protective Coatings-Related Work Experience

Applicant Information:

Your Name: A. Sample Phone: 409/111-4321

Current Employer: ZZZ Coating Inspection Inc. Fax: 409/111-1234

Address: 987 Gage Avenue E-mail:

City: Millspec State/Province: TX

Zip/Postal Code: 77987 Country: USA

Please summarize below the information on each copy of Form 2, Individual Job Documentation. List your experience beginning with the most recent, followed by less recent experience.

From Month/Year	To Month/Year	Number of months in this job	Points for this job	Job Title	Company Name
1/92	1/95	36	72	Coating Inspector	ZZZ Inspection Inc.
12/89	12/91	24	36	Painter	AAA Painters
12/87	12/89	24	36	Helper	AAA Painters
/	/				
/	/				
/	/				
/	/				
/	/				
/	/				
/	/				
		TOTAL POINTS:	144		

SAMPLE

Applicant Affidavit: I understand that if I knowingly provide false information in connection with my recognition under this program, it will be grounds for disciplinary procedures.

Signed: XXX Date: XXX

S A M P L E

Form 2: Individual Job Documentation

Use one of these forms for each job; that is, each period of work experience you wish to document. Note that for this form, ***job*** is defined as ***a position in which you are regularly employed for a period of time***. Make and use as many copies of this form as you need. Please provide all information requested in the form.

JOB INFORMATION:

Job Title: Painter

AAA Painters

From: Month 1 Year 92

To: Month 1 Year 95 (present)

Who can NACE contact to verify this experience?

Name: Bob Roberts

Company: AAA Painters

Address: 123 Coating St.

City: Paintersville

State/Province: TX Zip/Postal Code 77123

Country: USA

Phone: 409/123-4567

Fax: 409/123-7654

SAMPLE

WORK EXPERIENCE POINT CALCULATION:

a. Number of months in this job: 24

b. Experience Points (check one):

☐ Field, coating inspection (2 points)

☒ Field, other than inspection (1.5 points)

☐ Non-field experience (1.0 points)

Write the point value here: 1.5

c. Points for this job

Multiply a. (number of months) by b. (experience points).

Write results in this box: 36

Describe in detail what are/were your specific coatings-related duties in this job. NOTE: Do not write on the back of this form, attach additional sheets if necessary, writing only on one side of each page.

LIST COATING RELATED JOB DUTIES IN THIS AREA

Experience with conventional airspray and airless spray equipment. Responsible for making sure that equipment was set up right, and cleaned up at end of day.
Responsible for correctly applying the coating as directed by supervisor. Took wet-film readings as directed.
Worked mainly on offshore structure during this time, but also had a couple of projects in refineries.
Applicant Affidavit: I understand that if I knowingly provide false information in connection with my certification under this program, it will be grounds for disciplinary procedures.

Signed: XXX_____ Date: XXX_____

Form 1: Summary of Protective Coatings-Related Work Experience

Instructions: Make and use as many copies of this form as needed. Please provide all information requested. Forms must be printed legibly in black ink or typed. Illegible information can delay the application process. For assistance with this form, contact the Education Division at NACE International Headquarters.

Applicant Information:

Your Name: _____ Phone: _____

Current Employer: _____ Fax: _____

Address: _____ Email: _____

_____

City: _____ State/Province: _____

Zip/Postal Code: _____ Country: _____

Please summarize below the information on each copy of Form 2, Individual Job Documentation. List your experience beginning with the most recent, followed by less recent experience.

From Month/Year	To Month/Year	Number of months in this job	Points for this job	Job Title	Company Name
/	/				
/	/				
/	/				
/	/				
/	/				
/	/				
/	/				
/	/				
/	/				
/	/				
		TOTAL POINTS:			

Applicant Affidavit: I understand that if I knowingly provide false information in connection with my certification under this program, it will be grounds for disciplinary procedures.

Signed: _____ Date: _____

Form 2: Individual Job Documentation

Use one of these forms for each job; that is, each period of work experience you wish to document. Note that for this form, ***job*** is defined as ***a position in which you are regularly employed for a period of time***. Make and use as many copies of this form as you need. Please provide all information requested in the form.

JOB INFORMATION:

Job Title: _____

_____

From: Month _____ Year _____

To: Month _____ Year _____

Who can NACE contact to verify this experience?

Name: _____

Company: _____

Address: _____

_____

_____

City: _____

State/Province: _____

Zip/Postal Code _____

Country: _____

Phone: _____

Fax: _____

Email: _____

WORK EXPERIENCE POINT CALCULATION:

a. Number of months in this job: ☐

b. Experience Points (check one):

☐ Field, coating inspection (2 points)

☐ Field, other than inspection (1.5 points)

☐ Non-field experience (1.0 points)

Write the point value here: ☐

c. Points for this job

Multiply **a.** (number of months) by **b.** (experience points).

Write results in this box: ☐

<u>BRIEFLY DESCRIBE</u> what are/were your specific <u>coating-related</u> duties in this job. Your application will NOT be accepted if this section is not completed. NOTE: Do not write on the back of this form. Attach additional sheets if necessary, writing only on one side of page.

Applicant Affidavit: I understand that if I knowingly provide false information in connection with my certification under this program, it will be grounds for disciplinary procedures.

Signed: _____ Date: _____

PRINTED NAME:_____

I affirm that:

1. I understand that I am **solely** responsible for making sure that all necessary work experience documentation is completely submitted in good order to, and on hand at NACE Headquarters not less than 60 days prior to the first day of the Peer Review I wish to attend, and that failure to do so may result in my not being able to take the Peer Review.
2. I understand that if I knowingly provide, or cause to be provided, any false information in connection with my recognition under the NACE International Coating Inspector Program, that it will be grounds for action against my standing in the program.
3. It is the responsibility of the individual to complete the renewal or update process, and to notify NACE International of address changes. Each level successfully completed expires on the date noted on the wallet card issued (or three years from the completion date). Failure to receive notices from NACE does not alleviate the individual's responsibility to contact NACE to complete the renewal or update process.
4. With respect to the Peer Review examination;
   a. I understand that passing the Peer Review examination is significantly more difficult than passing any of the training courses and that successful completion of the training courses does not guarantee successful completion of the Peer Review examination. I also understand that in the event that I do not pass the Peer Review examination I must wait not less than one week before making a second attempt.
   b. I understand that in the event that I fail the Peer Review examination twice, I must wait not less than six months before a third or additional retake, and that any person who fails the second or subsequent attempts must wait a minimum of six months between additional attempts.
5. I understand that the names of the categories within the NACE International Coating Inspector Program are as follows:

Highest Level Successfully Completed	**Category Title**
CIP Level 1	NACE Coating Inspector Level 1—Certified[1]
CIP Level 2 (must also have CIP Level 1)	NACE Coating Inspector Level 2—Certified[2]
CIP Level 2 – Maritime Emphasis (must also have CIP Level 1 or approved documentation on file)	NACE Coating Inspector Level 2 – Marine Certified[3]
CIP Levels 1, 2 (standard or maritime) and Peer Review Examination	NACE Certified Coating Inspector—Level 3

[1]The NACE Coating Inspector Level 1 – Certified person is qualified to undertake basic coating inspection of structural steel using nondestructive techniques and instrumentation under the supervision of a NACE Certified Coating Inspector – Level 3. The person certified at this level has basic knowledge of coating materials and techniques for surface preparation and application on steel substrates.

[2]The NACE Coating Inspector Level 2 – Certified person is qualified to perform advanced coating inspections using both nondestructive and destructive techniques and instrumentation. The person certified at this level has sufficient knowledge of specialized coating materials and techniques for the surface preparation and application used on a wide variety of substrates. He/she also has ample knowledge in advanced report writing, condition surveys, failure analysis, and refurbishment.

[3]The NACE Coating Inspector Level 2 – Marine Certified person is qualified as stated above as well as the skills and knowledge required to correctly address the inspection requirements of the International Maritime Organization's (IMO) Performance Standard for Protective Coatings (PSPC).

6. NACE has a firm policy regarding the use of its logos and certification numbers and titles. The certification number and category title may be used only by individuals who are NACE Coating Inspector Level 1—Certified, NACE Coating Inspector Level 2—Certified, or NACE Certified Coating Inspector—Level 3 and may not be used by any other persons. All active CIP card holders are permitted to use the term ***NACE Coating Inspector Level 1—Certified***, ***NACE Coating Inspector Level 2—Certified***, or ***NACE Certified Coating Inspector—Level 3*** (whichever level of certification is attained), and their certification number on business cards. This example illustrates how this information can be used someone who has achieved the status of **NACE Coating Inspector Level 1—Certified**:

John Smith
NACE Coating Inspector Level 1—Certified, Cert. No. 9650
ACE Inspections, Inc., Knoxville, TN

Those who have achieved any level of certification and who are members in good standing of NACE International may display the NACE Logo for the purpose of identifying the individual as having achieved NACE certification.

I understand that violation of these rules will result in action against my standing in the program on the basis of violation of the NACE International Coating Inspector Program Attestation.

7. I (re) affirm the NACE International Coating Inspector Program attestation and agree to abide by its provisions as long as I hold any level of certification under the program.

Signature:_____ Date:_____

ATTESTATION: Requirements for certification under the NACE International Coating Inspector Program include the signing of the following Attestation. In order to maintain your certification as a NACE International Coating Inspector, you must, on an ongoing basis, fully comply with the NACE International Coating Inspector Program Code of Professional Conduct and the standards contained in this Attestation. Failure to fully comply with the Code of Professional Conduct and/or the Attestation constitutes unprofessional conduct and is a sufficient reason for a reprimand, suspension, revocation, or for the denial of the initial certification or recertification, which will be determined at the sole discretion of NACE.

I, the undersigned, recognize and acknowledge that:

1. Proper coating inspection can be critical to the safety and welfare of the general public and industrial facilities.
2. Coating inspection is obligatory to maximize conservation of our material resources and to reduce economic losses.
3. The entire field of coatings encompasses many diverse skills and disciplines and level of technical competence which must often be taken into consideration.
4. Through continual association and cooperation with others in the coatings field, the safest and most economical solutions may be found to many types of coating problems.
5. The quality of work and personal conduct of each coating inspector reflect on the entire profession of coating inspection.

Therefore, I hereby agree to:

1. Give first consideration in my coating inspection work to safety and public welfare.
2. Apply myself with diligence and responsibility to my coating inspection work.
3. Pursue my work with fairness, honesty, integrity, and courtesy, ever mindful of the best interests of the public, my employer and my fellow workers.
4. Not represent myself to be proficient or make recommendations concerning coatings-related work for which I am not qualified by knowledge and experience.
5. Avoid and discourage untrue, sensational, exaggerated, or unwarranted statements regarding my work.
6. Treat as confidential my knowledge of the business affairs or technical processes of clients, employers, or customers.
7. Inform clients or employers of any affiliations, interests, or connections which might influence my judgment.
8. Accept no money gratuities of any kind or other gratuities whose value could cause a question as to whether they may have influenced my inspection activities, decisions, or reports.
9. Be fair, reasonable, and objective in my work, not allowing myself to be influenced by personalities or other individual considerations.
10. Completely, accurately, and honestly fulfill the reporting requirements of the specifications for any coating operation I may be responsible for inspecting.
11. Take it upon myself to determine from my superiors the scope of my authority and work within it.
12. Ensure, to the best of my ability, that the terms, language, and requirements of the coating specification are clearly understood and agreed to by all parties involved.
13. Strive to obtain the best possible results under given conditions within a given coating specification.

I hereby agree to uphold and abide by the NACE International Coating Inspector Program Code of Professional Conduct and the standards contained in this Attestation as an applicant under this Program, and so long as I am a participant in the NACE International Coating Inspector Program. I understand that failure to fully comply with the Code of Professional Conduct and/or the Attestation will be deemed to constitute unprofessional conduct and is a sufficient reason for a reprimand, suspension, revocation, or for the denial of the initial certification or recertification, which will be determined at the sole discretion of NACE.

Signature:_____ Date:_____

Printed Name:_____

Coating Inspector Program Level 1

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Chapter 1: Introduction

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- NACE policy regarding logos, titles, and certification numbers
- NACE Coating Inspector Program (CIP) update and renewal programs
- Classroom policies
- Examinations

This module will close with classroom introductions and a team exercise.

1.1 NACE International Coating Inspector Program

The NACE CIP is composed of two training sessions and a peer review. The training sessions must be taken in sequential order. A minimum of two year's work experience in coatings, whether done prior to, during, or after attending the training sessions, is required before any candidate can register for the Peer Review examination. In other words:

- No prior knowledge is required to take the CIP Level 1 training session
- Successful completion of each level is required to move on to the next level
- Two year's work experience is required before Peer Review

Upon successful completion of CIP Level 1, CIP Level 2, and the Peer Review, the candidate will become a NACE Certified Coating Inspector─Level 3.

1.2 Introduction

The intended service life of a corrosion protection system represents the engineered economic value of that system by providing protection for an asset (i.e., ship, bridge, power plant, oil rig, etc). The selection of a particular corrosion protection system is typically a function of economic, operational, environmental, and safety issues.

Inspection during the coatings system installation is used as a tool to ensure that the system is installed within the intended design parameters. This mission is accomplished through emphasis on industry practices, standards and training.

1.2.1 Economy — Value

The life of any coating system on a steel substrate depends significantly on the quality of the surface preparation. Smooth welds, radius edges and clean surfaces all contribute to a longer service life for installed coatings.

The level of effort required to prepare the steel substrate properly has an associated increase in fabrication costs. The initial cost to prepare the surface properly is completely outweighed by the benefits (i.e., long-term cost savings and lengthened service life) of a properly installed coating system. Extensive down-time for repairs and re-coating are minimized, thus providing maximum utilization of the asset for its intended service and revenue generation lifetime.

1.3 Course Overview

The NACE CIP is an intensive and extensive training program; Level 1 is the more intensive of the two courses. It is designed to accommodate the inexperienced candidate. Students with prior experience may well exceed some of the stated capability and intent of this course. However, both the inexperienced candidate and competent basic inspector will benefit from the structured training presented in this course. Upon successful completion of CIP Level 1, participants will have demonstrated the ability to undertake basic coating inspection work.

For those inspectors wishing to become a NACE Certified Coating Inspector─Level 3, this training course is the first of two that must be successfully completed. The program for this training course covers many topics including:

- Corrosion
- Team building
- Role of the inspector
- Environmental testing
- Coatings fundamentals
- Coatings types and curing mechanisms
- Coating project specifications
- Surface preparation
- Surface preparation instrumentation
- Pre-job conference
- Inspection project documentation
- Coatings application
- Film thickness measurement instrumentation
- Product technical data sheets and Material Safety Data Sheets (MSDS)
- Coatings defects
- High voltage and low voltage holiday testing instrumentation
- Additional standards
- Safety

There will be several hands-on practice labs in which students can get the feel of the different tools and techniques of the coating trade and understand ***exactly*** what it takes to do the job right. As part of the exercise, students will work with the basic tools and techniques of coating inspection, including:

- Surface preparation inspection
- Use of replica tape
- Use of written surface cleanliness standards, pictorial standards, and visual comparators
- Measurement of wet- and dry-film thickness

Students must also keep good records in a logbook of all tests performed; this is a part of the final grade.

1.4 NACE Policy: Use of Logos, Titles and Certification Numbers

NACE has a firm policy regarding the use of its logo and certification numbers and titles. The certification number and category title may be used only by individuals who are NACE Coating Inspector Level 1─Certified, NACE Coating Inspector Level 2─Certified, and NACE Certified Coating Inspector─Level 3 and may not be used by any other persons.

Individuals who are NACE Coating Inspector Level 1─Certified, NACE Coating Inspector Level 2─Certified, or NACE Certified Coating Inspector─Level 3 Certified and are members in good standing of NACE International may display the NACE Logo

for the purpose of identifying the individual as having achieved NACE certification.

All active CIP card holders are permitted to use the terms "NACE Coating Inspector Level 1 ─ Certified," "NACE Coating Inspector Level 2 ─ Certified," or "NACE Certified Coating Inspector ─ Level 3" (whichever level of certification attained) and their certification number on business cards. The following example illustrates how this information can be used by an individual who is NACE Coating Inspector Level 1 ─ Certified.

John Smith

NACE Coating Inspector Level 1 ─ Certified

Cert. No. 9650

ACE Inspections, Inc., Knoxville, TN

This example illustrates how this information can be used by a NACE Coating Inspector Level 3─ Certified.

John Smith

NACE Certified Coating Inspector ─ Level 3

Cert. No. 9650

ACE Inspections, Inc., Knoxville, TN

1.5 CIP Update and Renewal Programs

Update or renewal of NACE CIP certification must be completed every three years.

The **Update Program** applies to individuals who have not passed Peer Review. The update process can be accomplished by one of two methods:

1. Attendance at the next Coating Inspector Program course or Peer Review
2. Completion of a home study program

If a student takes another CIP within a three-year period, the date of the next required update will be three years from the date the most recent course was completed.

The **Renewal Program** applies to Level 3 inspectors. The renewal process can be completed by one of three methods, depending on the number of work experience points accumulated in the three years since passing Peer Review, or from the last renewal:

1. 73+ points requires only work experience
2. 37 to 72 points requires work documentation and completion of a home study program
3. 36 or fewer points requires work experience documentation and class attendance with successful completion of CIP Level 2 at a regularly scheduled offering

Work experience documentation forms and instructions for completing the forms are located at the back of this manual.

It is important that certification holders maintain a current address on file with NACE, because they will be notified of the update/renewal process by mail 90 days prior to the expiration date. The notification packets supply all the information and forms required to begin the update or renewal process. It is vital that students keep address and all contact information current with NACE.

1.6 Classroom Policies

To provide the best environment for training, certain policies must be maintained. Please observe the following requirements:

- No smoking or other tobacco products
- Class starts at designated times

- Participants are responsible for their own learning and for timekeeping
- Please turn off audible mobile phone ring tones, and do not make or answer calls, text, or tweet while in the classroom
- Designated lunch breaks, coffee breaks, smoke breaks are scheduled
- Designated toilet location(s), smoking location(s) are specified

1.7 Examinations

At the end of the week, there are two final examinations: one written and one a hands-on practical examination covering selected test instruments. Both exams must be passed with a minimum grade of 70%. Additionally, students must receive a minimum of 70% on the logbook (written legibly in ink) in order to pass Level 1.

1.7.1 Written Exam

The written exam is closed book and consists of 125 multiple-choice questions. It lasts 2 hours.

1.7.2 Practical Exam

The practical exam covers the tools and techniques for inspection. Students are required to demonstrate how well they know how to perform the coating inspection tests covered in this course. Tasks are assigned to each student, who is then required to record the results. The grade is based on the accuracy of those recorded results. Eight inspection tools and 8 minutes are allowed at each work station.

To help prepare for the practical exam, the course includes lectures, practical labs, and practice sessions using the basic inspection tools and techniques listed in Level 1.

During the course, short, written, closed-book quizzes are given to help students prepare for the final written exam.

Written notification of exam results are processed as quickly as possible. Exam results are not available on exam day. The following is essential information about exam results:

- Exams are electronically marked by a computer at NACE HQ.
- Written notification of exam results are mailed from NACE within 2 to 3 weeks.
- Exam results are made available on the internet at www.nace.org. Access requires a password and course ID number.
- PLEASE DO NOT CALL NACE HQ for exam results! NACE staff are NOT ALLOWED to give out this information by telephone.

1.8 Introductions

Before going further, it would be beneficial to learn more about each other. Please stand one at a time and introduce yourself to the class. Tell us your:

- Name
- Company's name and location
- Job function
- Experience in coating inspection
- Hobbies

1.9 Team Formation Exercise

NACE believes that the coating inspector's job is part of a team effort with others involved in the coating project. We will form teams that reflect a cross-section of the industries represented in this class. Since the teams will work together throughout the course, we will change the seating arrangement so team members can sit together.

At the end of the course, the lead instructors will review students' expectations and reservations to see how well the course fulfilled expectations and, hopefully minimized any reservations.

Since the teams will work throughout this session on a wide variety of tasks, exercises and assignments, please get together with your team now and do the following:

- **Team name**: Decide on a name to represent who you are, tell how you intend to perform during the workshop, and give the team a personality.
- **Reason for team name**: Select the team name for a specific reason, i.e., do not just give the team an arbitrary name. Think it through carefully. Be prepared to report the reasons to the class when this exercise is completed.
- **Team logo**: Create a team logo or trademark that graphically represents the team name and the rationale behind it.
- **Expectations and reservations**: As a team, develop a list of expectations and reservations about the course.

On a flip chart, summarize the results from this exercise, select a spokesperson to deliver a five minute presentation to the class. Teams have 20 minutes to complete the this work.

1.10 Additional Resources

1.10.1 NACE Corrosion Network

The NACE Corrosion Network is an active message board with members from around the world who work in the corrosion prevention industry. You must sign up as a member at www.nace.org

1.10.2 Technical Committees

More than 1,000 NACE members participate in technical committee activities. The committees are led by the **Technical Coordination Committee** (**TCC**), which serves as the administrative and policy-making body.

The technical committees are organized by **Specific Technology Groups** (STGs). STGs are assigned specific technical areas within three administrative classes:

- Industry-Specific Technology (N)
- Cross-Industry Technology (C)
- Science (S).

Technology Management Groups (TMGs) are formed under the TCC to provide a structure and a conduit for communication between the TCC and the various STGs within their respective areas. They provide assistance, when necessary, to help STGs achieve their objectives.

1.10.3 Standards and Reports

NACE Standards are prepared by the Association's technical committees to serve as voluntary guidelines in the field of prevention and control of corrosion. These standards are prepared using consensus procedures. NACE offers its standards to the industrial and scientific communities as voluntary standards to be used by any person, company, or organization. Standards are free to NACE members.

A Technical Committee Report is a limited-life document developed by a Technical Committee. Typical categories for committee reports are:

- State-of-the-art reports dealing with the current science and technology of a method, technique, material, device, sys-

tem, or other aspect of corrosion control work

- Informational reports that can be statements on a specific problem (summarizing its ramifications, controversial points, and possible solutions), surveys of common practices, bibliographies on special subjects, etc.

Reports are free to NACE members.

1.11 Disclaimer

Attendees of this course are hereby advised that NACE International's view on in-process inspection with respect to an inspector is to "inspect and document" the functions described. The inspector must always work solely within and abide by the job description and documents governing responsibilities and authority granted by management.

Be advised that students fulfilling the requirements of this course, with its qualifying terminology, understand and accept the fact that NACE International does not state, affirm, imply, endorse, or otherwise by any action, express or implied, indicate that the use of the words *ensure and/or enforce* neither intends to convey any meaning of guarantee nor assumes any responsibility for the adequacy of work inspected and documented by the inspector.

Chapter 2: Corrosion

Objectives

When this module is complete, the training candidates will have knowledge and understanding of:

- Basic Corrosion
- Types of Corrosion
- Effects of Corrosion
- Corrosion Control
- Corrosion Control Programs

Key Trade Terms

- Corrosion
- Passivation
- Corrosion Cell
- Anode
- Cathode
- Return Path
- Electrolyte
- Mill Scale
- Galvanic Series
- Generalized Corrosion
- Localized Corrosion
- Pitting Corrosion
- Crevice Corrosion
- Corrosion Inhibitor
- Cathodic Protection

2.1 Corrosion and Corrosion Control

2.1.1 Corrosion

Corrosion is usually described by its results. Familiar terms include rust, scaling, discoloration, oxidation, pitting, etc. These descriptive terms focus on the readily-observable characteristics of the corrosion products — the results of the corrosion process. The actual process of corrosion is less noticeable and was not accurately characterized until the early 20th century. Research is still conducted to increase understanding and better arm inspectors in the battle to control corrosion. Knowledge of the corrosion process is necessary to properly identify and deal with its outward effects.

The corrosion process acts on engineered materials, usually metals. Engineered materials are produced to serve as components of society's infrastructure. For the purpose of this discussion, steel is the most common material used in construction. Steel, in turn, is composed principally of iron (Fe). Steel contains approximately 95% iron. Most economically significant corrosion in the industry is the result of deteriorating iron. While steel contains elements other than iron, some of which dramatically impact corrosion resistance, these are ignored in this discussion of the basics.

2.1.2 Definition

The corrosion process involves the deterioration of a substance, usually a metal, or its properties because of a reaction with its environment.

This definition is very broad and recognizes that materials other than steel, such as wood, concrete, and plastics, are also subject to corrosion. Because the underlying processes of non-metallic corrosion are fundamentally different than metallic corrosion,

for purposes of clarity, they are not addressed in this course.

In essence, corrosion processes (Figure 2.1) change the iron in steel to another substance that no longer has the desired properties (i.e., strength, toughness).

The most common product of corrosion is an oxide of iron ("rust" or iron oxide) formed by the addition of oxygen. Iron oxide has few desirable properties for use as an engineered material. Iron oxide produced in the corrosion process consumes the metal. The volume of metal (and its thickness) is eventually reduced to a point where a structural component made of steel is not able to perform the function for which it was designed.

Corrosion is the reverse process of steel manufacturing (Figure 2.2). Steel is made in the steel mill when an ore (commonly iron oxide) is subjected to a large amount of energy to extract the iron from the ore. The resulting product is naturally unstable, so when the right conditions occur, the iron converts back to the more stable iron oxide. Identifying and controlling the corrosion process (corrosion control) is much easier when it is understood:

- How metals corrode
- How fast they corrode
- Factors that tend to increase or decrease the rate of corrosion

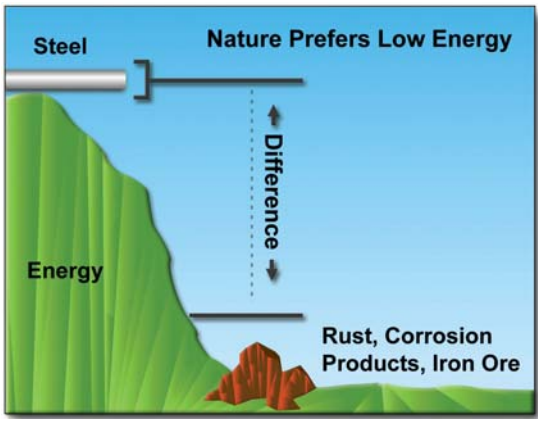

Figure 2.1 Energy Mountain for Iron

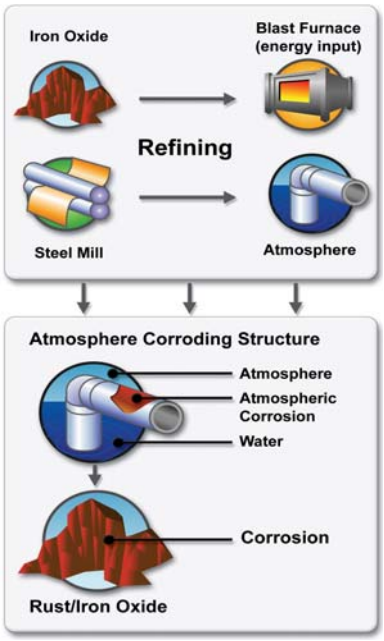

Figure 2.2 Life Cycle of Iron in Steel

Steel is not the only engineered metal used in construction; others commonly used include:

- Copper
- Brass
- Zinc (i.e., as the coating on galvanized steel)
- Aluminum
- Nickel

- Chromium (as a major element in “stainless” steel)

The corrosion of these metals follows the same principles described in the next section; however, corrosion may proceed at slower rates. The slower corrosion rate of these metals is often due to the production of a tightly adherent surface layer formed from the corrosion product (oxide, carbonate, chloride, sulfate, or another compound).

The formation of this surface layer, while relatively thin, can form an effective barrier against further attack, and thus slow the rate of the corrosion process. This phenomenon is known as **passivation**. Unfortunately, in offshore environments, iron alone does not form such a barrier.

2.1.3 Corrosion as an Electrochemical Process

All corrosion of iron at normal ambient conditions is an electrochemical process. Simply put, this means that ions and electrons transfer across a surface which implies the generation of a current (corrosion current). Both electrons (through a metallic conductor) and ions (through an electrolyte) carry the corrosion current.

Corrosion is established as direct current (DC) circuits. DC circuits are defined by the relationship called Ohms Law:

E=IR

- Where “E” is the driving voltage of the circuit
- “I” is the current magnitude
- “R” is the resistance of the circuit

The greater the current flow in the corrosion circuit, the greater the metal loss.

2.1.4 The Corrosion Cell

Figure 2.3 illustrates the corrosion process by comparing it to an ordinary dry-cell battery, which depends on galvanic corrosion to generate electrical power. Note that the four elements listed below are present in the battery:

- An electrolyte (moist ammonium chloride and zinc chloride)
- A negative electrode (zinc case), which corresponds to the anode in a corrosion cell
- A positive electrode (carbon, i.e., graphite), which corresponds to the cathode in a corrosion cell
- A conductive wire, which corresponds to a metallic pathway in a corrosion cell

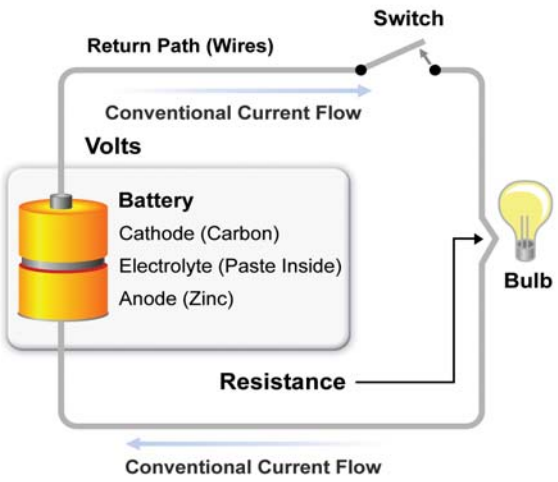

Figure 2.3 Dry-Cell Battery Schematic

These same four elements are shown in Figure 2.4 in the corrosion cell.

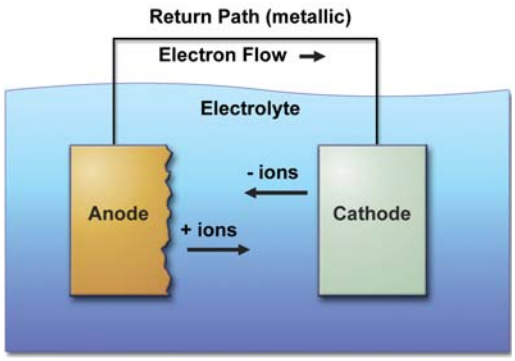

Figure 2.4 Corrosion Cell

In order for corrosion to occur, certain conditions and elements are essential. These are collectively referred to as the ***corrosion cell*** and include:

- Anode
- Cathode
- Metallic pathway (or external conductor)
- Electrolyte

2.1.4.1 Anode

The **anode** is that part of the metal that corrodes (i.e., dissolves in the electrolyte). The metal that dissolves does so in the form of positively charged ions. The electrons generated are conducted to the cathode. Metal deterioration occurs at the anode. It is the portion of the cell where metallic iron is first converted to another substance. The anode represents the location on the metallic surface where oxidation takes place. The metal is transformed into positively charged ions (cations). During oxidation, excess electrons are generated.

> Oxidation requires a complementary reaction at the cathode.

2.1.4.2 Cathode

The **cathode** is the more noble region on the electrode (metal surface, or in the battery analogy, the carbon rod) where the electrons are consumed. The electrical reaction continues at the cathode, which is said to be positive, the opposite of the anode. The reaction generally ionizes the electrolyte to form species such as hydrogen (released as gas) and hydroxyl ions. These often combine with the dissolved metal to form compounds, such as ferrous hydroxide (in the case of iron or steel), subsequently reacting further to become iron oxide or rust.

While oxidation occurs at the anode, reduction occurs at the cathode. Excess electrons generated at the anode are consumed at the cathode. Oxidation-reduction always occurs together — there cannot be just oxidation or just reduction. The anode and cathode have different potentials, creating a “voltage” difference between them. Potentials are a function of the chemical and physical states. The potential difference is the driving force for the corrosion process.

2.1.4.3 Return Path (Metallic Pathway)

The **return path** connects the anode and cathode and allows passage of electrons, generated at the anode, to the cathode. When corrosion takes place on a metal surface there is always a metal pathway joining the anode (or anodic areas) to the cathode (or cathodic areas). If there were no metallic pathway, the corrosion reaction could not take place.

2.1.4.4 Electrolyte

An **electrolyte** is a medium that conducts ionic (rather than electronic) current. The majority of electrolytes are based on water

and, in practice, the electrolyte contains ions, which are particles of matter that carry a positive or negative charge. In order for the oxidation and reduction reactions to proceed, a pathway is required to transport ions (negatively and positively charged species called anions and cations, respectively) between the anode and cathode. The electrolyte must be present to "close the loop" in the corrosion cell. The corrosion current is carried by ion transport through the electrolyte. Anions are attracted to the anode and cations to the cathode, where they may combine with the products of oxidation and reduction.

Summary

All four of the above components (anode, cathode, return path, and electrolyte) must be present for corrosion to occur. Removing one or more of them prevents corrosion from occurring. As you can imagine, it is not always possible or practical to remove these components, but the attempt to remove them is called **corrosion control**. On most structures, the anode and cathode can be at different locations, the structure itself is the return path, and water serves as the electrolyte.

2.1.5 Corrosion on Steel Structures

When a steel structure corrodes, all four elements of the corrosion cell are present. Steel conducts the electrical current and provides the metallic pathway, which generates many anodic and cathodic areas due to (electrical) potential differences and then corrodes when it comes into contact with an electrolyte.

Chemical salts dissolved in electrolyte increase the efficiency (rate) of the corrosion reaction. Steel conducts electricity, and thus provides its own metallic pathway between the anodic and cathodic areas on its surface. Since steel is not a perfectly uniform or homogeneous metal, a single steel plate can have many tiny anodic and cathodic areas on its surface as shown in Figure 2.5.

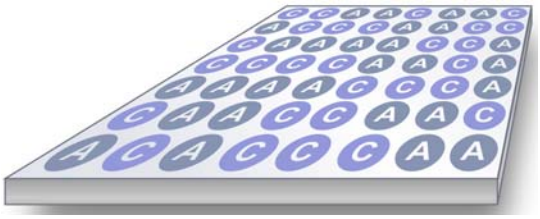

Figure 2.5 Anodes and Cathodes On the Steel Surface – Varying Potentials

The anodic and cathodic areas form from areas on the surface of the plate that differ (perhaps only slightly) from each other in their electrical potential. Therefore, steel already has three of the four elements necessary to create a corrosion cell. The same conditions exist in most other metals.

When a bare steel plate becomes wet from dew or rain, the water can act as an electrolyte. If the plate is exposed to the atmosphere, chemicals in the atmosphere or on the surface of the plate are likely to combine with the water to form a more efficient electrolyte on the surface of the plate.

Pure water is a very poor electrolyte, but if chemical salts (e.g., sodium chloride in a marine environment) are present, they are available to dissolve in the water, creating an electrolyte that becomes more efficient as the concentration of the dissolved chemicals increases.

Salt (sodium chloride) is present in the marine environment, in water produced in oil and gas production and refining, and in the road deicing salts used on many highways in the northern hemisphere. Other common chemical salts include sulfates

derived from sulfurous industrial combustion products.

Corrosion Cells

The corrosion reaction (Figure 2.6) can occur in an area smaller than a pin point. A steel surface with many corrosion cells may look like it is rusted uniformly over its entire surface.

If anodes and cathodes remain in the same place for a period of time, the corrosion is localized, and pitting corrosion occurs. When a pit forms, the corrosion cell becomes localized and fixed within the pit, accelerating the rate of corrosion at that specific point. The result is often penetration of the pitted area through the metal.

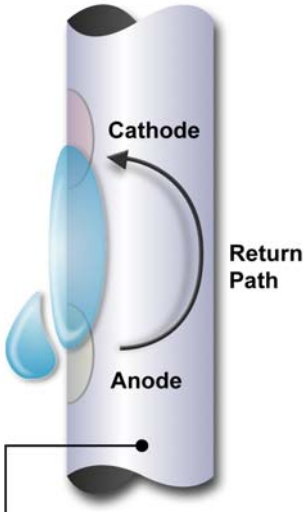

Figure 2.6 Corrosion Cell Example

2.1.6 Mill Scale

Corrosion may be encouraged on a steel surface by the presence of mill scale. Mill scale (Figure 2.7) can be seen on the surface of new iron and steel in the form of blue-black layers of iron oxide, some of which are harder than the parent metal. The mill scale is electrically positive relative to the iron or steel, so it is cathodic to the parent metal. A corrosion cell is set up in the presence of moisture, and the cathodic mill scale promotes corrosion at the anodic bare steel areas. Mill scale is:

- A blue-black layer of iron/iron oxide
- Cathodic relative to substrate
- Generally removed prior to painting

Figure 2.7 Mill Scale

This is one very important reason to remove mill scale from steel surfaces before coatings are applied. No one wants to encourage corrosion on the surface, or to cover active corrosion cells with the coating film.

2.1.7 Galvanic Series

A **galvanic series** (Figure 2.8) is a list of materials in order of their corrosion potentials, with the most easily corroded, or most active, at the top, and the least easily corroded, or least active, at the bottom.

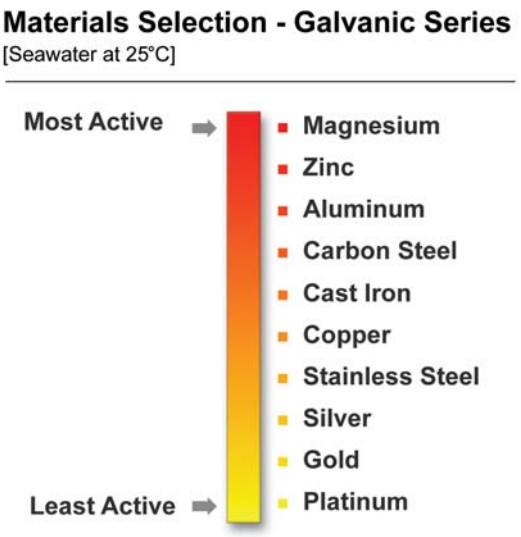

Figure 2.8 Galvanic Series

By convention, it is said that the more active metals have negative corrosion potentials, and are often referred to as anodic. The less active metals are often referred to as cathodic or noble.

The general rules of galvanic (dissimilar metal) corrosion are listed below:

- When dissimilar metals are connected, the most active (or anodic) metal corrodes more rapidly, while the more noble (least active or cathodic) metal is better protected and corrodes less rapidly
- As the potential difference between these two dissimilar metals increases, the rate of galvanic corrosion increases
- Corrosion rates increase as potential differences between metals increase

If, for example, zinc, which is fairly active, is electrically connected to platinum, which is fairly inactive, in the presence of a suitable electrolyte, the zinc is very heavily attacked.

Some metals, such as gold or platinum, corrode very slowly or not at all, so choosing a corrosion-resistant material can help reduce the rate of corrosion. Changes in ambient conditions or temperature, however, can affect the order of the galvanic series.

2.1.7.1 Factors that Affect the Rate of Corrosion

Corrosion rates are determined by a variety of factors, some of them quite complicated. However, five factors do play an overwhelmingly important role in determining corrosion rates. These factors are:

1. **Oxygen**: Like water, oxygen increases the rate of corrosion. Corrosion can take place in an oxygen-deficient environment, but the rate of the corrosion reaction (and destruction of the metal) is generally much slower. In immersed conditions, if an electrolyte is in contact with one area of metal containing more oxygen than the electrolyte in contact with another area of the metal, the higher oxygen-concentration area is cathodic relative to the remaining surface. An oxygen concentration cell then forms, which results in rapid corrosion.
2. **Temperature**: Corrosion reactions are electrochemical in nature and usually accelerated with increasing temperature; therefore, corrosion proceeds faster in warmer environments than in cooler ones.
3. **Chemical Salts**: Chemical salts increase the rate of corrosion by increasing the efficiency (conductivity) of the electrolyte. The most common chemical salt is sodium chloride, a major element of seawater. Sodium chloride deposited on atmospherically exposed surfaces also acts as a hygroscopic material (i.e., it extracts moisture from the air), which then increases the corrosion in non-immersed areas.
4. **Humidity** (or Wetness): Humidity and time-of-wetness play a large role in pro-

moting and accelerating corrosion rates. Time-of-wetness refers to the length of time an atmospherically exposed substrate has sufficient moisture to support the corrosion process. The wetter the environment, the more corrosion is likely to occur.

The aviation industry takes advantage of this fact when they store aircraft in the desert without enclosing them in air-conditioned buildings. Even at elevated temperatures, there is very little electrolyte available for a corrosion cell. Corrosion can occur without visible water, but the rate significantly decreases below approximately 60% relative humidity (for iron).

5. **Pollutants and Acid Gases**: Acid rain (a chemical by-product from manufacturing and processing plants), and chlorides (in coastal areas) promote corrosion. Acid gases, such as carbon dioxide, can also dissolve in a film of moisture in contact with the metal.

In addition to the direct effect of chemical attack, these materials reduce the electrical resistance of the electrolyte. Reduction of resistance in the corrosion cell permits higher corrosion currents so increased corrosion rates occur. To reiterate, corrosion is the degradation of engineered materials in contact with a corrosive environment. The corrosive environment is usually defined by the characteristics of the electrolyte. Service environments may be (1) immersion in a liquid (water), or (2) atmospheric. These are discussed in the next section.

2.1.8 Service Environments and Corrosion

Corrosion rates are affected by environmental influences. Several commonly used environmental terms are recognized by corrosion control professionals. Environments include:

- Chemical/marine
- Chemical with high humidity
- Marine with high humidity
- Chemical with low humidity
- Rural with low humidity
- Rural

2.1.8.1 Chemical/Marine Environment

This is a very severe environment that causes very rapid rusting (Figure 2.9). Airborne salts and chemical pollutants may serve to stimulate corrosion. Humidity and seawater provide electrolytes, which also hasten the process.

Figure 2.9 Chemical/Marine Environment — Offshore Platform

2.1.8.2 Chemical with High Humidity Environment

This environment is highly corrosive, because of its gases, chemicals, and high humidity, all of which can stimulate corrosion (Figure 2.10).

Figure 2.10 Chemical + High-Humidity Environment — Refinery

2.1.8.3 Marine with High Humidity Environment

This environment provides an active electrolyte because of the presence of moisture and salt particles. The splash zone area (generally defined as mid-tide level to 12 ft above high tide) is known to suffer particularly high corrosion (Figure 2.11).

Figure 2.11 Marine + High-Humidity Environment

2.1.8.4 Chemical with Low Humidity Environment

Low humidity generally makes a less corrosive environment than high humidity; however, both gases and chemicals can stimulate corrosion (Figure 2.12).

Figure 2.12 Chemical + Low-Humidity Environment — Power Plant

2.1.8.5 Rural Environment

This may be the least corrosive environment of the five because clean air provides no airborne contaminants and moisture is not present to serve as an electrolyte (Figure 2.13). Examples of rural low-humidity environments are rural Arizona, Wyoming, and West Texas. Other examples include desert oil facilities in Kuwait, Saudi Arabia, and other dry or non-industrialized areas.

Figure 2.13 Rural Environment — Railway Bridge

2.2 Types of Corrosion

There are two broad classifications of corrosion: **general** and **localized**.

2.2.1 General Corrosion

General corrosion results in a (1) relatively uniform loss of material over the entire surface (Figure 2.14) and (2) in a general thinning of the affected surface. General corrosion is relatively easy to inspect and does not cause catastrophic failures.

Figure 2.14 General Corrosion

2.2.2 Localized Corrosion

Localized corrosion occurs at discrete sites on the metal surface. The areas immediately adjacent to the localized corrosion normally corroded to a much lesser extent, if at all. Localized corrosion often occurs in areas that are difficult to inspect. This form of corrosion is less common in atmospheric exposure than in immersion or splash/spray exposures; some special factors are involved, such as long exposure to liquid water, pollutants, and/or galvanic cells. Galvanic cells are generated when different types of metals are in electrical contact in a common electrolyte. Corrosion activity at localized corrosion sites may vary with changes such as:

- Defects in coatings
- Changes in contaminants or pollutants
- Changes in the electrolyte

The predominant forms of localized corrosion found on offshore structures are **pitting** and **crevice** corrosion.

2.2.2.1 Pitting Corrosion

Corrosion does not proceed uniformly in pitting corrosion, but primarily occurs at distinct spots where deep pits are produced (Figure 2.15). The bottoms of pits are anodes in a small, localized corrosion cell, often aggravated by a large cathode-to-anode area ratio. Pitting can be initiated on an open, freely-exposed surface or at imperfections in the coating. Deep, even fully penetrating pits, can develop with only a relatively small amount of metal loss. Pitting can be isolated or a group of pits may coalesce to form a large area of damage. Pitting is especially prevalent in metals that form a protective oxide layer and in environments high in chloride contamination (where chlorides promote the breakdown of the oxide layer).

Figure 2.15 Pitting Corrosion

2.2.2.2 Crevice Corrosion

Crevice corrosion occurs on a metal surface that is shielded from full exposure to the environment because of the close proximity of another material that forms a narrow gap between them (Figure 2.16). Differences in

concentrations of corroding species or oxygen between the environment inside and outside the crevice generate the driving force for the corrosion cell, especially in areas acting as water traps. Crevices are common in situations where there is metal-to-metal contact, such as in support straps or at pipe flanges. In addition, deposits of debris and corrosion products (also known as poultice corrosion) also generate in crevices.

Figure 2.16 Crevice Corrosion

2.2.3 Significance of Corrosion

Of the two classifications of corrosion, localized corrosion is the most significant in terms of a need for unplanned maintenance. Localized corrosion is often hidden (i.e., in crevices or under multiple coats of a maintenance coating) so that the true extent of damage is hidden. Due to the risk of rapid penetration of the substrate, localized corrosion can lead to serious consequences unless detected and dealt with promptly.

Localized corrosion also produces characteristically sharp features that serve as "stress risers." These stress risers result in conditions that increase the level of stress at the leading edge of the pit or crevice, serving as initiation points for failure.

2.3 Effects of Corrosion

The effects of corrosion include safety, cost, and appearance.

2.3.1 Effects of Corrosion — Safety

Corroded structures can be unsafe in a variety of ways (Figure 2.17). Bridges and buildings that must support the weight of extreme loading are obvious examples.

Figure 2.17 Offshore platform rusted catwalk

Corrosion cannot be allowed in the food and beverage industry, where metal corrosion products would contaminate the products. Coatings and linings are often used to protect process vessels and metal food containers.

2.3.2 Effects of Corrosion — Cost

In the period from 1999 to 2001, a NACE International-sponsored study was conducted in a cooperative agreement with the Federal Highway Administration (FHWA). From that study, the cost of corrosion in the United States (US) was estimated to be $276 billion per year and $6.9 billion per year in the electrical utility industry.

According to the US Department of Commerce Bureau of Census, the total amount of organic coating material sold in the US in 1997 was 5.56 billion liters (1.47 billion gal-

lons) at a value or $16.56 billion. The total sales can be broken down into architectural coatings, product original equipment manufacturer (OEM) coatings, special purpose coatings, and miscellaneous paint products.

A portion of each of these was classified as corrosion coatings at a total estimate of $6.7 billion. It is important to note that raw material cost is only a portion of the total of any coating application project, which ranges from 4 to 20 percent of the total cost of application. When applying these percentages to the raw materials cost, the total annual cost of coating application ranges from $33.5 billion to $167.5 billion (an average of $100.5 billion).

It is estimated that opportunities exist–to save 25 to 30% of that cost by using "optimum corrosion control practices." Proportionally similar costs are seen in most other industrial nations.

The cost of re-painting and repairing rusted steel usually far outweighs the initial cost of protecting a surface against corrosion. The cost of corrosion in the US in 1994 was estimated at over $300 billion a year, which is approximately 4.5% of the gross national product (GNP). Other developed nations also estimate corrosion as a similar percentage of their GNP.

2.3.3 Effects of Corrosion — Appearance

Peeling coatings and rusting steel are eyesores in any environment. For many engineers or facility owners, appearance is a major reason for coating their structures (Figure 2.18).

Figure 2.18 Effects of Corrosion — Appearance

For all those reasons, corrosion prevention is extremely important.

2.4 Corrosion Control

Although faced with a difficult challenge, the corrosion engineer possesses a variety of tools to control corrosion, including:

- Design
- Inhibitors
- Material selection
- Cathodic protection
- Protective coatings
- Splash zone systems
- Alteration of the environment

2.4.1 Design

How a structure is designed can influence its resistance to corrosion. Generally speaking, corrosion-control design:

- Eliminates possible entrapment of water, chemical salts, and other matter that could promote corrosion "hot spots". Hot spots are areas particularly conducive to accelerated corrosion, and are often referred to as "critical areas".
- Eliminates complex shapes (e.g., back-to-back angles) and orientation of members that could serve as "traps"

- Provides access for maintenance activities allowing operators to implement corrosion control systems
- Eliminates sharp edges, crevices, and other difficult-to-protect elements

Design factors are covered later in the course.

2.4.2 Inhibitors

A **corrosion inhibitor** is a substance that, when added to an environment, decreases the rate of corrosion. Corrosion inhibitors are typically added in small amounts to the electrolyte, most commonly in closed systems such as piping. They can also be used in the form of vapor phase inhibitors (VPI) and migrating corrosion inhibitors (MCI).

2.4.3 Material Selection

There are alternatives to construction materials that may not corrode as fast as steel. Choosing a corrosion-resistant material (CRM) may be required in certain applications on the structure to be protected.

As noted earlier in this chapter, a galvanic series is a list of materials in the order of their corrosion potentials. The most easily corroded (most active) are at the top of the list and the least easily corroded (least active) are at the bottom.

2.4.4 Cathodic Protection Systems

Cathodic protection (discussed in more detail in CIP Level 2) uses sacrificial anodes made of more active metals such as aluminum, zinc, or magnesium. When connected to the immersed steel structure being protected, these anodes then corrode, in preference to the steel structure. When the anode is completely depleted, it must be replaced. Corrosion control by cathodic protection in the offshore industry is almost always used without protective coatings.

An alternate form of cathodic protection, impressed current, provides an external current to offset the current of the corrosion cell. Because impressed current systems are not widely used for protecting offshore structures, they are not addressed in this course.

2.4.5 Protective Coating Systems

Protective coatings represent the most common and extensively used corrosion protection system for offshore structures. The mechanism for protection varies depending on the particular material used. The chosen mechanism can isolate the substrate being protected from the environment (i.e., the electrolyte). This is generally known as barrier protection.

The protection afforded by protective coatings can be greatly influenced by:

- Breaks in the protective coating film (i.e., discontinuities)
- The type of protective coating system
- Protective coating system thickness
- The nature of the electrolyte
- Presence of mill and other scales

2.4.6 Alteration of the Environment

The environment, most often topside structures offshore, can be modified to make it less corrosive. This primarily means dehumidification (Figure 2.19), which is explored in CIP Level 2. While this is common practice for interior applications, or in temporarily installed containment, it does not play a major role in on-going corrosion control.

Figure 2.19 Dehumidification Unit in Operation

2.5 Corrosion Control Programs

Owners of industrial assets deal with corrosion by establishing and maintaining corrosion control programs. Individual programs differ in detail, but generally address most or all of the factors in the following list.

- Qualification and specification of materials used in corrosion protection systems
- Specification of the degree of surface preparation
- Selection of the proper corrosion protection system for a particular element of the structure
- Qualification and selection of application contractors
- Establishment of quality assurance and control
- Qualification and selection of in-process inspection firms
- Qualification and selection of in-service inspection firms
- Scheduling surveys
- Management of data derived from surveys
- Planning and engineering of maintenance actions
- Execution of maintenance actions
- Evaluation of overall corrosion control program effectiveness

Key Terms Definitions

Anode: The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter the solution at the anode.

Cathode: The electrode of an electrochemical cell at which reduction is the principal reaction. Electrons flow towards the cathode in the external circuit.

Cathodic Protection: A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.

Corrosion: The deterioration of a material, usually a metal, that results from a reaction with its environment.

Corrosion Cell: In order for corrosion to occur, certain conditions and elements are essential. This is the combination of an anode, cathode, return path, and electrolyte.

Corrosion Inhibitor: A chemical substance or combination of substances that, when present in the environment, prevents or reduces corrosion.

Crevice Corrosion: Localized corrosion of a metal surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity of the metal to the surface of another material.

Electrolyte: A chemical substance containing ions that migrate in an electric field.

Galvanic Series: A list of metals and alloys arranged according to their corrosion potentials in a given environment.

Generalized Corrosion: Corrosion that is distributed more or less uniformly over the surface of a material.

Localized Corrosion: This occurs at discrete sites on the metal surface.

Mill Scale: The oxide layer formed during hot fabrication or heat treatment of metals.

Passivation: A reduction of the anodic reaction rate of an electrode involved in corrosion.

Pitting Corrosion: Localized corrosion of a metal surface that is confined to a small area and takes the form of cavities called pits.

Return Path (Metallic Pathway): This connects the anode and cathode, allowing passage of electrons, generated at the anode, to the cathode.

Study Guide

1. Define corrosion:

_____
_____
_____

2. What is passivation?

_____
_____
_____

3. What are the elements of a corrosion cell?

_____
_____
_____

4. Describe what happens at the anode.

_____
_____
_____

5. What is the function of the electrolyte?

_____
_____
_____

6. What is the function of the metallic pathway?

_____
_____
_____

7. What is the galvanic series?

_____
_____
_____

8. The general rules of galvanic corrosion are:

_____
_____
_____

9. Name at least five factors that affect the rate of corrosion.

_____
_____
_____

10. General corrosion is:

_____
_____
_____

11. Localized corrosion is:

_____
_____
_____

12. List some of the common tools/methods used for corrosion control.

_____
_____
_____

Chapter 3: Team Building Exercises

3.1 Human Relations

Human relations and its relevancy to coating projects is vital to understand for two primary reasons:

1. Human relations are the **oil** that keep the wheels of the job running smoothly. Without oil, the friction typically generated during a project could cause the wheels to burn up. Someone can be technically competent but difficult to work with if they lack human relation and team building skills.
2. Human relations skills are taught during this course to help provide valuable skillsets for job advancement. People who get along well with others generally move up in their companies faster than those who do not.

3.1.1 Bad News

Table 3.1 gives response options for coating inspectors when they must break bad news to someone.

3.1.2 Defensive Behavior

It is important for coating inspectors to understand what psychologists call "defensive behavior." Defensive behavior may be an unfamiliar term, but inspectors have certainly come across it at one time or another. It occurs when people feel they have to defend themselves or, by extension, the people working for them, rather than objectively address the issues at hand. Some behaviors that can cause defensiveness include:

Critical or judgmental attitude: saying to someone, "if you weren't so careless, this mistake would not have happened."

- **Manipulative behavior**: playing politics and trying to maneuver people to suit a personal goal
- **Authoritarian, bossy behavior**: for example saying, "I'm the inspector here and you'd better look sharp or I'll shut the job down."
- **Lack of concern or indifference**: appearing not to care about problems on the job that are beyond the control of the worker
- **Know-it-all attitudes**: these may be expressed as "Look, I've been doing this for 15 years, and there isn't anything I don't know about this subject."

Table 3.1: Bad News Response Options

The person might:	In which case the coating inspector might:
• Work with the inspector to solve the problem	• Help with the solution to the extent of their stated responsibility and authority.
• Agree to do something, then not do it	• Restate the problem and work to get the other person's commitment to follow through on the solution
• Ignore the situation entirely	• Advise his or her supervisor
• Become hostile and defensive, and may argue	• As a last resort, shut the job down, if they have been granted the authority to do so

To avoid behaving in a way that could produce a defensive reaction try to be:

- Objective and descriptive; rather than say "that's the worst excuse for surface prepa-

ration I've ever seen," state the problem in objective terms like: "that wall still has loose mill scale and rust; remember the specification calls for a near-white blast"

- Open and honest
- Oriented toward solving the problem
- Interested in the other person's problem
- Open to suggestions

The **key** is to: ***concentrate on solving the problem.***

3.1.3 Conflict

There is no shortage of opinions or differences of opinion in the coatings industry. Differences of opinion can, and frequently do, lead to conflict. One person's opinion plus another person's opinion equals conflict. Conflict is a daily reality for everyone.

Handling Conflict

There are at least three ways of handling conflict:

1. **Avoid it**. Simply look the other way and ignore substandard surface preparations, or avoid the situation entirely by quitting the job.
2. **Smooth things over**. Try to smooth the issue over by delaying dealing with it; resolve minor points while ignoring the major issue; and/or postpone the confrontation until later.
3. **Resolve it**. Two resolution options are **power** and **negotiation**

Resolving Conflict

Power can either be physical (like a punch in the nose) or based on authority (like firing someone or shutting the job down). Power strategies are sometimes appropriate, **but** should be used sparingly.

The problem with power strategies is that they end up in win-lose confrontations in which the losers may respond with sabotage, attempts to get even, or being otherwise nasty and disagreeable. The best use of power is subtle. Knowing when and how to use power must be developed by conscious and focused effort.

Negotiation is working to arrive at a decision that is accepted by everyone involved, thus arriving at a consensus. Successful negotiation requires the ability to:

- Cut through ancillary issues to determine the real problem
- Initiate a situation where everybody wins, or at least no one walks away feeling defeated
- Listen to the other person's side of the story; it is not necessary to agree, but at least listen carefully to what the person has to say
- Show you are listening; respond by summarizing what the other person has said to be sure you understand and to indicate your interest in what the person has to say

Other steps to negotiate conflict successfully:

- Diagnose the real problem
- State the problem objectively
- Let every person involved have a say
- Discuss various solutions
- Decide together on the best solution
- Determine who is going to do what to ensure that the solution is achieved
- Follow up to be sure that the solution is carried out

The last item is usually the responsibility of the coating inspector, because the ultimate responsibility of the inspector is to ensure that the specification is followed.

Improving Listening Skills

Since listening is such an important part of successful conflict resolution, the following are ways to improve your listening skills:

- Be prepared to listen
- Listen for main and supportive ideas
- Remain objective
- Be prepared; know your subject
- Concentrate
- Take notes
- Don't argue
- Read between the lines (nonverbal language)
- Put yourself in the speaker's place
- Restate what you think you heard; make sure that what you think you heard, is what you actually heard or what the other person said.

Some people are very uncomfortable with conflict and attempt to avoid it whenever possible, but conflict, or a difference of opinion, can be useful.

When people work together as a team to solve a problem, the solution can turn out to be better than any one individual could have developed alone. This team effect is sometimes call "synergy" from the words *synthesis* and *energy*. **Team work is the key to any successful project completion!**

3.2 Team Building Exercise — Desert Survival

This section contains other information on team building for consideration.

3.2.1 Team Building

A team is an energetic group of individuals committed to achieving common objectives and to produce quality results. *This should be the commitment of all those involved in a coating project.*

3.2.1.1 Characteristics of a Team

As an inspector, working with a team is the most effective approach to completing a project on time, according to specifications, and within the budget. Some characteristics of an effective team are members that:

- Share a common vision/overall view of the project
- Understand the clear objectives and outcomes
- Use open communication to facilitate effective listening and discussion about issues
- Know the specific roles of each team member for the specific tasks at hand
- Approach the task with energy and enthusiasm
- Participation and demonstrate leadership as they work together
- Use appropriate and effective decision-making methods
- Trust and support team members
- Feel significant, which is highly motivating
- Know that cohesion is valued by their leaders
- Feel comfortable on the team

3.2.1.2 What is Team Building?

Team building is molding many diverse individuals into a cohesive group that shares or agrees on common objectives to complete the assigned task. Team members should be comfortable with each other; the more they know and appreciate each other as contributors, the better they work together. Team building techniques may include:

- A common vision or goal

- Stated objectives to achieve the vision or goal
- Defined roles for each team member
- Open information flow
- Shared commitment among team members

3.2.1.3 Team Building Process

Each team member has a responsibility to share information with each other (i.e., who you are, what you think about the organization, how you expect to fit in). The purpose of team building is to listen and discuss things to grow together into a team. Take the time for each member to answer the following good questions:

- Why are you interested?
- What do you expect to learn?
- What is your biggest asset?
- What is your biggest fear?
- How do you see yourself?
- What do want to accomplish?

3.2.1.4 Team Building Exercise

During inspectors' careers they find that working within a team is essential to getting the job done. The following exercise is to help understand the team building process.

Chapter 4: The Role of the Inspector

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- The inspector's responsibilities
- Team function
- Enforcing the specification
- Preparation
- Specification
- Product data sheets
- Standards
- Testing equipment
- Safety
- Material safety data sheets
- Roles of quality assurance and quality control

Key Trade Terms

- Quality control technician
- Materials inventory reports
- Instrument calibration history reports
- Coatings specification
- Standards
- Material safety data sheet (MSDS)
- Quality assurance (QA)
- Quality control (QC)

4.1 The Coatings Inspector's Responsibilities

The coating inspector's responsibilities are:

- To perform as a part of an effective team (as discussed in Chapter 3)
- To ensure that the project specification is followed as written or formally amended
- To document the results

The coating inspector's responsibilities may vary from job to job. For the purposes of CIP, NACE has defined the inspector's role as that of a **quality control technician** who is primarily responsible for observing and reporting the technical aspects of a coating project and its conformance or deviation from the project specification. Supervision is **not** considered to be part of the inspector's role.

The general duties of the inspector are:

- Observe
- Test
- Verify conformance to specification (with documentation)
- Report

4.1.1 Observe

Ultimately, the contractor is responsible for performing the work according to the project specification. The inspector should *observe and report* the quality of the work performed, noting its conformance or deviation to the project specification. Inspectors should *not* direct the contractor on how to perform the work or make any changes to the project specification without written authority. Doing so may lead to problems later in the project if issues regarding performance and/or possible non-conformance.

Inspectors should observe:

- The job site for safety issues that may affect themselves or the contractor

Safety enforcement is not the responsibility of inspector; however, it is their responsibility to report any issues that may affect the project.

- The weather conditions; observe, monitor and document
- The surface preparation
- The coating application
- Coating cure prior to return to service

Watch closely for small things learned from experience and training that may cause problems with the project. This close, informed scrutiny assists the contractor as well as your client.

4.1.2 Testing

All tests necessary, or required by the project specification should be done, to ensure the coatings project meets the requirements of the specification. Inspectors should also ensure that necessary test equipment is on site, is properly calibrated, and functions accurately.

Conduct tests honestly, accurately, and openly. There should be no surprises and nothing to hide! Remember, Inspectors are part of a team whose goal is a successful coating project. If there are issues or areas of non-conformance that become evident during testing, relay this information to both the contractor and your supervisor so appropriate corrective actions can be taken.

Some tests that may be needed during surface preparation and coating operations are:

- Check ambient conditions for proper relative humidity and dew-point parameters
- Ensure the surface temperature is in the required range
- Visually check for surface contaminants and perform needed tests for invisible contaminants (i.e., soluble salts testing) before surface preparation begins
- Check the abrasive media to ensure that it is the proper size and shape per the specification
- Check abrasives for cleanliness
- Check the air compressor for air cleanliness with the blotter test
- Check the blast hose for proper air supply
- Check the blast nozzle for size and wear condition
- Check the blasted surface for proper surface profile/anchor pattern
- Verify the blasted surface for the specified level of cleanliness
- Check the viscosity of the coating and its temperature
- Examine the application equipment to be used; ensure that equipment is functional and in good working order with correct setups
- Check the DFT of each coat and verify there are no drips, runs, or holidays
- Check for surface contaminants between applications of additional coatings

The above list is merely an example of what might be done for testing. There are various other tests that may be done throughout the process. Specifications govern which tests need to be performed.

Other items Inspectors need to monitor during surface preparation and coating application are:

- Check the product data sheets and material safety data sheets to ensure the proper paint is at the job site
- Check and document the batch numbers
- Check the mixing process (this is an often overlooked, but a critical step)
- Ensure adherence to proper induction time

- Make sure pot life is not exceeded
- Verify the recoat windows

4.1.3 Verify and Document Conformance

Performance and documentation of required testing and all work activities should be done thoroughly, accurately, and consistently, for the duration of the project. Inspectors should:

- Ask the client's representative if there are any special reporting procedures required
- Ensure there is agreement between the contractor and inspector about when and how to perform certain conformance tests
- Agree on "hold points" before the project begins

Coating inspectors are almost invariably required to provide the client with documentation of the inspection.

Documentation may include:

- A daily written report using standardized forms
- An inspection log or notebook to record all inspection activity
- Routine reports
- Notes from a weekly progress meeting
- Other reports, as required by the client

Even if documentation is not specifically required, good practice dictates that accurate, detailed records be kept.

Inspection records should show all environmental conditions and activities involved in the pretreatment, cleaning, and application, as well as all materials used.

Good inspection documentation can provide much valuable information for future employees on the durability of coatings and the economical protection they afford. Conversely, this type of information is often lost through a lack of or poor recordkeeping. Some organizations do keep records, but without the critical details, the records may be of little value for determining the protection afforded and the cost of protection per year. A company with a well-developed coatings program (including ongoing maintenance) benefits greatly from previous detailed inspection reports.

For example, a chemical plant producing a variety of chemicals may use several generic coatings throughout the facility based on known or expected performance in similar corrosive environments. With proper inspection reports of previous coating projects, management could:

- Detect and tag design defects for review by the engineering division for future work
- Evaluate coating performance
- Determine realistic annual cost data on each coating system
- Develop a sound ongoing maintenance program

Although personnel relocate in and out of a company, records usually remain with the facility. Good records can provide maintenance departments with detailed information on:

- What was coated
- What materials were used
- When coating was done
- How it was done
- By whom it was done
- At what overall cost it was done
- What knowledge was retained in lessons learned

4.1.4 Report

As noted earlier, always ask the clients' representative about any special reporting requirements or instructions they may need. An important part of an inspector's job is maintaining regular communication with the owner's representative and with the contractor. In addition to frequent, relatively informal conversations on the job, **the truly beneficial communication takes the form of regular reports and meetings**.

Objective and professional records are important because they may be used for reference at a later date, and may even be examined in a court of law, if there are later disputes. Reports should contain accurate statements of facts that are complete, clear, and concise.

Exactly the type of reporting required from the inspector should be identified in the coating specification or developed during the pre-job conference. As noted previously, a common understanding of specifications must be nailed down during the pre-job conference. The daily reports and routine reports generally are customized for each project.

4.1.5 Other Reports

The more documentation that reports activities related to the project, the better for everyone on the team and project. Inspectors may elect, or may be required by the client's representative, to maintain reports on such things as materials inventory and instrument calibration history.

4.1.5.1 Materials Inventory Reports

These reports contain information on the inventory of job site materials, i.e., coatings, thinners, abrasives, etc., and are normally submitted periodically. The reports should contain:

- The name of the material
- Quantity of onsite material
- Material batch numbers
- Date of material's arrival on the job site

It is good practice for the contractor to use coatings in a structured manner. Typically, applicators do not do a very good job of monitoring the batch numbers of material used. As the inspector, it is good to ensure that:

- Coatings with the same batch number are kept together
- First-in first-out (FIFO) rotation of materials is utilized

4.1.5.2 Instrument Calibration History Reports

Calibration reports normally contain information on how frequently each instrument is to be, or has been calibrated. Each instrument should carry a label clearly indicating its serial number, or special label noting the date it was last calibrated. The inspector may be required to record on the daily report the serial number of each instrument.

4.1.5.3 Weekly Reports

In addition to daily reports, a weekly report may be required. The weekly report may be less detailed (i.e., a summary of the week's progress and events), written in layman's terms and in narrative form. Often it is written at the office rather than prepared by the inspector in the field. Copies of both daily and weekly reports are given to the client, the company doing the inspection, and the onsite engineer to ensure that everyone is well informed about progress.

The weekly report may be used by the project manager for his/her weekly progress report. There are at least as many recording formats as there are clients. Some forms require recording such items as:

- Location (general and detailed)
- Contractor's name and phone number
- Area (quantity) treated
- Dates of application
- Equipment list
- Personnel
- Quantities of abrasive and paint used

It is the coating inspector's responsibility to clearly understand what records and reports are required. These items should be discussed and agreed on in the pre-job conference.

4.2 Team Function

As discussed in detail in Chapter 3, it is extremely important the inspector knows the relationship responsibilities with the owner and the contractor (team work). Ultimately, all parties should work in concert to do quality work per the contract specifications. Although inspectors specific responsibilities may vary from one project to the next, they are not typically expected to direct the contractor's work.

The inspector's role is to work within the team, as the owner's representative and with the contractor, to ensure the engineered lifecycle is achieved according to the project specifications, design and contract requirements. Generally, the owner is represented by an engineer or a project manager who depends on the inspector to observe and verify that the project continues according to the specifications and moves in a positive direction.

4.3 Verify Specification — Do Not Change

It is vital to understand that almost every user of coating inspection has a unique concept of the duties and responsibilities of an inspector. There seems to be no general agreement within the industry on the day-to-day activities of inspection and the inspector. This is particularly true for independent, third-party inspectors, who find job responsibilities changing according to each client's point of view.

In addition to normal quality-control testing, some owners may regard the inspector as a project supervisor and assign non-inspector duties such: as supervising labor, overseeing safety issues, or keeping track of and ordering materials. Other owners may instruct the inspector to simply observe the work, make tests and measurements, and report directly to the owner without any dialogue with contractors or their workers. Conceivably, at some point, inspectors may be called on to function at either extreme.

To reiterate, for the purposes of CIP, NACE International has defined the inspector's role as that of a **quality control technician** whose primary responsibility is to observe the technical aspects of a coating project. Supervision is **not** considered to be part of the inspector's role.

Regardless of the responsibilities assigned to the inspector, **the specification is the document that governs any project**. An inspector's primary responsibility is to **"verify"**

the specification. **The inspector does not make changes to the specification for any reason.** Changes to the specification may only be made in writing by the owner or the author of the specification at the owner's direction. Inspectors should only follow changes that are submitted in writing. Verbal agreements of change can cause problems and should be avoided.

4.4 Preparation

In order to do the job properly, inspectors must be prepared for the specific job assigned. Ensure any questions about the project are answered before work begins. The pre-job conference is the best opportunity to get answers. For this reason, thoroughly review any information that can be obtained before the pre-job conference and complete a list of questions or concerns to bring to the meeting.

4.5 Specification

Always obtain, read and fully understand the **coating specification**. Be prepared to bring up questions with the appropriate person and get them resolved. Most specifications are formal, structured documents. **A good coating specification contains** most or all of the following sections, each with information and criteria for the job:

- Scope of work
- Terms and definitions
- Reference standards and codes
- Safety
- Pre-job conference
- Surface preparation
- Coating materials (includes the coating schedule)
- Sampling coatings
- Workmanship
- Application
- Work schedule (sequence of work to be done)
- Repairs and remedial coating work
- Inspection
- Documentation

As the inspector, ensure that none of the listed elements are missing or, if present, they must provide enough detail to do the job properly. For example, the specification may address the proper DFT, but may not address how to handle areas of non-conforming high or low DFT. This could create confrontation on the job site. Ambiguity of issues like that should be addressed during the pre-job conference.

4.6 Product Data Sheets

Obtain the manufacturers' product data sheet (MPDS) or technical data sheet (TDS), read and fully understand the coating system required in the specification. The MPDS and/or TDS are prepared by manufacturers to answer many questions about their products. Manufacturers provide the MPDS for each coating product. Inspectors should always have copies of each MPDS on the job site during surface preparation and coating application.

Verify by date of publication that the most recent copy is being used. Look for discrepancies between the MPDS and the specification. Inspectors can question these discrepancies, but always remember the written specification overrides the MPDS, unless written permission is given to go outside the specification and approved by the owner's project manager. Some specifica-

tions integrate the MPDS as part of the specification.

4.7 Standards

Know the standards required in the specification and have copies of them readily available during inspection work. If the written and/or visual standard(s) required are not at hand, know how to obtain them. The specification should include a list of published standards referenced by particular sections or parts of the document. If it does not, this is another issue that may be resolved during the pre-job conference. Any part of a referenced standard may be as binding on all parties as the entire standard, unless an exception is noted.

4.8 Testing Equipment

Some of the equipment needed to conduct inspections is listed below. In later chapters these items are discussed and instructions given on how, when, and where to use them.

- Psychrometers (sling or electronic), including charts
- Profilometer or Testex tape and anvil micrometer
- Wet-film thickness (WFT) gauges
- Dry Film thickness (DFT) gauges, including:
    - — Pull-off magnetic gauges
    - — Fixed probe magnetic gauges
- Holiday detectors, including:
    - — Low-voltage DC (wet sponge) detector
    - — High-voltage DC detector
    - — High-voltage AC detector

4.9 Safety

Safety enforcement is not the responsibility of inspectors. Safety is the responsibility of all workers on the job site. The employer has the primary liability for safety, but Inspectors should be knowledgeable enough to recognize safety violations because both their safety and the crew's safety is at stake. All observed safety violations should be immediately reported to the proper personnel.

4.10 Material Safety Data Sheets (MSDS)

The MSDS is an information form from manufacturers that contains data about known substances in a particular product. It is an important tool for workplace safety; its purpose is to inform workers and emergency personnel about how to work with or handle the substance safely. It also includes information about:

- Toxicity
- Health effects
- First aid
- Reactivity
- Storage
- Disposal
- Personal protective equipment (PPE)
- Spill handling procedures

Although the MSDS should be brought on to the job site by the material handler, it is important that the inspector, for safety reasons, knows where the MSDSs are located. Be familiar with their data on chemicals that workers may contact. The MSDSs should be country- and supplier-specific. The same product can have very different formulations in different countries. The MSDSs of every

material used must be kept onsite and available to site workers.

4.11 Roles of Quality Assurance and Quality Control

The main role of the QA/QC inspector is to verify the coating specification. The inspector must have a thorough understanding of the specification, product data sheets, and all other documents related to the project.

4.11.1 Quality Control

Quality control (QC) is similar to, but not identical with, quality assurance (QA). QC is a procedure or set of procedures intended to ensure that a manufactured product or performed service (i.e., installed coatings or linings) adheres to a defined set of quality criteria or meets the requirements of the client or customer. It is usually performed by contractors as part of their process.

4.11.2 Quality Assurance

During the development of products and services, **Quality Assurance** (**QA**) is any systematic process that checks whether a product or service being developed is meeting specified requirements. A quality assurance system is said to:

- Increase customer confidence
- Improve work processes and efficiencies

Quality assurance was initially introduced during World War II when munitions were inspected and tested for defects post production. Quality assurance systems em-phasize catching defects before they get into the final product. “QA” is sometimes paired with “QC” in a single expression called, quality assurance and control (QA/QC). QA verifies the permanence of the QC effort.

4.12 Ethics Case Study

Razorback Industries is a large, diversified company. The majority of its business, however, is in petrochemicals.

Because of a recent plant expansion, extensive coatings operations were done. A small local contractor was hired to do the work. To cut his costs, the contractor arranged the work schedule so that every Saturday he came in by himself to spray paint.

John Simmons, an employee at one of Razorback's subsidiary plants for several years, works in the plant's quality control department. When the coating operations began, John was appointed Razorback's newest coating inspector.

While this involved a substantial increase in his workload, there was no increase in pay. He frequently had to work several hours overtime per day and had to come in every Saturday to inspect the work being done by the contractor.

"Boy, if I were getting paid for this, I'd earn a mint of money, but I guess working unpaid days, nights, and weekends is a privilege of salaried management," John thought to himself more than once.

Since he could leave as soon as the last of the work was inspected each day, John began to give the contractor a hand with minor things like arranging the hose line, handing up the gun when the contractor was working on scaffolding, and so on, in order to speed things up so he could get home.

Finally, the project was finished. John had finished his daily inspection, and, while finishing his summary final inspection report in the field office by himself, the contractor walked in.

"Hey, Simmons," the contractor said "Look, I really appreciate you helping me. Otherwise, I'd be there painting for another month, and I have another big job starting up in two days."

"Well, if you were still here painting, I'd still be there inspecting, and I'm ready to start spending my Saturdays at home," John replied.

"Yeah, but a lot of guys would be real happy to just sit and watch someone else work or slip out for a few beers while they're waiting. But you really were a big help to me. Look, this is for you. I saved a lot of money sending the crew home on weekends, and I could have lost a lot of money if I stayed any longer. And it will ***really*** cost me money if I have to do any rework."

John looked down at the brown envelope thrust at him, obviously filled with cash, with a $50 bill on top.

4.12.1 Attestation

Should John take the money? Why or why not?

Read the case study, discuss the situation with your team for no more than 20 minutes, and write your conclusions on a flip chart. Select one member of the team to present your team's findings to the rest of the group.

You may record your team's result in the following space:

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Key Terms Definitions

Coatings Specification: A formal, structured document containing information on a project (such as scope, terms, schedule, inspection, etc.).

Instrument Calibration History Reports: Reports that normally contain information on how frequently each instrument is to be or has been calibrated.

Materials Inventory Reports: Reports that contain information on the inventory of jobsite materials, and are normally submitted periodically.

Materials Safety Data Sheets (MSDS): A form containing data of known substances in a particular product.

Quality Assurance (QA): Any systematic process that checks whether a product or service being developed is meeting specified requirements.

Quality Control (QC): A procedure intended to ensure that a manufactured product or performed service meets the requirements of the client or customer.

Quality Control Technician: The inspector's role, primarily responsible for observing and reporting the technical aspects of a coating project and its conformance or deviation from the project specification.

Standards: A term applied to codes, specifications, recommended practices, procedures, classifications, test methods, and guides that provide interchangeability and compatibility. Standards enhance quality, safety, and economy; they are published by a standards-developing organization or group.

Study Guide

1. How does NACE define the inspector's role?

_____
_____
_____

2. What is the inspector's responsibility when it comes to safety on a project?

_____
_____
_____

3. Name some tests that may need to be conducted during surface preparation and coating operations.

_____
_____
_____

4. Name some of the documentation/reports that may be required to be maintained on a coatings project.

_____
_____
_____

5. What are the most important characteristics of a good report?

_____
_____
_____

6. What is the inspector's primary responsibility and what should the inspector not do as it pertains to the specification.

_____
_____
_____

7. What type of information could you expect to find on a product data sheet?

_____
_____
_____

8. What type of information could you expect to find on a material safety data sheet?

_____
_____
_____

9. Explain the difference between quality assurance (QA) and quality control (QC).

_____
_____
_____

Chapter 5: Environmental Testing

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Environmental conditions
- Surface temperature instruments
- Relative humidity instruments
- Wind speed

Key Trade Terms

- Relative humidity (RH)
- Dew point
- Infrared thermometers
- Repeatability
- Magnetic surface contact thermometer
- Sling psychrometer
- Psychrometric tables
- Psychrometric charts
- Wind speed monitor

Prerequisites

Prior to class, be sure to:

- Review manufacturer's instruction guide
- Review National Calibration Standard

5.1 Environmental Conditions

Environmental, or ambient, conditions can greatly affect all phases of a coating operation. This chapter examines: (1) specific environmental conditions, (2) testing equipment, and (3) methods that are most likely to be of concern to the coating inspector (Figure 5.1).

Figure 5.1 Environment

5.1.1 Surface Temperatures

Surface and air temperatures are the first conditions to check when assessing the risk of moisture formation on a substrate. The temperature of the surface awaiting preparation or coating application, and the temperature of the air near that surface, can have a great effect on the coatings application itself. At night, steel usually ***radiates*** heat and cools to below air temperature. During the day, it ***absorbs*** heat and is usually warmer than the air temperature.

Since surface temperature is often different from air temperature, especially for work done outside. Both air and surface temperatures should be measured to avoid application problems should either become too hot or too cold for satisfactory film formation (Figure 5.2). Application at incorrect temperatures can cause defects such as:

- Blistering
- Pin holing
- Cratering
- Dry spray
- Mud cracking

The coating manufacturer should specify the maximum and minimum surface temperatures for coating application.

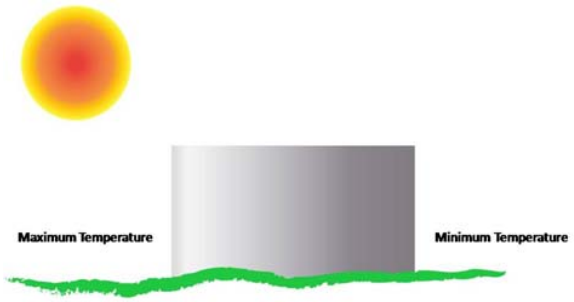

Figure 5.2 Surface Temperatures

ASTM D3276, *Standard Guide for Painting Inspectors (Metal Substrates)*, states that the ***minimum surface temperature*** for coating application is usually 40°F (5°C). It may be as low as 0°F (-18°C) for cold-curing one- or two-component systems or 50°F (10°C) for conventional two-component systems. Coating specifications may further state that coating should not be undertaken when the temperature is dropping and within 5°F (3°C) of the lower limit.

The ***maximum surface temperature*** for coating application is typically 125ºF (50ºC), unless otherwise clearly specified. A surface that is too hot may cause the coating solvents to evaporate so fast that application is difficult, blistering takes place, or a porous film results. Most epoxy formulations stop the curing process below 50°F (10°C).

Also of note, we should only apply coatings to a substrate when that substrate is at least 5°F (3°C) above the determined dew point in order to prevent moisture on the surface from being coated.

5.1.2 Relative Humidity

Relative humidity is a measure of the amount of moisture in the air compared to saturation level (the amount it can hold at a given temperature) and may affect the coating operation because of either too much or not enough relative humidity (Figure 5.3). Many coating specifications restrict coating application when the relative humidity is expected to be too high. Typically, there are solvents in the coating film that need to evaporate and, if the relative humidity is too high, there is no available space for the solvent to evaporate. If this happens, the solvents that remain in the coating cause problems with the film such as solvent entrapment and lack of curing.

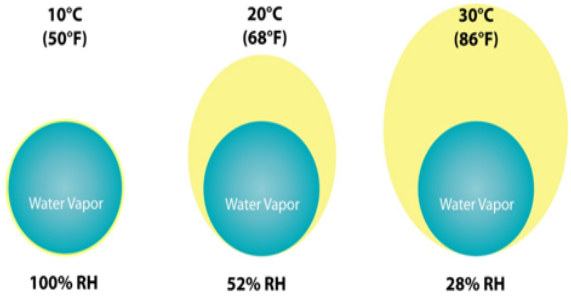

Figure 5.3 Relative Humidity Changes Relative to a Parcel of Air (yellow) as Temperature Increases

Dew Point is the temperature at which moisture begin to form on a steel surface. It is the temperature to which a volume of air must be cooled in order to reach saturation. It is a function of air temperature and the relative humidity. A good illustration is a simple glass of ice water. The moisture condenses on the outside of the glass because the glass's surface temperature is below the dew point.

5.1.3 Wind Speed

Wind speed can adversely affect a coating job in several ways. It can:

- Blow abrasives past the boundaries of the abrasive-blast work area to an area where coatings are being applied
- Cause excessive drift or overspray of sprayed coatings
- Accelerated solvent evaporation after application
- Contribute to the formation of dry spray

The coating inspector should also stay alert to possible affects wind-blown contaminants (e.g., sea spray, salt, blast media, dust, or sand) might have on the coating job. If the wind speed is determined to be harmful, the coating inspector (if possessing the authority) should immediately advise the supervisor and the contractor.

5.2 Surface Temperature Instruments

5.2.1 Digital Infrared Thermometers

Digital infrared thermometers are non-contact thermometers that are used to measure temperature from a distance. If the amount of infrared energy emitted by an object and its emissivity are known, the object's temperature can be determined (Figure 5.4).

The most basic digital infrared thermometer consists of: (1) a lens to focus the infrared energy; (2) a detector that converts the energy to an electrical signal; and (3) the electrical signal displayed (in temperature units after compensating for ambient temperature variation). This design makes it easier to measure the temperature of an object from a distance without touching it.

The infrared thermometer is useful for measuring temperature under circumstances in which thermocouples or other probe-type sensors cannot be used or do not produce accurate data for a variety of reasons.

Figure 5.4 Infared Thermometers

Proper use of the equipment is very simple: point, shoot, and read. There are three basic measuring techniques:

1. **Spot temperature:** aim the sensor at the desired target and activate the unit. The spot temperature is indicated on the instrument.
2. **Temperature of a stationary or fixed surface:** aim the sensor at the starting point and "sweep" it across the surface.
3. **Surface temperature of a moving object:** scan, aim the sensor at a fixed point and measure the temperature as the target moves past, or continually scan across the target as it moves past.

Instrument Calibration

Standards such as ASTM WK21204, *"Guide for the Selection and Use of Wide Band, Low Temperature Infrared Thermometers,"* aid users in selecting the correct instrument for a specific use. For the purpose of this class, the instruments of choice are the hand-held IR or direct contact digital units.

Calibrating IR thermometers must be done individually to achieve even moderate levels of accuracy. The initial calibration is usually done in-house during manufacturing. Periodic (annual) calibration should be done by the manufacturer or a third party laboratory to ensure that the most qualitative measurements are achieved. In other words, calibrating these instruments at the jobsite or in the office should ***not*** be attempted.

The operating parameters for the IR thermometer are the instrument's **accuracy** and **precision** which depend on the:

- Means by which the calibration was done
- Frequency of calibration
- Drift rate of the system

Most manufacturers identify the accuracy and precision of one to three percent of actual readings observed.

Repeatability

Repeatability is the ability of the instrument to give the same readings under similar ambient and target conditions. The Elcometer† [1] 214 has a repeatability of ±0.5% in reading ±1 digit with a response time of 1 second.

Anyone, particularly inspectors, should question a noticeably high or low reading. Take spot readings around the area to set a benchmark. This helps discern a reading that is outside the limits, or the possibility that the reading is incorrect. Have other instruments at hand, such as a sling psychrometer, to help determine which readings are either extremely high or extremely low.

While IR thermometer reading errors may be equipment-based, some of the more common errors are operator errors. Operator-based errors can occur if the eye was not held on the exact location within the specified distance needed for an accurate reading, or the instrument may have been dropped and damaged.

Some equipment-based errors (disadvantages or limitations of the equipment) are: (1) IR thermometer's inability to read through transparent surfaces such as glass; (2) compromised reading accuracy via obstruction of the optics by Steam, dust, smoke and/or vapors can prevent accurate readings by obstructing the unit's optics.

The unit cannot accurately measure reflective surfaces such as stainless or aluminum wrapping.

5.2.2 Magnetic Surface Contact Thermometer

The **magnetic surface contact thermometer** is one of the most common instruments used to determine substrate temperature. The instrument (Figure 5.5) consists of a bimetallic sensing element, which is protected from drafts. It also includes two magnets on the sensing side which are attracted to the steel surface.

1. Trade Name

Figure 5.5 Magnetic Surface Contact Thermometer

For proper use: (1) ensure the substrate is clean and dry to enable good magnetic attraction, (2) place the magnetic back of the thermometer on the surface, and (3) allow the instrument to stabilize before taking measurements. Stabilization time varies, but is usually 2 to 3 minutes.

Once the thermometer is stabilized, read the dial and record the results in the daily log. With any instrument used to determine surface conditions, measurements should be **made at the actual work locations**. The steel surface temperature should be measured at a variety of points within the area to be coated, including those that are likely to be hotter or colder than the norm (Figure 5.6).

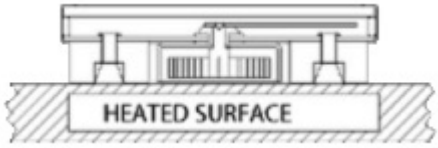

Figure 5.6 Magnetic Surface Contact Thermometer In Use

When using the magnetic surface thermometer, be aware of, or have in your possession:

- The **manufacturers' instructions** which are simple to understand and use. The thermometers are specifically designed for use on any horizontal surface or any magnetic surface. Two high-temperature magnets act as the base holding the instrument to the surface. The bimetallic sensor (located in a draft shield) is in virtual thermal contact with the surface to be measured. This gives the instrument a quick response time.
- The **standard** for using the magnetic surface contact thermometer in a coating application calls for the manufacturers' instruments to meet all Coating Thickness standards for quality and use, and be in accordance with ANSI/NCSL Z540-6 (National Calibration Standard).

Calibration of the magnetic surface thermometer is done at the manufacturers' facility and ***cannot be done*** at the jobsite. The instrument's low cost indicates that it should be replaced if there is any doubt about its accuracy, rather than send it to a third party laboratory.

The operating parameters of this instrument vary with the temperature range needed on the substrate.

The accuracy and precision range most manufacturers for the coating industry use is ±5%. This can be confirmed by the serial number each manufacturer is required to place on the instrument (IAW ANSI/NCSL Z540-6 2006 version).

Question the readings that are very high or low variations compared with the actual temperature of the substrate. Before taking actual measurements, know what the approximate surface temperature range should be on the surface. This information is found on the manufacturers' product data sheet.

Some common errors are operator-based and some are equipment-based. Operator-based reading inaccuracy examples: (1) reading

taken in direct sunlight, (2) instrument left in place too long, or (3) instrument removed before it stabilized (most manufacturers recommend 3 to 5 minutes for the best accuracy).

It is very possible that erroneous readings are equipment-based due to calibration or equipment malfunction and, therefore, the instrument should be replaced.

Many surface temperature gauges lose their accuracy easily and should be checked regularly (perhaps daily) against a known standard. Mercury or spirit thermometers used with sling psychrometers (whirling hygrometers) are generally much more accurate and can be used as a convenient reference.

5.2.3 Electronic Surface Contact Thermometer

Electronic surface contact thermometers use a thermocouple in contact with the surface to measure temperature (Figure 5.7). Some models are available with a variety of interchangeable probes that may allow measurement of a number of surfaces, including liquids, over a wide temperature range.

An advantage of electronic thermometers is the speed at which readings are delivered. They deliver temperature readings much more quickly (usually < 1 second) than magnetic surface contact thermometers, because the instrument does not require a stabilization period.

Remember that as a reading is taken the temperature measurement is only for that precise spot on the surface. If readings are being taken prior to a coating application over a large area, a number of readings should be taken throughout the entire area with high or low readings taken into account.

Proper use of an electronic surface contact thermometer is very simple:

- Ensure the proper probe is used for the surface and the expected temperature range
- Turn on the instrument
- Place the probe on the surface where measuring the temperature (Figure 5.8)
- Read the display screen

Figure 5.7 Digital Thermometer

Figure 5.8 Digital Surface Contact Thermometer

Calibration of these instruments must be done in-house by the manufacturer. Do not attempt calibration at the jobsite. Periodic (annual) calibration should be carried out by the manufacturer or a third party laboratory to ensure that the most qualitative measurements are achieved.

The operating parameters (temperature range) of this instrument vary. Check manufacturer's instructions. The Elcometer† [1] 213/2, has a measuring range of -56°F to 2500°F (–49°C to 1372°C).

The accuracy and precision (resolution) of instruments, again, may vary between manufacturers. The accuracy of the Elcometer 213/2 is ±1% of the reading is ± 1 digit and the precision (resolution) is 1°F (1°C).

As with all other temperature sensing instruments, question readings with either very high or low variation compared with the actual temperature of the substrate. If there are questions about the accuracy of the readings, send the instrument immediately to the manufacturer for service and calibration or replacement.

Some common errors and causes encountered when using this type of instrument are inaccurate readings from using the wrong sensing probe, using an instrument that is not correctly calibrated, or not verifying substrate temperature across the entire area.

5.3 Relative Humidity Instruments

5.3.1 Electronic Digital Hygrometers

These multi-purpose instruments determine relative humidity, air temperature, and dew-point temperature and are convenient and easy to use. Their care and use is detailed in this section.

It is an inspector's responsibility to know and understand the proper use of the electronic digital hygrometers (Figure 5.9).

Be aware that when moving from one temperature/humidity extreme to another the meter needs time to stabilize. After opening the sensor's protective shutter, press the "on" button then start taking measurements. Temperature readings are displayed in either Celsius or Fahrenheit. Users may switch between the two as needed when readings are taken.

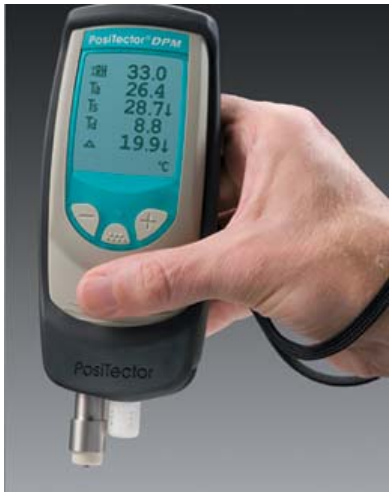

Figure 5.9 Electronic Hygrometer

After stabilizing, the ***temperature*** and ***relative humidity*** are displayed.

To display the:

- ***dew point*** temperature, press the "wet bulb" button once
- ***wet bulb*** temperature, press the "wet bulb button" a second time
- ***ambient*** temperature, press the "wet bulb" button a third time

The display indicates when dew point and wet bulb temperatures are selected.

1. Trade Name

Press the “Hold” button once to freeze the displayed readings and stop taking measurements. To continue taking readings, press the “Hold” button again. Some instruments have minimum, maximum, storage, save, print and recall abilities for easier record-keeping.

These instruments, from any manufacturer, need to meet all coating thickness standards for quality and use in accordance with ANSI/NCSL Z540-6 (National Calibration Standard).

Hygrometers come from the manufacturer already calibrated; however, **this calibration requires** certification by an independent lab as well as verification in the field.

The accuracy and precision of electronic digital hygrometers inspectors use must be near the top of its scale (i.e., close to 100% RH). This is the ***critical point*** at which contractors and inspectors make decisions on whether to work or not. Most manufacturers’ guidelines state the degree of accuracy in both Celsius and Fahrenheit, as well as the range and resolution for each reading (i.e., temperature, relative humidity, dew point, and wet bulb).

The repeatability of results depends on individual instrument manufacturers, so consult the correct manufacturers’ technical data sheet.

Routinely question readings when highs and lows are outside known parameters. Check local weather for the work site each morning to get a good idea of expected ambient conditions. Use this as the benchmark for the day.

Common hygrometer errors are either operator-based and/or equipment-based. Operator-based inaccuracy examples are: the reading was taken in direct sunlight, the instrument was left in place too long, or removed before it stabilized.

Equipment-based erroneous readings are very likely due to calibration or equipment malfunction and, therefore, must be replaced.

5.3.2 Sling Psychrometer

The **sling psychrometer** (sometimes called a whirling hygrometer) is the type of psychrometer (Figure 5.10) most often used in coating inspection, especially in hazardous environments. It measures the ambient air temperature (dry-bulb and wet-bulb temperatures) as close to the worksite as is practicable. These temperatures are used to calculate the dew point and relative humidity.

It is the inspector’s responsibility to have all equipment information and manufacturers’ instructions prior to arrival on the jobsite.

The psychrometer consists of two identical thermometers, using either mercury or red spirit (alcohol). One thermometer bulb is covered with a sock saturated in distilled water. The covered thermometer is called the wet bulb, the other the dry bulb.

Figure 5.10 Sling Psychrometer

The dry-bulb thermometer measures the air temperature as it is; the wet-bulb thermometer measures a lower temperature, because of latent heat loss from water evaporating from the wet sock. The faster the water evaporates, the more cooling occurs, resulting in lower humidity and dew point temperature.

To use the sling psychrometer:

- Saturate the sock with clean water.
- Whirl the instrument rapidly for about 40 seconds.
- Read the wet-bulb temperature.

Repeat the process (spin and read without additional wetting) until the temperature stabilizes. When the wet-bulb temperature remains constant, record the result. Read and record the dry-bulb temperature after the stabilized wet-bulb reading is recorded.

The standard for sling psychrometers is ASTM E337-02 (2007), *Method B Standard Test Method for Measuring Humidity with a Psychrometer (the measurement of Wet- and Dry-Bulb temperatures)*. This test method details how to determine humidity of atmospheric air by means of wet and dry bulb temperature readings and incorporates use of the psychrometer ventilated by whirling (sling psychrometer). The methods described are applicable within an ambient temperature range of 32–122°F (0–50ºC), wet bulb temperatures not lower than 33.8°F (1ºC) and restricted to ambient pressures not differing from standard atmospheric pressure by more than 3%.

How do you "field-calibrate" the sling psychrometer? It is very simple: (1) remove the two thermometers, (2) place them in a cup of room temperature water, and (3) remove the thermometers from the cup in 3 to 4 minutes. The two thermometers should have identical readings. If the readings are **not** identical, replace the thermometers. A sling psychrometer must have two thermometers that read the same in a like temperature environment.

Sling psychrometer operating parameters follow in this section. Crucial factors are:

- The *accuracy* and *precision* of the sling psychrometer is ± 2% when used properly.

The *repeatability* is unlimited with proper care.

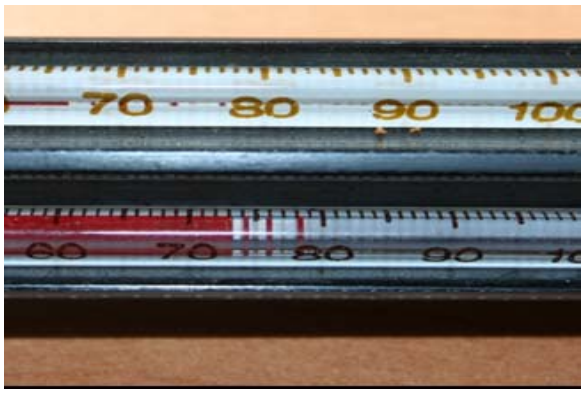

Figure 5.11 Sling Psychrometer Split Bulb

Routinely question readings when the highs and lows are outside known parameters. In other words, know the local weather forecast

before arriving on site. This provides a benchmark temperature range for the day.

5.3.3 Some Common Errors and Causes

Operator-based errors include:

- Not ventilating the psychrometer long enough to reach equilibrium
- Not getting the wick wet enough
- Letting the wick dry out too much
- Holding the psychrometer too close to the body
- Taking too long to read the thermometers
- Touching the bulb ends with hands while reading
- Not facing into the breeze

All of these lead to a wet bulb readings that are too warm; i.e., preventing inspectors from doing the job properly.

Equipment-based errors are easier to identify with this instrument, i.e., it is obvious if the thermometers or the units are broken. Ensure that the sock does not get too dirty, as it frequently does in blasting and painting operations. If it becomes too dirty, replace it, or inaccurate readings will result.

The powered air flow psychrometer (Figure 5.12) operates similarly to the sling psychrometer, but air is moved using a fan, rather than slinging the instrument. After about 2 minutes, the temperature stabilizes. Monitor only the wet-bulb temperature; when it remains stable, record both wet- and dry-bulb temperatures. Be very careful when temperatures are below 32°F (0°C). Sling or fan-operated psychrometers are ***not*** reliable at those temperatures since the water freezes. When the temperature is this low, determine humidity with a direct-readout humidity instrument.

Coatings are not usually applied at low temperatures.

Figure 5.12 Air Flow Psychrometer

Psychrometric tables (Figure 5.13) are used after dry-bulb and wet-bulb temperatures are measured. Psychrometric tables from the US Department of Commerce Weather Bureau are used to determine the relative humidity and dew-point temperature of the air.

The difference between dry-bulb temperature and wet-bulb RH is calculated; it is called the ***wet-bulb depression***. Both the dry-bulb temperature and wet-bulb depression are found on the vertical and horizontal axes, respectively, of psychrometric tables. The point where the two temperatures intersect indicates the relative humidity or dew-point temperature (depending on the particular table).

Please note that both relative humidity and dew-point temperature may vary with barometric pressure. The differences are generally small, and although many tables (calculated at different pressures) are provided in a typical book of tables, it is reasonably accurate to use tables based on a barometric pressure equivalent to 30 inches of mercury. For absolute accuracy, determine the actual barometric pressure and use

the appropriate table to determine RH and dew point.

Figure 5.13 Psychrometric Tables

A ***psychrometric chart*** (Figure 5.14) is a graph of the physical properties of moist air at a constant pressure (often equated to an elevation relative to sea level). The chart graphically shows how various properties relate to each other, and is thus a graphical equation. The thermo/physical properties found on most psychrometric charts are the same as the psychrometric tables (i.e., wet bulb, dry bulb, barometric pressure, etc.).

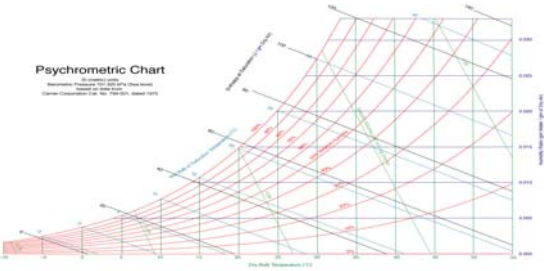

Figure 5.14 Psychrometric Chart

Psychrometric calculators (Figure 5.15) may also be used to determine relative humidity and dew point temperature. Keep the manufacturers' instruction guide on the job and know how to use it.

Record results of measurements in a daily report using a standard format shown in Table 1.

Figure 5.15 Psychrometric Calculator

5.4 Wind Speed

High wind speed can be a safety hazard. When work is performed at a particular height, winds of 40 mph (64 kph) or more are considered dangerous. When work is performed on offshore platforms, safety boats and rescue craft cannot operate reliably with high wind speeds, so work close to the sea or below deck level may be postponed until the wind speed drops.

Many countries provide weather bureau information or meteorological services. Applicators or inspectors can obtain both daily and historical data concerning weather conditions. Weather forecasts for the next day and for several days in advance may be obtained from the local weather bureau.

Weather bureau records may also be useful to check conditions when records of weather conditions were not kept on site or when the accuracy of recorded measurements is suspect.

Figure 5.16 Wind Speed Monitor

A **wind speed monitor** (Figure 5.16) is an effective instrument to determine if conditions are appropriate for coating application. When using a wind speed monitor there are several items beneficial to know.

Instructions for the proper use of the instrument are in the manufacturers' instruction guide, (the essential knowledge base for instruments). A critical part of an inspector's responsibility is to ensure that the wind speed monitor instruction manual is at hand on the job. Always stand facing the wind with the digital dial facing the user. Hold the

Table 1: Inspection Details — Ambient Conditions

Time					
Wet-bulb temperature					
Dry-bulb temperature					
RH%					
Dew point					
Steel temperature					
OK to work? Yes/No					

instrument at arms length so the air flows through without obstruction.

Remember that manufacturers' instruments should meet all coating thickness standards for quality and use in accordance with ANSI/NCSL Z540-6 (National Calibration Standards). Wind speed monitors come from the manufacturer already calibrated and should never need recalibration.

Operating parameters for the wind speed monitors include:

- The accuracy and precision of ~~the~~ instruments vary, but most manufacturers indicate that the degree of accuracy is ± 3% of the indicated reading.
- The repeatability of the instrument will vary depending on the individual unit.

Routinely question readings when the instrument reading is ***not*** the actual wind speed. Always check local weather forecasts; this provides benchmark ranges for the day.

Common errors and causes of inaccurate readings from the wind speed monitor include:

- The user is not facing into the wind
- The user is not holding the instrument away from the body
- The wind is too high for the instrument (will wear out the roller bearing)

Key Terms Definitions

Dew Point: The temperature at which moisture will begin to form on a steel surface.

Infrared Thermometers: Devices that measure temperature, using blackbody radiation emitted from objects.

Magnetic Surface Contact Thermometer: One of the most common instruments used to determine substrate temperature**.**

Psychrometric Chart: A graph of the physical properties of moist air at a constant pressure (often equated to an elevation relative to sea level).

Psychrometric Tables: Booklet used to determine the relative humidity and dew-point temperature of the air.

Relative Humidity: The ratio, expressed as a percentage, of the amount of water vapor present in a given volume of air at a given temperature to the amount required to saturate the air at that temperature.

Repeatability: The ability of the instrument to give the same readings under similar ambient and target conditions.

Sling Psychrometer: The type of psychrometer most used in coating inspection. It is used to measure the ambient air temperature to calculate dew point and relative humidity.

Wind Speed Monitor: An instrument to help decide if conditions are appropriate for coating application projects.

Study Guide

1. Identify some of the defects that can be caused by incorrect application temperatures.

2. Describe relative humidity.

3. What is the dew point temperature?

4. Name some of the effects wind may have on a coating project.

5. What are some of the common errors when using an electronic hygrometer?

6. Explain the process for use of the sling psychrometer.

Chapter 6: Environmental Testing — Practice Lab

Environmental Testing

We will now put into practice what we have learned to use:

- A sling psychrometer
- US Weather Bureau tables or other means for computation
- A surface thermometer to determine the dew point, steel temperature and relative humidity

Please divide into your teams and complete the attached assignments. You have a maximum of 45 minutes to use the instruments and record your results. Take this opportunity to actively use the both the sling psychrometer and digital instruments. You need to understand the instrument and how to use it for the final practical exam.

It is _____now

We will reconvene at_____

We will compare the results as a class.

Measuring Humidity and Determining Dew Point

For guidance, consult:
ASTM E 337, Method B

Procedure

Equipment Required Per Class:

1. Four (4) sling psychrometers, complete with red spirit thermometers (Celsius or Fahrenheit, as appropriate)
2. Four (4) magnetic surface thermometers; 0 to 50°F (-10 to 60°C)
3. Four (4) sets of US Weather Bureau tables or look-up charts (Celsius or Fahrenheit to match psychrometers and thermometers)
4. One (1) jar of distilled water
5. Four (4) wicks (socks) to cover the thermometers
6. Two (2) spare, red-spirit thermometers
7. One (1) digital hygrometer

Purpose of Practice Lab

1. To learn how to use a surface thermometer and how to standardize it with other instruments
2. To learn the proper procedure for whirling the psychrometer to get a stabilized wet-bulb reading
3. To learn how to use the US Weather Bureau tables to determine humidity and dew point values at an established barometric pressure

Environmental Testing, Task Procedures

1. Each team is issued the following:
   - Sling psychrometer
   - Digital hygrometer
   - Distilled water
   - Surface thermometer
   - US Weather Bureau Tables
2. Each student will be required to perform the following exercises:
   - Allow the surface thermometer and red-spirit thermometers to come to equilibrium in the classroom.
   - Attach thermometer to a metal plate and immediately record temperature; then record the temperature again after 5 minutes, after 10 minutes, and, finally after 15 minutes.
   - Whirl the psychrometer properly until a stable reading is obtained for the wet-bulb. Record the wet-bulb and then the dry-bulb readings.
   - Consult the Weather Bureau Tables to determine humidity and dew point values. Record this data. Otherwise, consult the look-up chart.
   - Take readings with digital hygrometer and record.
3. Repeat the procedure in an outdoor setting. Students are to make the above determinations both indoors and outdoors.
4. Complete the inspection record on the following page and answer the questions on the subsequent page.

Station 1: Environmental Test Equipment

Equipment: Sling psychrometer, surface thermometer, magnetic-coated steel test panel, ambient conditions chart

Answer both questions.

Environmental Instrument Test Lab Data

Date: _____

Location: In Class

	Sling Psychrometer		Digital Hygrometer	
Time				
Air Temp				
Wet Bulb				
RH				
DP				
ST				
Comments				

Location: Outdoors

	Sling Psychrometer		Digital Hygrometer	
Time				
Air Temp				
Wet Bulb				
RH				
DP				
ST				
Comments				

Use Metric or Imperial units as appropriate.

Chart for Calculation of Relative Humidity and Dew Point

Chart for Calculation of Relative Humidity and Dew Point										
Dry-Bulb Temp. (°C)	Depression of Wet-Bulb Temperature (°C)									
	1	2	3	4	5	6	7	8	9	10
5	86/3	72/0	58/-	45/-						
6	86/4	73/1	60/-	47/-						
7	87/5	74/3	61/0	49/-						
8	87/6	75/4	63/1	51/-						
9	88/7	76/5	64/3	53/0		Reproduced by NACE with permission				
10	88/8	77/6	65/4	54/1	43/-					
11	88/9	77/7	66/5	56/3	46/-	36/-				
12	89/10	78/8	68/6	57/4	48/1	37/-				
13	89/11	79/9	69/7	59/5	49/3	39/0				
14	90/12	79/10	70/8	60/6	51/4	41/1	32/-			
15	90/13	80/12	71/10	62/8	52/5	43/3	35/0			
16	90/14	81/13	71/11	62/9	54/7	46/4	38/2			
17	90/15	81/14	72/12	64/10	55/8	47/6	39/3	32/0		
18	91/16	82/15	73/13	65/11	56/9	49/7	41/5	34/2		
19	91/17	82/16	74/14	65/12	58/10	50/8	43/6	35/3	28/0	
20	91/18	83/17	74/15	66/13	59/12	51/10	44/7	37/5	30/2	
21	91/19	83/18	75/16	67/15	60/13	52/11	46/9	39/6	32/4	
22	92/21	83/19	76/17	68/16	61/14	54/12	47/10	40/8	33/6	
23	92/22	84/20	76/19	69/17	62/15	55/13	48/11	42/9	36/7	
24	92/23	84/21	77/20	69/18	62/16	56/15	49/13	43/11	37/10	
25	92/24	84/22	77/21	70/19	63/17	57/16	50/14	44/12	38/10	33/8
26	92/75	85/23	78/22	71/20	64/19	58/17	51/15	46/13	40/11	35/9
27	92/26	85/24	78/23	71/21	65/20	59/18	52/16	47/15	41/13	36/11
28	93/27	85/25	79/24	72/22	65/21	59/19	53/18	48/16	42/14	37/12
29	93/28	86/26	79/25	72/23	66/22	60/20	55/19	49/17	43/15	38/13
30	93/29	86/27	79/26	73/25	67/23	61/22	56/20	50/18	44/17	39/15
31	93/30	86/28	80/27	73/26	67/24	62/23	57/21	51/20	45/18	41/16
32	93/31	86/29	80/28	74/27	68/25	62/24	57/22	52/21	46/19	42/17
33	93/32	87/30	80/29	74/28	69/26	63/25	58/23	52/22	47/20	43/19
34	93/33	87/31	81/30	75/29	69/27	64/26	58/25	53/23	48/21	44/20
35	93/34	87/32	81/31	75/30	70/30	65/28	60/27	55/24	50/23	45/21
36	94/35	87/33	81/32	76/31	70/30	65/28	60/27	55/25	51/24	46/22
37	94/36	87/35	82/33	76/32	70/31	65/29	60/28	55/27	51/25	46/23
38	94/37	88/36	82/34	76/33	71/32	66/30	61/29	56/28	51/26	47/25
39	94/38	88/37	82/35	77/34	71/33	66/31	61/30	57/29	52/27	48/26
40	94/39	88/38	82/36	77/35	72/34	67/33	62/31	57/30	53/28	48/27

Note: For any pair of figures, the first is relative humidity (%) and the second is dew point temperature (°C).

Note: For any pair of figures, the first is relative humidity (%) and the second is dew point

Chart for Calculation of Relative Humidity and Dew Point																				
Dry Bulb Temp	Depression of Wet-Bulb Temperature (°F)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
51	94/49	87/47	81/45	75/43	68/41	62/38	56/36	50/33	45/30	39/27	34/24	28/20	23/16							
52	94/50	87/48	81/46	75/44	69/42	63/40	57/37	51/34	46/32	40/29	35/26	29/22	24/18	19/13						
53	94/51	87/49	81/47	75/45	69/43	63/41	58/38	52/36	47/33	41/30	36/27	31/24	26/20	20/15						
54	94/52	88/50	82/48	76/46	70/44	64/42	59/40	53/37	48/34	42/32	37/29	32/25	27/22	22/18						
55	94/53	88/51	82/50	76/48	70/45	65/45	59/43	54/41	49/38	43/33	38/36	33/33	28/30	23/27	19/24	Reproduced by NACE with permission				
56	94/54	88/53	82/51	76/49	71/47	65/44	60/42	55/40	50/37	44/34	39/32	34/29	30/25	25/22	20/17					
57	94/55	88/54	82/52	77/50	71/48	66/46	61/43	55/41	50/39	45/36	40/33	35/30	31/27	26/24	22/21					
58	94/56	88/55	83/53	77/51	72/49	66/47	61/45	56/42	51/40	46/37	41/35	37/32	32/29	27/25	23/21					
59	94/57	89/56	83/54	78/52	72/50	67/48	62/46	57/44	52/41	47/39	42/36	38/33	33/30	29/27	24/23	20/19				
60	94/58	89/57	83/55	78/53	73/51	68/49	63/47	58/45	53/43	48/40	43/38	39/35	34/32	30/29	26/25	21/21				
61	94/59	89/58	84/56	78/54	73/52	68/50	63/48	58/46	54/44	49/42	44/39	40/36	35/33	31/30	27/27	22/23	18/19			
62	94/60	89/59	84/57	79/55	74/53	69/51	64/48	59/47	54/45	50/43	45/43	41/40	36/38	32/35	38/32	24/29	20/25			
63	95/61	90/60	84/58	79/56	74/55	69/53	64/51	60/49	55/47	50/44	46/42	42/39	37/36	33/34	29/30	25/27	21/23	17/19		
64	95/62	90/61	84/59	79/57	74/56	70/54	65/52	60/50	56/48	51/46	47/43	43/41	38/38	34/35	30/32	26/29	22/25	18/21		
65	95/63	90/62	85/60	80/59	75/57	70/55	66/53	61/51	56/49	52/47	48/45	44/42	39/40	35/37	31/34	27/31	24/27	20/24	16/19	
66	95/64	90/63	85/61	80/60	75/58	71/56	66/54	61/52	57/50	53/48	48/46	44/44	40/41	36/38	31/35	29/32	25/29	21/26	17/22	
67	95/65	90/64	85/62	80/61	75/59	71/57	66/55	62/53	58/52	53/49	49/47	45/45	41/43	37/40	33/37	30/34	26/31	22/28	19/24	
68	95/67	90/65	85/63	80/62	76/60	71/58	67/57	62/55	58/53	54/51	50/49	46/46	42/44	38/42	34/39	31/36	27/33	23/29	20/26	16/22
69	95/68	90/66	85/64	81/63	76/61	72/59	67/58	63/56	59/54	55/52	51/50	47/48	43/45	39/43	35/40	32/37	28/34	24/31	21/28	18/24
70	95/69	90/67	86/65	81/64	77/62	72/61	68/58	64/57	59/55	55/53	51/51	48/49	44/47	40/44	36/42	33/39	29/36	25/33	22/30	19/26
71	95/70	90/68	86/67	81/65	77/63	72/62	68/60	64/58	60/56	56/54	52/52	48/50	45/48	41/46	37/43	33/41	30/38	27/35	23/31	20/28
72	95/71	91/69	86/68	82/66	77/64	73/63	69/61	65/59	61/58	57/56	53/54	49/52	45/50	42/47	38/45	34/42	31/40	28/37	24/33	21/30
73	95/72	91/70	86/69	82/67	78/66	73/64	69/62	65/60	61/59	57/57	53/55	50/53	46/51	42/49	39/46	35/44	32/41	29/38	25/35	22/32
74	95/73	91/71	86/70	82/68	78/67	74/65	69/63	65/62	61/60	58/58	54/56	50/54	47/52	43/50	39/48	36/45	33/43	29/40	26/37	23/34
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76	96/75	91/73	87/72	82/70	78/69	74/67	70/66	66/64	62/62	59/60	55/59	51/57	48/55	44/53	41/51	38/48	34/46	31/43	28/41	25/38
77	96/76	91/74	87/73	83/71	79/70	74/68	71/67	67/65	63/63	59/62	56/60	52/58	48/56	45/54	42/52	39/50	35/48	32/45	29/42	26/39
78	96/77	91/75	87/74	83/72	79/71	75/69	71/68	67/66	63/64	60/63	56/61	53/59	49/57	46/55	43/53	39/51	36/49	33/46	30/44	27/41
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80	96/79	91/77	87/76	83/74	79/73	75/72	72/70	68/68	64/67	61/65	57/63	54/62	50/60	47/58	44/56	41/54	38/52	35/50	32/47	29/44
81	96/80	91/78	87/77	83/75	79/74	75/73	72/71	68/70	64/68	61/66	57/65	54/63	50/61	47/59	44/57	41/55	38/53	35/51	32/49	29/46
82	96/81	91/79	87/78	83/77	80/75	76/74	72/72	69/71	65/69	61/67	58/66	55/64	51/62	48/60	45/59	42/57	39/55	36/52	33/50	30/48
83	96/82	92/80	88/79	84/78	80/76	76/75	72/73	69/72	65/70	62/69	58/67	55/65	51/64	48/62	45/60	42/58	39/56	37/54	34/52	31/49
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87	96/86	92/84	88/83	85/82	81/80	77/79	73/78	70/76	66/75	63/73	60/72	57/70	53/68	50/67	47/65	45/63	42/61	39/59	36/57	34/57
88	96/87	92/85	88/84	85/83	81/81	77/80	74/79	70/77	67/76	64/74	61/73	57/71	54/69	51/68	48/66	46/64	43/62	40/61	37/59	35/57
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91	96/90	92/88	89/87	85/86	81/85	78/83	75/82	71/80	68/79	65/78	62/76	59/75	55/73	52/71	49/70	47/68	44/66	41/65	40/63	36/61
92	96/91	92/89	89/88	85/87	82/86	78/84	75/83	72/81	68/80	65/79	62/77	59/76	56/74	53/73	50/71	48/69	45/68	42/66	40/64	37/62
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94	96/93	93/92	89/90	85/89	82/88	79/86	75/85	72/84	69/82	66/81	63/79	60/78	57/76	54/75	51/74	49/72	46/70	43/68	41/67	38/65
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99	96/98	89/97	89/95	86/94	83/93	80/92	76/90	73/89	70/88	67/86	64/85	62/83	59/82	56/81	53/79	51/78	48/76	45/74	44/73	41/71
100	96/99	89/98	89/96	86/95	83/94	80/93	77/91	73/90	70/89	68/87	65/86	62/85	59/83	56/82	54/80	51/79	49/77	46/76	44/74	41/72

Chapter 7: Coating Fundamentals

Objectives

When this module is completed the training candidate will have knowledge and understanding of:

- Coating chemistry
- Coating classifications
- Modes of protection
- Adhesion
- Basic inspection considerations
- The inspector checklist

Key Trade Terms

- Organic coatings
- Inorganic coatings
- Pigment
- Additive
- Binder
- Solvent
- Barrier coatings
- Inhibitive pigments
- Sacrificial coatings
- Adhesion

7.1 Introduction

This course focuses primarily on inspection of industrial and marine structures protected by coatings. Most of the protective coatings are supplied and applied in liquid form to a prepared surface, then transformed into a solid, protective film by one or more curing mechanisms.

In later chapters, other protective coating technologies available for corrosion control are presented, including:

- **Metalizing:** Metals and alloys deposited on steel substrates in a liquid state.
- **Galvanizing:** Steel components dipped into a molten zinc bath to form a metallic coating.
- **Powder Coating:** Many of the chemistries discussed in this course can be formulated as solids. After electrodeposition, they are heated to a molten state for curing.

7.2 Coating Chemistry

7.2.1 Properties of a Coating

A coating must exhibit a variety of properties to fulfill its role in corrosion control. Desirable properties include:

- **Chemical Resistance:** The coating must resist breakdown from the chemicals to which it is exposed. Chemical resistance is primarily a function of the resin used.
- **Water Resistance:** Water affects virtually all coatings. Greater water resistance equates to more effective corrosion control.
- **Ease of Application:** Ease of application is a vital characteristic, especially with intricate structural details. The more difficult the application, the more opportunity for defects to be created, leading to premature failure.
- **Adhesion to Substrate:** Adhesion is based on physical and chemical interactions between the coating and the substrate. Poor adhesion equates to poor performance.
- **Cohesive Strength:** Coatings must be able to withstand the stresses of the curing process and changes in temperature and moisture content.

- **Flexibility and Elongation:** The ability to expand and contract with the substrate is critical in some coating applications.
- **Impact Resistance:** The coating may have to resist impact loads.
- **Abrasion Resistance:** Coatings in some areas may have to be abrasion-resistant.
- **Temperature Resistance:** The environment may expose the coating to extremes of temperature, usually elevated.
- **Dielectric Strength:** A key variable in ~~the~~ barrier coatings and when using coatings in conjunction with cathodic protection.

When formulating coatings, there is usually a trade-off made among the properties mentioned above. Properties alter when the components of the coating are changed.

7.3 Coating Classification

Coatings are broadly classified as organic or inorganic. Most industrial and marine coatings are organic coatings.

Organic coatings' binders are made from living or once-living things. Until the early 1900s most coatings were from vegetable or animal oils. Most coatings now come from petroleum products that are refined and modified to impart the properties desired in coating. All organic coatings contain carbon.

Inorganic coatings use inorganic binders, most commonly based on either silicone or zinc. Metallic coatings (e.g., metallizing and galvanizing coatings) are also inorganic.

Broadly speaking, the major performance difference between organic and inorganic coatings is *heat resistance*. Organic coatings have less resistance because of the relative weakness of the carbon-to-carbon bond.

7.3.1 Composition

Liquid-applied coating components (Figure 7.1) are characterized by the following terms:

- Pigment
- Additive
- Binder
- Solvent

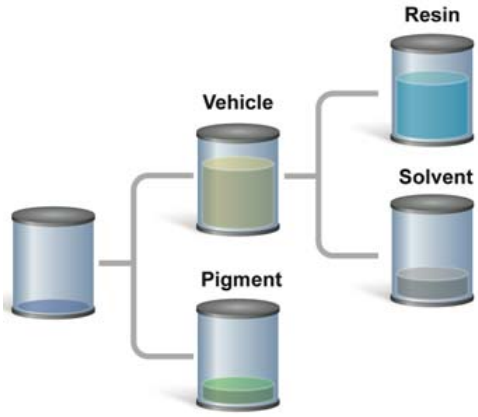

Figure 7.1 Coating Components

7.3.1.1 Pigment

A **pigment** is a discrete particulate solid used to impart specific properties to the coating in the liquid and solid state (Figure 7.2). Pigments do not dissolve in the coating, and they serve multiple functions in the coating. Among other things, pigments may be used to:

- Impart color
- Protect binder from weathering
- Provide inhibitor protection
- Control water resistance
- Provide a form of cathodic protection
- Modify mechanical or electrical properties

Figure 7.2 Pigment and Resin

7.3.1.2 Additives

Additives are liquid components of a coating typically added in small amounts to perform a specific function. There are thousands of additives and new ones are presented frequently. Additives give each individual product its unique characteristics (Figure 7.3).

Some additives ensure coating stability; they may keep it from settling, reduce foaming, retard color float and/or build thixotropy. **Others aid application** by improving the coating's flow out and wetting, which in turn increases pot life and decreases sag. Additives can also: add UV resistance, increase or decrease gloss, prevent skinning over in the can, increase shelf life and retard or speed up curing. Additives could be called the "secret ingredient" when applicators find a particular coating much easier to apply than a similar coating supplied by a different coating manufacturer.

Figure 7.3 Glass Flakes

7.3.1.3 Binder

The **binder** (Figure 7.4) is the backbone of the coating and supplies most of the heavy-duty features and functions of the material. **A coating typically gets its name from the binder,** such as: epoxy, polyurethane, alkyd, acrylic, etc. Two or more binders can be combined in a coating.

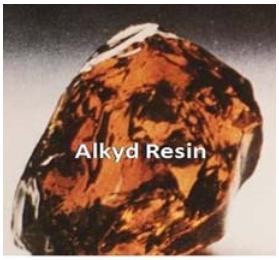

Figure 7.4 Binder

To create a protective coating film on the substrate, the binder resins must convert from a liquid state (which allows application) to a solid state that adheres to and protects the surface. In order to be suitable for use as a corrosion protection systems in the industrial and marine environment, the binder should:

- Have good wetting and adhesion properties
- Resist transmission of water, oxygen, and other chemical species
- Tolerate variability in the application process
- Resist chemical and physical change in the service environment
- Dry within an acceptable period
- Form a stable film that maintains its characteristic properties (strength, hardness, flexibility)

7.3.1.4 Solvents

Some of the resins used as binders are solids at normal temperatures. Successful application and establishment of adhesion is impractical when the binder is in the solid state. Therefore, **solvents** are added to liq-

uefy the binder (Figure 7.5) and allow for application in a productive manner.

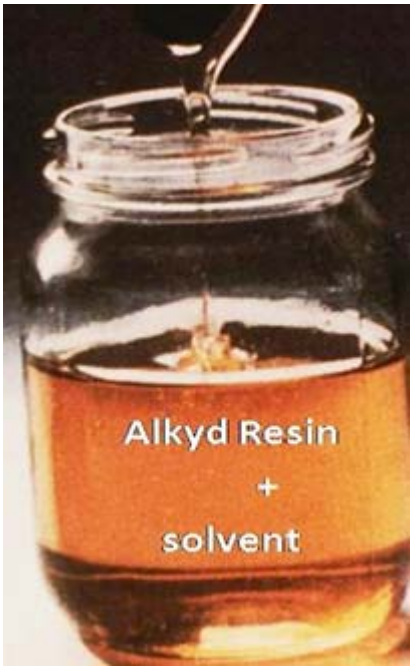

Figure 7.5 Solvent

Solvents have two major characteristics that influence their use in protective coatings:

- **Solvency Power:** The ability to dissolve the resin
- **Volatility:** Governs evaporation rate (the speed at which the solvent leaves the coating film during and after application)

Solvents play only a fleeting role in protective coatings. Once applied and cured, solvents serve no purpose and, in fact, may cause performance problems if they remain in the coating film. Because of environmental legislation, coating users and manufacturers are actively researching technologies to reduce or eliminate the need for solvents.

The air pollution boards of many countries regulate the use of solvents in coatings. Organic solvents, known as volatile organic compounds (VOC) are harmful to the Earth's ozone layer. Strict limits on the amount of solvent used in coatings have led to a tremendous advance in the coating industry since the early 1990s. Solvent-free coatings are commonly used in many areas and new solvent-free or very-high-solids coatings are continually being developed.

Improper field use of solvents causes many coating problems and can affect its useful life span. The coating inspector should confirm that only the specified solvent is used and only in amounts allowed by the specification, the local law, or the coating manufacturer.

7.4 Modes of Protection

Corrosion control of coatings can occur in one of only three processes:

- Barrier coatings
- Inhibitive coatings
- Sacrificial (cathodic protection)

7.4.1 Barrier Coatings

Figure 7.6 illustrates, in a simplified fashion, the concept of a barrier coating. The **barrier coating** impedes the ingress of oxygen, water, and soluble salts (exemplified by the most common salt in seawater, sodium chloride). The barrier coating prevents the formation of an effective electrolyte at the coating/metal interface (water and soluble salt) and restricts access of the strongly depolarizing oxygen molecule. Water and oxygen penetrating to the surface is not a significant issue if there are no ions present on the surface. If ions are present then corrosion does initiate.

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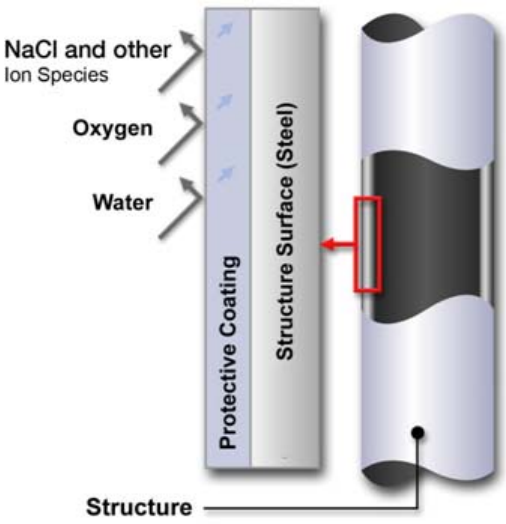

Figure 7.6 Barrier Concept

During coating formulation, three mechanisms are thought to achieve barrier protection:

- Resistance inhibition
- Oxygen deprivation
- Adhesion

7.4.1.1 Resistance Inhibition

Many people assumed that barrier coatings completely prevent oxygen and water from permeating the coating. However, when subjected to scientific inquiry, scientists discovered that water and oxygen permeability of barrier coatings typically were ***much higher*** than the levels at which corrosion is usually initiated and sustained on unprotected steel.

A theory was then proposed that the barrier films control corrosion by maintaining a high level of electrical resistance at and near the coating/substrate interface. This high resistance prevents significant current flow between the anodic and cathodic sites on the metal (local action cells). This phenomena reduces the potential for corrosion on the substrate.

The high electrical resistance is maintained by films with low permeability to ions, i.e., resistance inhibition. If ions are restricted, the water that reaches the interface is not conductive enough to carry a significant corrosion current to initiate and sustain corrosion. As explained previously, water and oxygen permeating the coating film to the substrate ***is not a significant event if ions are not present on the surface.***

Formulators of barrier coatings can now modify the components of the coating to decrease the film's permeability to both ions and water.

The generally accepted and simplified concept is that coatings can provide a barrier between the substrate and the environment (normally the electrolyte), thus removing one of the four required elements for a corrosion cell. Most coatings provide some level of barrier protection. Barrier coatings should exhibit the following attributes:

- Resistance to the chemical environment
- Resistance to moisture
- Excellent adhesion to the substrate, even in wet conditions
- Good wetting properties during application to prevent voids in the film and maximize effective surface area
- Resistance to vibration

7.4.2 Inhibitive Coatings

Figure 7.7 illustrates, in a simplified fashion, the inhibitive coating concept. Inhibitive coatings, in addition to serving as a barrier, actively slow down the reaction occurring at the anode, cathode, or both. To be effective, inhibitive coatings must be in contact with the substrate (i.e., they must be the primer). Generally, inhibitive coatings:

- Have chemicals added to the coating to hinder reactions occurring on the substrate
- Need a small amount of moisture to be activated
- Have been regulated out of existence, including lead and chromate inhibitive pigments

Inhibitive pigments actually passivate the metal surface by forming a thin, tightly adherent film or by reinforcing and plugging defects in the natural air-formed film. An example of such a coating is an alkyd based on zinc molybdates.

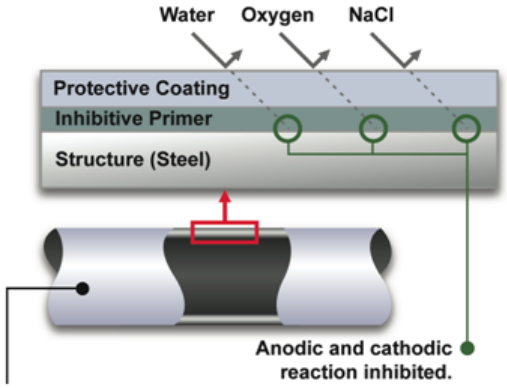

Figure 7.7 Inhibitive Concept

7.4.3 Sacrificial Coatings

Figure 7.8 illustrates in a simple fashion the concept of a sacrificial coating. **Sacrificial coatings** use a metal that is anodic to steel and which corrodes preferentially. Essentially, sacrificial coatings provide cathodic protection, especially in the vicinity of film defects. Sacrificial coatings:

- Usually contain zinc dust as the predominant pigment
- Must have a minimum loading of zinc dust to be effective

Examples of sacrificial coatings include inorganic zinc and flame-sprayed aluminum (FSA).

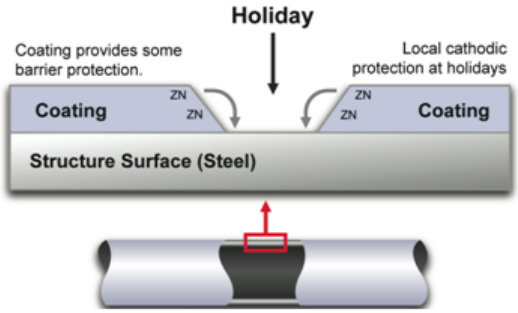

Figure 7.8 Sacrificial Concept

7.5 Adhesion

The most basic function of any coating is its ability to adhere to the surface on which it is placed. **Strong adhesion is the key to coating performance and long life** (Figure 7.9)**.** If adhesion is marginal, the coating gradually fails due to blistering, under-film corrosion, or chipping and flaking.

High levels of adhesion enable the coating to withstand moisture vapor transmission, abrasion, impact, flexing, humidity, chemicals, microorganisms and all the other factors it may be subjected to in service.

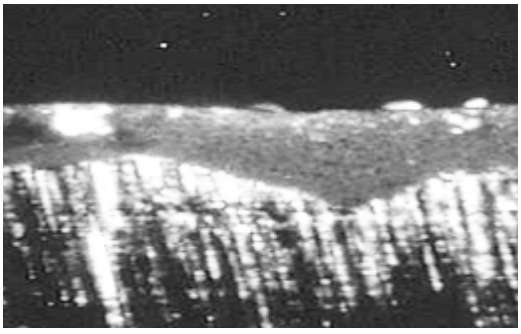

Figure 7.9 Illustration of Adhesion Concept

Adhesion can be chemical, mechanical, polar, or a combination of all three. The **chemical bond**, formed by a reaction between the coating and the substrate is the most effective bond. An example of a chemical bond is the galvanizing process, in which the molten zinc melts the surface

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layer of the steel and the two materials combine and form a series of alloys, essentially making the coating a part of the surface.

Inorganic zinc coatings also form a chemical bond between the silicate molecule and the steel substrate. Wash primers that normally include an acid element also form a chemical bond with the substrate.

Polar adhesion (*aka* **valance bonding**) is the most common type of bond for organic coatings. The resin acts as a weak magnet with the north and south poles attracting opposite poles on the substrate. Another explanation of this is that the polar groups are positively and negatively charged portions of the coating molecule that are attracted to oppositely charged areas on the substrate. Epoxies fall within this type of adhesion concept.

Mechanical adhesion is associated with surface roughness (anchor pattern). The roughness of the surface created by some types of surface preparation allows more points of contact between the molecules of the coating and the molecules of the surface. As contact points increase, adhesion increases.

Concrete has a different type of mechanical adhesion. The concrete surface is relatively porous with many minute surface pockets, surface checking, and other natural surface roughness. Coatings for such surfaces should be highly penetrating.

All forms of adhesion depend on direct contact between the coating and the substrate. Any type of contaminant on the surface interferes with this point-to-point contact and reduces the amount of adhesion.

7.6 Basic Inspection Considerations

The coating inspector should check to see if the materials delivered to the job site (coatings, thinners, cleaners, abrasives, putties, fillers, etc.) are the materials shown in the specification or as approved by the owner or his representative.

The inspector should have a copy of each approved product data sheet to compare the labels on the cans with the approved material named on the product data sheet. Any substitution of material should be reported immediately to the owner's representative. Be aware that even ***when two products have the same generic name they are not necessarily equal or even equivalent.***

The inspector should also check:

- Shelf life
- Storage conditions and temperatures
- Batch numbers and record them for each unit of coating

Batch numbers are always found on the coating pail, not on the product data sheet. It may be necessary to check each can in each shipment to ensure it is the proper material and to record all the batch numbers.

It is not unusual for a manufacturer to mix products on a pallet or to ship the same product but from different batches on the same pallet.

When two component materials are being used, the inspector should ensure that the correct amount of each component is on site, based on the mix ratio.

7.7 Inspector Checklist

- Specified material on site
- Expiration date of coatings when delivered on site
- Correct color(s)
- Correct and sufficient amounts of each component
- Legal and protective storage conditions

Key Terms Definitions

Additives: Liquid components of a coating, typically added in small amounts to perform a specific function.

Adhesion: The process in which dissimilar molecules cling together due to attractive forces. Adhesion can be chemical, mechanical, polar, or a combination of all three.

Barrier Coatings: A coating that: (1) has a high resistance to permeation of liquids and/or gases, or (2) is applied over a previously coated surface to prevent damage to the underlying coating during subsequent handling.

Binder: The nonvolatile portion of the vehicle of a formulated coating material.

Inhibitive Pigment: A pigment that passivates the metal surface by forming a thin, tightly adherent film or by reinforcing and plugging defects in the natural air-formed film.

Inorganic Coatings: Coatings whose binders are made from non-living things, most commonly based on either silicone or zinc.

Organic Coatings: Coatings whose binders are made from living or once-living things.

Pigment: The fine solid particles added during the manufacture of a coating which are substantially insoluble in the vehicle, used to impart color, corrosion control, or decorative properties.

Sacrificial Coatings: Coatings that use a metal that is anodic to steel and corrodes preferentially. Essentially, sacrificial coatings provide cathodic protection, especially in the vicinity of film defects.

Solvents: Added to coatings to liquefy the binder and allow for application in a productive manner.

Study Guide

1. List three (3) desirable properties of a coating.

   _____
   _____
   _____

2. Two (2) broad classifications of a coating are:

   _____
   _____

3. What are two (2) primary components of a liquid applied coating?

   _____
   _____

4. Describe the three (3) methods by which a coating provides corrosion control.

   _____
   _____
   _____

5. What are the three (3) different ways a coating can adhere to the surface?

   _____
   _____
   _____

Chapter 8: Coating Types and Curing Mechanisms

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Curing mechanisms
- Coating types
- Coating systems

Key Trade Terms

- Curing
- Nonconvertible coatings
- Convertible coatings
- Thermosetting
- Thermoplastic
- Acrylic resin
- Alkyd
- Chlorinated rubber
- Epoxy
- Furan
- Latex emulsions
- Phenol

8.1 Introduction

In the previous chapter, common functions of industrial and marine coatings were covered. In this chapter, individual coatings will be covered in greater detail.

Topics presented are:

- Curing mechanisms
- Coating types
- Coating systems

8.2 Curing Mechanisms

Curing is used to describe the way a coating transforms from a liquid to a solid state. For the majority of coatings used in industrial and marine work, a cure involves chemical reactions; however, some types of coatings may cure simply by solvent evaporation.

Understanding the curing mechanism is very important for the coating professional. Numerous factors: the time frames involved, the environmental elements during cure, the applied film thickness, and the mixing of the coating components have an effect on the cure and the ultimate service life of the coating. Testing and recording these events consumes a significant amount of an inspector's time.

There are two broad classifications of curing mechanisms:

- Nonconvertible
- Convertible

8.2.1 Nonconvertible Coatings

Nonconvertible coatings (Figure 8.1) cure by evaporation of the solvent. There is no chemical change to the resins in nonconvertible coatings as they transform from the liquid to the solid state. Once applied, nonconvertible coatings can be redissolved in the original solvent. Because they can be redissolved, these types of coatings are sometimes referred to as **thermoplastic** materials. Since it requires a large amount of solvent to dissolve the resin, in many parts

of the world use of nonconvertible coatings has been limited by VOC regulations.

Figure 8.1 Nonconvertible (Vinyl) Coatings. Chosen for Ease of Maintenance

8.2.1.1 Evaporation Cure

Dissolving the resin with a suitable solvent makes coatings that cure solely by solvent evaporation. No chemical change occurs upon evaporation. In fact, this type of coating may redissolve when exposed to the original solvent or one with similar solvency power. Examples include vinyl and chlorinated rubber.

Many of the antifouling coatings used on ships are nonconvertible and, due to the nature of the coating and small quantities used, are typically exempted from VOC regulations.

Areas of concern for the coating inspector are:

- Film thickness (typically very thin)
- Drying times (typically short)
- Ventilation in the area being painted

Overcoating these materials can be problematic since the solvents in the overcoating material may soften or dissolve it.

8.2.1.1.1 Coalescence

Coalescence cure is a specialized case of evaporation cure. In these coatings, tiny particles of resin are dispersed in water with the aid of specialized additives called surfactants. When the water evaporates, the resin particles fuse (coalesce) together to form the film. Particle fusion is assisted by small quantities of organic solvents (coalescing solvents). These types of coatings are also known as latexes or acrylic latexes, and are being used more and more.

Areas of concern for the coating inspector are:

- High surface temperature during application
- High wind flow over freshly coated surface
- Excessive film build
- Freezing temperatures

8.2.2 Convertible Coatings

Convertible coatings cure by one of several polymerization mechanisms, even when solvent evaporation is also involved. The resins used in convertible coatings undergo a chemical change as the cure progresses, so the resulting film is not readily redissolved in the solvent(s) used in application. These types of coatings are also known as ***thermoset*** materials.

There are a number of types of chemical reactions that take place. We present the primary chemical reactions in this chapter:

- Oxidation
- Co-reaction (polymerization)
- Hydration
- Fusion

8.2.2.1 Oxidation

Once the solvent evaporates from the film, these coatings cure by reaction with atmospheric oxygen. The main ingredient of the resin is a drying oil modified with synthetic molecules. The source of the drying oil is typically a vegetable oil (e.g., soy). Oxygen reacts with the oil portion of the resin, prompting a polymerization reaction known as ***oxidative cross-linking***. This reaction can be accelerated by the addition (during manufacturing) of driers.

Oxidation cure coatings are unsuitable for immersion service and cannot withstand an alkaline environment due to the reaction of alkaline materials with the oil portion of the resin (saponification). It should be noted that inorganic zinc coatings and galvanizing are not good primers for most oxidative curing materials. A common oxidative cure material is an alkyd.

The major area of concern for the coating inspector when using an oxidation-cure material is excessive film build. Even a slight amount of extra coating can retard the transmission of the oxygen molecule through the top portion of the film and stop the curing of the lower portion of the coating film. Wrinkling of the top portion of the coating is a visible sign of excessive film thickness.

8.2.2.2 Co-Reaction

Co-reaction coatings cure by polymerization reactions between at least two chemical entities. Polymerization basically means that a small molecule is transformed to a larger molecule by a variety of mechanisms. Polymerization is also referred to as ***cross linking***.

Co-reaction curing coatings cover a vast range of chemistries. Examples include:

- Epoxies
- Polyurethanes
- Polyureas
- Polyaspartics
- Polysiloxanes
- Others

These coatings generally come from the manufacturer in two separate containers; one contains the base, and the other contains the hardener or catalyst (cure).

These two components are mixed together just prior to application. Mix ratios range from 1:1 to 100:1 or more, depending on the material's chemistry. After mixing, the cure molecule attaches to the base molecule, and then another base molecule attaches to another spot on the cure molecule, and so on, until nearly all of the molecules are linked together as a single molecular chain (Figure 8.2).

For most solvent-borne coatings (those requiring solvents for application) the first step in the curing process is solvent evaporation. For ***co-reaction coatings the second step is polymerization, which may take several days or even several weeks before the film develops all of its properties.***

Once mixed together the reaction starts and the applicator has a limited amount of time to apply the coating before the reaction reaches its gel state. The time period when the mixed material is usable is called *pot life*. The exact amount of time in the **pot life** varies depending on the chemistry, temperature, and mass of the mixed material. Some co-reaction cured coatings also *require a*

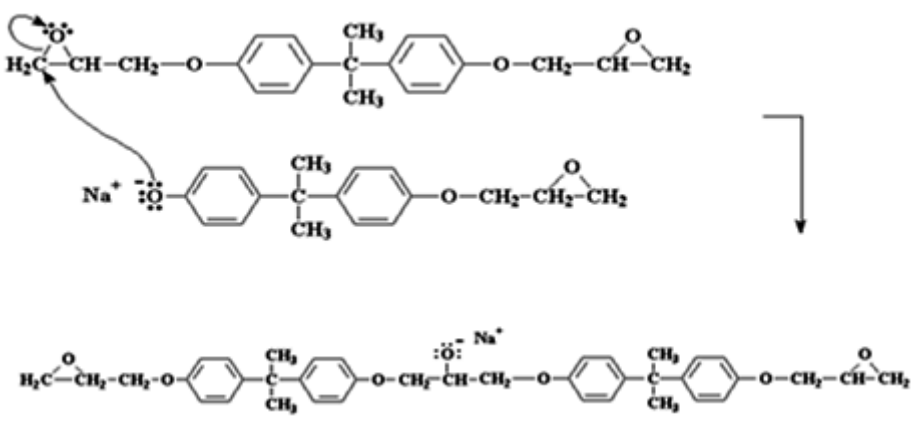

Figure 8.2 Illustration of Cross-Linking

period of time after mixing but before application for the chemical reaction to start; this is referred to as *the induction time*.

The coating inspector must confirm that the:

- Coating components are the correct ones
- Mixing ratio is correct
- Materials are fully mixed
- Induction time (if required) is observed
- Pot life is not exceeded

Another concern with many co-reaction coatings is the top coating; they must be top coated in a prescribed time frame known as the "overcoat window." It may be only a few hours or it may be a few days. Missing the overcoat window reduces the adhesion of the topcoat and may cause a premature failure of the coating system. Some products cannot be top coated at all and must be used as a stand-alone single coat system.

8.2.2.3 Hydration

Like concrete, hydration coatings require some amount of water to complete their cure.

Moisture-cured polyurethane is a hydration-cured coating material. It must have some level of humidity in the surrounding air for it to cure.

Another example is a solvent-based inorganic zinc coating based on an ethyl silicate resin. Upon application and solvent evaporation, water from the atmosphere reacts with the silicate to form silicic acid. The silicic acid reacts with the zinc pigment and polymerization proceeds until full cure.

A slightly different cure reaction takes place when using water-based inorganic zincs. These materials use some of the water that is in the product but also require carbon dioxide from the surrounding atmosphere to complete the cure process.

The areas of concern for the coating inspector are to ensure that the:

- Applied film thickness does not exceed the specified thickness
- Material is not top coated before it is cured

These materials appear to dry very rapidly — sometimes in a matter of minutes, and at a minimum, appear dry and cured in less than an hour. It may take as many as 24 hours before it is cured for top coating.

8.2.2.4 Fusion

Fusion is forced-heat curing. It is polymerization, but requires a particular temperature to complete the cure. Fusion-cured coatings may be single- or two-component materials.

An example is fusion-bonded epoxy (FBE) commonly used to coat pipelines in the petrochemical industry.

The area of concern for the inspector is to ensure the applicator follows the prescribed heat cycle for the coating in question.

8.3 Coating Types

Industrial and marine coatings are commonly referred to by their generic resin type, such as alkyd, epoxy, and polyurethane. In addition, they may be referred to by the type of resin and the curing agent used, such as epoxy amine, where an amine is used as the cure. Still other products contain more then one resin, such as an epoxy acrylic or a silicone alkyd.

The same generic materials from two different manufacturers may have very different features, depending on the exact formula and the manufacturing process used by each. Each manufacturer has its own blend of resin, pigment, additives and solvent, resulting in major differences in the serviceability of each one's particular coating.

8.3.1 Selection

The selection of a coating is based on many factors that include:

- Service environment of the coating:
  - — Interior or exterior
  - — Immersion or atmospheric
  - — Chemical
  - — In-service temperature (plus typical range and upset conditions)
- Substrate being coated
- Size and configuration of item to be coated
- Surface preparation available and possible at job site
- Application temperature and humidity
- Life expectancy of both item being coated, and coating
- Ability of applicators
- Availability of application equipment
- Availability of both item to be coated and coating material
- Critical safety requirements, e.g., a nuclear power plant, buried pipeline, or commercial ship
- Owner's comfort level with products or manufacturers
- Budget

8.3.2 Generic Types

8.3.2.1 Acrylic

Acrylic resins are primarily polymeric derivatives of acrylic and methacrylic acid. Acrylic coatings have excellent UV and weathering resistance and in some cases resistance to splash and spill of certain acids. These resins are commonly co-reacted with other resins to add UV and general weathering resistance to the combined material. Acrylics can also be applied as coalescence-cure emulsions and water dispersions.

Historically, these were applied as decorative coatings rather than for corrosion resistance. However, recent improvements in the manufacture of water-borne acrylics have created "industrial grade" acrylic coatings with very good corrosion resistant properties along with enhanced color and gloss retention.

Inspector's area of concern for water-borne acrylics:

- Must be aware of shipping and storage temperatures; anything below freezing 32°F (0°C) harms the material

8.3.2.2 Alkyds

Oxidative curing **alkyd coatings** sometimes referred to as "oil-based coatings" or oleo-resins have been in use in one form or another for thousands of years. Modern day alkyds are typically a combination of natural drying oils and synthetic resins. A beneficial feature of alkyds is that they are single package and are easy to apply with low cost equipment. A negative feature is that they can be very slow to cure.

Urethane alkyds are alkyd drying oils reacted with an isocyanate to produce a hard and durable film. These materials have been used in the food processing industry and have proven to stand up well to the necessary and constant cleaning required in those facilities. Urethane alkyds do not normally have better UV resistance than a standard alkyd but do have better chemical resistance and a harder more abrasion-resistant finish.

A small amount of an epoxy resin can be added to an alkyd coating to make an epoxy ester. This single package coating has better moisture and chemical resistance than a plain alkyd, but it should not be confused with a two-component epoxy which has far higher levels of water and chemical resistance.

Another common combination of alkyd is with a silicone when the material is used as an exterior coating. The US Navy uses silicone alkyds as their exterior topcoat on all surface ships.

Inspectors' areas of concern:

- Need to know the specific type of alkyd being used and follow the manufacturer's recommended curing times and over-coat information
- Very important to watch for excessive film build
- When an alkyd is used as a shop primer for industrial equipment it may be necessary to remove it prior to applying a two component coating over it
- Alkyd-based coatings are not normally compatible with concrete or zinc-based materials

8.3.2.3 Chlorinated Rubber

Evaporation-cure chlorinated rubber coatings were one of the earliest corrosion resistant coatings. They were developed in the 1930s and widely used in many industries. Chlorinated rubber coatings contain a large quantity of VOCs (regulated materials) and subsequently its use has been almost eliminated in most parts of the world. They were single package materials that exhibited excellent resistance to water, sunlight and many petroleum-based chemicals.

Inspector's concerns include:

- Ensuring the coating is applied only in a very thin film thickness per coat
- Understanding that sometimes as many as six (6) coats are needed to achieve full corrosion resistance
- Understanding that chlorinated rubber coatings should not be over coated with two-component coatings

8.3.2.4 Epoxy

Epoxy-based coatings were first developed in the mid-to-late 1950s and are now the most widely used industrial and marine protective coating. They are two-component

coatings packaged in separate containers. One container holds the epoxy resin (base), the other a curing agent (converter). Epoxies get their name from the reactive portion of the base, an epoxide (oxirane ring).

Most of the epoxy resins are formed by the reaction of bis-phenol A or bis-phenol F with epichlorohydrin. Numerous modifications can be made to optimize coating performance. Curing agents include amines, amides, ketamines, and isocyanates.

There are literally hundreds of epoxy resins and curing agents commercially available. These materials are also used in other applications, such as adhesives and structural repair materials. There are also numerous combinations of bases and curing agents.

Epoxies can be solvent-based, water-based, or essentially solvent-free. Epoxies can also be used in powder coating. Epoxies have excellent adhesion, chemical resistance, water resistance, and wet adhesion. They are susceptible to chalking and are normally top coated with a UV-resistant coating when in atmospheric service.

Epoxy resins can be blended with other resins or special pigments to modify the resistance characteristics of the basic epoxy:

- Blending with an acrylic resin increases UV resistance
- Blending with a phenolic resin increases chemical resistance
- Adding glass flakes increases impact and wear resistance
- Adding aluminum oxide or other irregular shaped material creates a non-skid material

Some epoxies, called **epoxy mastics**, are frequently sold and used as "surface tolerant coatings." This simply means that the manufacturer of the material has said their material adheres well to a surface that is not white-metal abrasive cleaned. These materials are formulated with excellent flow-out and penetration. They also may have an aluminum pigment in flake form to aid in reducing moisture penetration.

Inspector's concerns for epoxies:

- Ensure that the correct components are used in the correct ratio
- Ensure that the correct film builds are achieved during application
- Ensure that the necessary time frames for overcoating or in-service exposure are adhered to
- Amine-cured epoxies are especially sensitive to amine *blush*

Blushing is caused by absorption of moisture and carbon dioxide from the atmosphere during curing. This can happen when the coating is subjected to a drop in temperature shortly after application. Carbon dioxide in the air along with any moisture that is present combines with the amine-curing agent and forms a carbamate on the surface of the coating. This carbamate is an oily-feeling sticky liquid that cannot be coated over. It must be removed prior to overcoating.

Blush is relatively easy to see with the unaided eye. View the surface under a good light, rub a swab or gloved finger across it to disturb the oily layer enough to refract the light and the blush becomes visible. Sometimes a greasy feel is evidence enough.

There are a number of commercial methods to determine if blush is on the surface.

8.3.2.5 Furan

Furan resins, made from organic materials such as corn cobs, oat hulls and others, are

used as cements for acid-resistant brick floors and tanks. They have a broad range of chemical resistance including high concentrations of acids, alkalies and salt. This range of materials is not a true liquid applied coating but is blended with cement to form a trowel applied mortar.

These materials are applied by bricklayers, not coating applicators and are not inspected like liquid applied coatings. The coating inspector needs to discuss the inspection methods with the manufacturer of the furan materials.

8.3.2.6 Latex Emulsion

Latex emulsions are coatings that can contain a number of different resin particles that are covered with an emulsifier to keep them apart in the liquid stage. The resins are normally thermoplastic resins such as:

- Styrene-butadiene
- Vinyl acetate
- Vinyl-acrylic
- Acrylic esters

As the water and the emulsifier solvents leave the film, the particles coalesce into a solid film.

Inspectors' concern:

- Humidity in the area of the coating application must be low enough for the water to evaporate efficiently.

8.3.2.7 Phenolic

Phenol, also known as carbolic acid, is an organic chemical used in a very wide variety of manufactured items, including:

- Food
- Medicine
- Embalming procedures
- Bowling balls

In its pure form it is a very dangerous chemical and burns skin on contact. In fact, it was used for executions in World War II.

As a coating, it has a wide range of applications from thin-film coatings for plywood to thick-film baked-on coatings for lining rail cars carrying acid. Phenol resins can be blended with epoxy resins to form an epoxy phenolic, a product commonly used in containment areas of nuclear power plants.

Phenolic coatings offer consistent high quality protection for many applications including immersion service for most acids, solvents, and salts. It is typically used in low pH environments and when high temperature is a factor. Phenolic coatings have excellent resistance to 92–98% sulfuric acid at temperatures up to 120°F (49°C). They are also resistant to hydrochloric acid, phenol, anhydrous chloro-benzene, carbon tetrachloride, and many other chemicals.

Inspectors' concerns:

- Because there is a wide variety of these coatings, be prepared for the inspection by carefully reading each specific product data sheet.
- Baked-on phenolic coatings require a slow rise in temperature and strict adherence to the cure schedule.

8.3.2.8 Polyaspartic

Initially introduced in the 1990s as reactive diluents in conventional high-solids polyurethane coatings, polyaspartic coatings are now being used to achieve low- or near-zero VOC systems.

Technically, polyaspartics are aliphatic polyureas because these two-component materials involve the reaction between an aliphatic

polyisocyanate and a polyaspartic ester (aliphatic diamine). However, they are distinguished from polyureas because of different application and performance properties.

Polyaspartics are now being used as finish coats for exterior applications to replace high VOC polyurethane finish coats. Polyaspartics can be formulated with a range of reaction rates, allowing for pot lives from five minutes to several hours. Thus, these systems can be applied by conventional spray, as well as plural-component spray equipment. Polyaspartics also allow film builds up to 15 mils (380 µm) DFT in a single pass.

Coating inspectors perform normal inspection processes with these coatings, including environmental, cleanliness, holiday, and DFT.

8.3.2.9 Polyester

Industrial and marine grade polyester coatings are usually two-component coatings applied at normal temperature. Polyester coatings have a rather short pot life and should therefore be applied by a two-component airless spray equipment (regular airless spray use is possible with some materials on the market). At 68°F (20°C) the pot life is approximately 40-45 minutes. Styrene-free polyester, in which the styrene is replaced with vinyl toluene, can be applied in temperatures as low as 41°F (5°C) when applied with two-component airless spray equipment.

Polyester coatings are quick curing, glass flake reinforced, high-build coatings. They have excellent resistance to water and moisture, and are widely used in salt- and freshwater exposures. Polyester coatings have been used in petroleum storage tank linings for 50+ years.

These coatings also have exceptionally high abrasion resistance making them ideally suited for use on decks and walkways, hulls of icebreakers, tidal and splash zones of steel structures and concrete.

Inspectors' concerns:

- When used as tank bottom linings and when impregnated into glass cloth, ensure that all the glass is wetted out completely.
- Hardness tests may be required to ensure the lining is cured.

8.3.2.10 Polysiloxanes

Polysiloxane coatings are used in services characterized by abrasion, chemicals, extreme UV and high temperatures. The term polysiloxane refers to a polymer with a silicon-oxygen backbone. The silicon-oxygen backbone is much more resistant to the effects of UV radiation than the carbon-carbon backbone of organic polymers.

Advances in polysiloxane chemistry have resulted in the development of three major categories of this type of coating:

- **Inorganic Polysiloxanes:** Typical inorganic polysiloxanes cure by hydrolytic polycondensation. Formulated with the proper selection of additives and pigments, coatings can resist temperatures of approximately 1,400°F (760°C). Variation of pigment creates coatings with excellent solvent resistance.
- **Epoxy-Polysiloxane Hybrids**: Formulation with aliphatic epoxy resins, silicone intermediates, oxysilanes, and aminosilanes creates weather and corrosion-resistant hybrids. These coatings cure by both hydrolytic polycondensation and more conventional epoxy-amine mechanisms, resulting in what are known as ***interpene-***

trating polymer networks (IPN). The resulting formulations provide improved resistance to weathering over conventional epoxy coatings.

- **Acrylic-Polysiloxane Hybrids:** By combining acrylic and siloxane resins, a low-VOC, highly weatherable topcoat is produced. These systems can be produced as one- or two-component systems.

Each manufacturer of polysiloxane coatings makes a compatible primer and intermediate coating (called a tie coat in this case).

The coating inspector needs to ensure that the proper coatings are being used and are applied in the proper time frame.

8.3.2.11 Polyurethane

Polyurethanes are two-component materials involving the reaction between a polyisocyanate and a poly-functional alcohol. Properties of polyurethanes vary from very soft polymers to very hard cast materials.

There are two major types of polyurethanes: ***aromatic*** and ***aliphatic***.

Aliphatic polyurethanes are more resistant to UV attack and are typically used in exterior coating formulations. Aliphatic isocyanates, when used in the formulation of polyurethanes, provide coatings with excellent gloss and color retention.

Aromatic polyurethanes are extremely tough and have better chemical resistance in immersion than aliphatic types, but chalks rapidly in sunlight. They are commonly used in a thin film 1.5–2 mils (75– 100 microns) as the finish coat for exterior exposure in many industrial, marine, and commercial applications.

The main hazard associated with the use of polyurethane chemistries is the toxicity of the isocyanate component. Prolonged exposure to isocyanates can cause irreversible sensitization problems. Users must follow safety precautions identified in the MSDS and by their local safety officer.

Polyurethane coatings are available with a variety of curing times, from less than one minute to several hours. Apply slow curing coatings with conventional or airless spray equipment or by brush or roller. Use brush or roller application for small area touch ups. Use conventional airless spray systems to coat large surface areas. It is typical to use plural-component spray systems to apply very rapid cure coating systems, particularly for coatings with pot lives of fewer than five minutes. The advantage of plural-component spray equipment is that the coating components are kept apart until they mix at the spray gun.

Inspectors' concerns for polyurethanes include:

- Ensuring the proper materials, components, thinners and colors are used.
- Most polyurethanes, except moisture cured, are moisture sensitive during and just after application.

8.3.2.12 Polyureas

With many uses, from truck bed liners, to coatings for foam statues in amusement parks, to waste water treatment plant clarifiers, polyureas come in a wide range of formulations. Polyurea users have their own trade association, *Polyurea Development Association*: http://www.pda-online.org/

These two-component, very flexible materials have a very short cure time and may require special application equipment, such as plural component spray with a mixing

head in the gun. ***Reaction time can be as little as 9 seconds***. Because of the rapid cure, they do not adhere well to themselves after a very short period of time and are commonly applied in a single coat.

Many polyureas require an epoxy primer, as their adhesion to steel may not be sufficient for heavy-duty service. They are, however, commonly applied directly to concrete without a primer. They can also be applied to a backing cloth and used to form lining for an earthen pond.

A polyurea hybrid currently in use in the field is essentially a very high-build flexible polyurethane. When made in this formulation the material has excellent adhesion to steel.

Inspectors' concerns:

- When inspecting application of a polyurea or polyurea hybrid, pay close attention to the mix ratio and heating of the material.
- Check the applied DFT-at the beginning of the job to avoid problems later.
- When used on concrete tanks, the patching, filling, and overall design of the system is very important and must be completed prior to application of the lining.

8.3.2.13 Silicones

Silicones are formed by chemical modification of quartz, sand, or silicon and may be thought of as hybrids of glass and organic resins. They have the same inertness as glass but can be incorporated into coatings the same way as organic resins. Their major features are excellent resistance to high temperatures and UV radiation. However, their resistance to acids is not very good and they have a fairly high permeability rate. They are normally used over an anti-corrosive primer. They cure by a combination of solvent evaporation and heat.

Silicones are also used as foul-release coatings in the marine industry. Foul-release coating's surface makes it difficult for marine organisms to attach or stay attached. When ships reach a certain speed, the marine growth detaches since the "slick" coating compromises adhesion to the ship's hull.

An example of a blended silicone is the silicone alkyd discussed in the earlier section on alkyds. The major use of silicone coatings is for high temperature service. When pigmented with aluminum, silicone coatings can withstand temperatures up to 1,180°F (640°C), and when pigmented with ceramic, they can withstand temperatures up to 1,400°F (760°C). Silicone coatings are commonly used as topcoats for inorganic zinc applied to high temperature smoke and exhaust stack exteriors.

Coating inspectors' concerns:

- Must watch application and ensure the film is applied correctly in the usual very thin film 1–2 mils (25–50 microns).
- Many silicones require a slow rise in heat during first use; if temperatures rise too quickly, the silicone tends to delaminate on first use of the structure.
- Ensure workers carefully follow the manufacturer's instructions on heat cure.

8.3.2.14 Vinyl Esters

Vinyl ester coatings are often referred to as linings. A "lining" in the coating industry is commonly defined as:

" ... a material used to protect the inside surface of a tank, vessel, or similar structures

from highly corrosive or potentially highly corrosive environments."

Common uses include stack linings in power plants or linings of tanks and sumps in chemical plants.

Vinyl ester linings are normally two-component coatings applied at normal temperature. They are usually applied in thick coats 2 x 30 mils (2 x 750 microns). Vinyl ester coatings have a rather short pot life and should be applied with two-component airless spray equipment.

They are effective against a wide range of chemicals including acids and solvents. Their temperature resistance is also higher than most traditional organic coatings, and they have excellent abrasion resistance when glass flakes are added.

The inspector must ensure the surface is very clean, per NACE 2 (SA 2).

8.3.2.15 Vinyls

Vinyl coatings were one of the earliest industrial coatings and are still in use as linings for water pipes, penstocks and in waste and water plants. Thirty plus years is not an unusual life span for a well-applied system. Vinyl coatings were also the favorite topcoat for inorganic zinc used on highway bridges and were also used extensively in the marine industry. However, like the chlorinated rubber coatings they were commonly paired with, they contain a large amount of VOCs and have been banned from use in most countries.

When inspecting these materials, watch the applied WFT since these materials can be as low as 23% solids and are applied at high WFT to achieve very low DFTs. For tank and pipeline liners a system of six or seven coats in not unusual.

8.3.2.16 Inorganic Zinc

Inorganic zinc (IOZ) is probably the most-used primer for steel structures in the world at this time. It was developed in the late 1950s and has been used worldwide since then with very few changes in its basic chemical structure. Perhaps the latest development is a water-borne version marketed since the early 1990s. It is always used as a primer and can only be applied to a blast-cleaned steel surface. A common standard for cleaning is NACE 2 (SA 2 1/2) for atmosphere service and NACE 1 (SA 3) for immersion service.

The primary reason to use a zinc coating is to have a primer with the ability to provide cathodic protection. For the cathodic protection process to work properly, it is extremely important that the coating contains a sufficient quantity of zinc, usually above 75% weight of the dry film for water-borne coatings and 82% for solvent-borne coatings.

Inorganic zinc is very resistant to a variety of chemicals and solvents. Zinc ethyl silicate (solvent-based) and alkali silicate (water-based) are often used inside storage tank solvents because of its extremely good solvent resistance. Inorganic zinc coatings generally are not used in continuous water immersion service.

Typical practice in the use of inorganic zinc coating systems varies with the exposure environment and type of structure. One coat of inorganic zinc, typically 75–125 microns DFT, is often used for tank linings. The water-borne zinc silicate has to be applied with conventional spray. The solvent-borne

zinc-ethyl silicate, however, applies extremely well with airless spray. Multiple topcoats over inorganic zinc coatings are used for offshore structures, ships, industrial plants, refineries, tanks, bridges etc.

Inorganic zinc has very high heat resistance with a max of 400°C (750°F).

Coating inspector's concerns:

- Solvent-borne ethyl silicate zinc requires moisture, normally in form of humidity, to cure fully. It *appears* dry in a very short period of time but may take up to 24 hours at 50% RH to fully cure before it can be top coated.
- Solvent borne IOZ can be applied at very low temperatures, below the freezing point of water.
- Water-borne IOZ is limited to temperatures higher than freezing, and requires carbon dioxide to cure; it normally takes 24 hours to reach a point at which it can be topcoated.

Top coating IOZ requires a special application technique: apply a *mist coat* to barely wet out the surface, then as soon as the solvent flashes off, apply the full top coat. The mist coat helps seal the porosity of the inorganic zinc primer so pinholes are not created during the wet-coat application.

Apply inorganic zinc at a normal DFT of 50–75 microns (2–3 mils) and generally no more than 125 microns (5 mils) to avoid mud cracking. Inorganic zinc does not adhere to itself so a second coat should not be applied. If it is necessary to repair IOZ the inspector may suggest using organic zinc or surface-tolerant epoxy mastic.

8.3.2.17 Organic Zinc

Do not confuse *organic* zinc with *inorganic* zinc; they are very different coatings. Organic zinc is an epoxy coating with zinc filler. Since epoxy resins are very efficient insulators. They stop the cathodic protection reaction from taking place unless the coating film is cut, allowing the zinc to come in contact with the steel.

These materials do serve a function as they are commonly used as touch up primers for IOZ and for water and salt water immersion service, something for which IOZ is not recommended.

Organic zincs are not as application sensitive as IOZ but still require the same inspection considerations of standard epoxy.

8.4 Coating Systems

Coating materials are components of coating systems. A coating system is comprised of the:

- Surface preparation method used
- Application equipment and processes
- Materials used for one or more layers of coating

8.4.1 Single Coat

For many years, the main premise was that a single coat coating system was not sufficient to protect an industrial structure. However, with new technologies, advances in application equipment, and craft worker training, it is now possible to have a single coat coating system for certain applications.

Solvent-free polyurethanes and epoxies are now being used in the mainstream business of corrosion protection. Tank linings, both in the marine industry and in the water and wastewater business, are using these single

coat systems. Some manufacturers are pushing for use in other areas.

A single coat system requires that the applicator applies the coating very carefully, and the inspector carefully inspects the surface for holidays or other defects. Specialized equipment is necessary and planning the coating application for ease of access is also very necessary.

8.4.2 Multiple Coat

In most cases, a multiple-coat system is used in industrial and marine coating work. There are numerous reasons to use a multiple coating system. In many cases certain materials do an excellent job in one aspect of corrosion protection but not so well in other areas. The most common system uses IOZ as the primer, mainly because of its excellent adhesion to steel and its ability to provide cathodic protection at cuts, thus reducing the likelihood of undercutting corrosion. The second coat is normally a high-build epoxy, used as a barrier coat to reduce moisture penetration to the substrate. The final coat in an exterior system is typically polyurethane, used for its excellent resistance to UV.

8.4.3 Compatibility

Not all coatings work well together! A classic example is applying an alkyd coating over inorganic zinc or galvanizing; the high PH of the zinc forms a soap like material. The fatty oil in the alkyd reacts (saponification) between the two coatings. Some alkyds modified with phenol prevent saponification.

Another common mistake is applying a chemical-cure coating over a solvent-evaporation cure coating. The strong solvents in the topcoat soften the undercoat; the stress of curing the topcoat pulls the softened material from the surface.

8.4.4 Inspection Steps for Coatings

8.4.4.1 Prior to Job Start Up

- Acquire and read the project specification
- Acquire and read all coating work related documents that are in the reference section of the project specification
- Acquire and read all product data sheets for specified coatings
- Take training about unfamiliar materials from coating manufacturers and/or unfamiliar testing equipment from its manufacturers
- Review the specification and communicate with the owner if you find inconsistencies, or conflicting and/or incorrect statements
- Confirm and document that the submitted coatings match the specification
- Confirm and document that the colors submitted match the specification
- Confirm and document that the coating contractor has all certifications specified by the owner or required by international, national or local regulations
- Confirm and document that the craft workers have the certifications that are specified
- Review coating contractors' plans for storage of coating materials and confirm they meet national, local and owners' fire and environmental regulations
- Review the contractors' equipment plan and confirm that he intends to use the correct application equipment and procedures as required by the specification and the coating manufacturers' requirements
- Confirm that sufficient quantities of coating materials have been ordered

- Confirm that all the required testing equipment for the project are at hand
- Test all of equipment (including PPE) to ensure it is in working order and all spare parts and batteries are on hand
- Set up any computer-related documentation system needed
- Arrange for any laboratory testing of supplied coatings required by the specification
- Be aware of all environmental and disposal regulations

8.4.4.2 Upon Arrival of Coating Materials

Confirm that the materials received are the approved materials:

- Document the overall condition of the as-received materials
- Document the batch numbers as printed on each unit of material
- Document the date of manufacture and reject any material past its shelf life
- Confirm that the thinners and cleaners received match the technical specifications from the coating manufacturer and any special requirements of the owner
- Draw samples to send to laboratory for testing if required by specification
- Confirm that sufficient quantities of all materials have been received
- Confirm and document the storage conditions and temperatures
- Confirm and document that the storage conditions meet the coating manufacturers' and owners' requirements and any government regulations
- Confirm and document that the necessary components in the correct quantity are available
- Confirm and document that the correct colors have been received

8.4.4.3 At Application Start Up

- Confirm and document that all surface preparation has been accomplished and that the surface meets the required cleaning standard at the time of application
- Confirm and document that environmental conditions are within the range for the material being used
- Inspect and document that all required masking is in position and in working order, report any problems to the coating supervisor prior to application
- Inspect and document that any required environmental controls are in place and working properly, report any problems to the coating supervisor prior to application
- Confirm that materials brought to job location from storage are the correct materials and colors for each phase of project
- Observe and document the amount of material and batch numbers of material to be applied
- Observe and document that the correct components are being used for multicomponent materials
- Confirm and document that the equipment to be used is the correct equipment for the application
- Confirm and document that equipment set up meets owners' requirements
- Observe and document any approved portioning of the materials
- Observe and document the mixing of the materials
- Observe and document the addition of any thinner
- Observe and document the visual appearance of the mixed material and report any irregularities to the project supervisor before the material is used
- Observe and document any required induction time

- Observe and document the beginning of pot life if necessary for the material in use
- Review your test equipment instructions
- Check and document the calibration of your inspection equipment

8.4.4.4 During Application

- Observe pot life during application and report to the project supervisor if the material has reached the end of its pot life
- Document the use of any material that was applied after the end of its pot life
- Observe and document application of material, report any observed problems as soon as possible to the project supervisor
- Check and document wet film thickness if required
- Observe and document that the applicator checked WFT at regular intervals during application
- Visually check application for equipment problems and workmanship during application
- Report any observed problems as soon as possible to project supervisor
- Document all observed application irregularities and how they were repaired
- Check for holidays, pinholes and other irregularities of the applied material as soon as reasonable during and at the end of the application
- Observe and document time frame and environmental conditions between each coat
- Inspect the cleanliness of each coat prior to application of additional material

8.4.4.5 After Material Has Cured

- Visually observe and document any holidays
- Perform holiday test if required and in accordance with the specification
- Test and document the DFT of the applied material after it has cured and in accordance with the specified procedure
- Test (adjust if necessary and allowed), confirm, and document the accuracy of any gauges you use at the beginning and the end of each shift
- Perform any other tests such as hardness, color, or gloss that may be specified
- Observe and document any repairs to the coating system made necessary by your inspection

8.4.4.6 At the End of the Project

- Observe and document the cleanup of the project site
- Document all materials left over and how they are to be disposed of with regard to regulatory requirements
- Complete and deliver all reports

Key Terms Definitions

Acrylic: A type of resin polymerized from acrylic acid, methacrylic acid, esters of these acids, or acrylonitrile.

Alkyd: A type of resin formed by the reaction of polyhydric alcohols and polybasic acids, part of which is derived from saturated or unsaturated oils or fats.

Convertible Coatings: Coatings that cure by one of several polymerization mechanisms, even when solvent evaporation is also involved.

Chlorinated Rubber: One of the earliest corrosion resistant coatings; developed in the 1930s, they were widely used in many industries. Chlorinated rubber contains a large amount of VOC and its use has been almost eliminated in most parts of the world.

Curing: Chemical process of developing the intended properties of a coating or other material (e.g., resin) over a period of time.

Epoxy: A type of resin formed by the reaction of aliphatic or aromatic polyols (such as bisphenol) with epichlorohydrin and characterized by the presence of reactive oxirane end groups.

Furan: A type of resin formed by the polymerization or polycondensation of furfuryl, furfuryl alcohol, or other compounds containing a furan ring.

Latex Emulsions: Coatings that can contain a number of different resin particles that are covered with an emulsifier to keep them apart in the liquid stage.

Nonconvertible Coatings: Coatings that cure by evaporation of the solvent. There is no chemical change to the resins as they transform from the liquid to solid state.

Phenol: An organic chemical used in a very wide variety of manufactured items. Also known as carbolic acid.

Thermosetting: A coating that is formed as a result of a chemical cross-linking reaction (oxidation, polymerization, chemical additive reaction, heat, or a combination of these).

Thermoplastic: A material capable of being repeatedly softened by heat and hardened by cooling.

Study Guide

1. The two (2) broad classification for curing mechanisms are:

   _____
   _____

2. List two (2) non-convertible coating types.

   _____
   _____

3. List three (3) convertible coating curing mechanisms.

   _____
   _____
   _____

4. List two (2) characteristics of oxidation cure coatings.

   _____
   _____

5. List three (3) coatings types that cure by polymerization.

   _____
   _____
   _____

6. Induction time is:

   _____
   _____

7. What is a main requirement for a hydration coating to cure?

   _____
   _____
   _____

8. Industrial and marine coatings are commonly referred to by:

   _____
   _____

9. Oil based coatings applied over alkaline surfaces may result in:

   _____
   _____

Chapter 9: Coating Project Specification

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Coating specification definition
- Elements of a typical specification
- Owner's relationship to the coating inspector
- Inspector's responsibilities

9.1 Introduction

In this chapter, the coatings specification and its relationship to the coatings inspector through the following aspects is examined:

- Coating specification definition
- Relationship to the coating inspector
- Elements of a typical specification
- Specification critical examination
- References and resources
- Resolving technical conflicts
- Inspector's responsibilities regarding the coatings specification

9.2 Coating Specification Definition

In Webster's 20th Century Dictionary the definition of a specification is:

"A particular and detailed description of a thing: specifically a statement of particulars describing the dimensions, details, or peculiarities of any work about to be undertaken as in architecture, building, engineering, etc."

NACE modifies that formal definition to simply say:

"A coating specification is a formal document that tells the contractor (applicator) what to do and where to do it, but generally does not tell him or her how to do it."

Throughout this course you will observe, except in rare cases, that the terms *contractor* and *applicator* will be used interchangeably to mean the same thing

Coating specifications are normally tailored to meet the requirements for a particular job, and they come in many forms and in various degrees of quality and clarity. Sometimes a coating specification is so vague it defies interpretation by anyone, including the person who wrote it.

For example, years ago a registered professional engineer in the US issued this specification for an elevated water tower:

> *Clean and paint the elevated tank tower at 1121 Julia Street, Anywhere, Texas, with (3) coats of a good paint.*

If you were the contractor how would you interpret this specification? How would you bid the job? There are many questions that must be asked:

- What is clean?
- What is good paint?

- Are the legs and the bowl to be painted or just the bowl?
- Is the interior to be painted also?

If you were the paint supplier, what material would you try to sell the contractor?

If you were the inspector, how would you know what to inspect?

Clearly, this type of specification is a nightmare for everyone. If allowed to stand, the owner would be lucky to get a decent job.

Today most specifications are written on computers so it is very easy to "cut and paste" a specification from a previous job without paying attention to the accuracy, practicability, and adaptability to the current job without taking into consideration advances in technology. "Cut and paste" without careful and thoughtful attention can mean a worthless specification.

A well-prepared specification goes a long way toward making a job go smoothly *and* pleasing all parties — the owner gets a good job and the contractor makes money.

The coating specification is the inspector's guideline to the coating job. Before any coating job starts, the coating inspector should:

- Obtain and read every part of the specification
- Make certain that he or she has a complete and accurate understanding of the specification
- Clarify with the supervisor or owner's representative any aspects of the coating specification that seem inaccurate, impractical or not easily understood

9.3 Elements of a Typical Specification

Most specifications are formal, structured documents. A good coating specification contains most or all of the following sections, each with information and criteria for the job:

- Scope of work
- Terms and definitions
- Reference standards and codes
- Safety
- Pre-job conference
- Surface preparation
- Coating materials (includes the coating schedule)
- Sampling coatings
- Workmanship
- Application
- Work schedule (sequence of work to be done)
- Repairs and remedial coating work
- Inspection
- Documentation

9.3.1 Scope of Work

This section describes the work to be done and when and where it is to be done. The scope should list each item to be coated, as well as a list referring to all areas that are to be protected and ***not*** coated. This section may also indicate the purpose of the coating project and any unusual or specific limitations that the contractor may encounter.

Please note: *Text in italics* are samples of possible specification text.

This specification is intended for use by the owner and appointed contractors who work

directly or indirectly for the company (owner).

Contractor shall clean and repaint the exterior surfaces of tanks numbered Tank #1642 — 10,000 bbl and Tank #1626 — 7,500 bbl, and shall furnish, at their cost, all labor, supervision, equipment, materials as necessary to perform the work. Consult the attached shop drawing (Plate #32, dated August 21, 1987 prepared by Echo Engineering Co.) for location of the above described tanks and appurtenances.

Some specific exclusions may be made:

- *All instruments, recorders, gauge glasses, and galvanized surfaces in the tank farm shall be covered and protected and shall NOT be coated.*
- Issues related to timing of the project, including start dates and intended milestones for the project may also be included:
- *The project is scheduled to commence operations within 270 days from the date of this tender proposal. The owner will conduct an inspection of the facilities to be painted and will hold a pre-tender meeting of all prospective tender submitters on site at 1400, April 26, 2002. Tenders will be due on or before 1400, May 5, 2002, and the contractor will be required to commence work on or before May 19, 2002. All coating work covered by this specification must be completed on or before August 21, 2002, subject to a penalty of $5,000 for each day completion of the job is delayed beyond August 21, 2002.*

The specifier may also define any special conditions that the contractor must know about in this opening section. Issues that involve regulatory authorities must be communicated clearly, for example:

The owner has inspected these tanks and believes there is no lead in the existing paint on these tanks.

Contact information may be provided to allow gathering of information related to the project and to make available full information before a price for the work is proposed:

- *The owner of this facility to be painted is:*

  Alpha Refining Company
  10920 Bledsoe Avenue
  Roaming Creek, VA 17216

- *Echo Engineering, Boulder, NC is the designated representative responsible for all aspects of this coating project entitled Job #RP-16378.*
- *For additional information on this project, contact Mr. James Glenn, Project Engineer, Echo Engineering* Co. *(666) 213-8000.*

Finally, the owner may choose to emphasize that the contractor is responsible for completion of the work in accordance with the specification:

All work shall be subject to inspection by the owner, but this in no way reduces the responsibility of the contractor to comply with the technical requirements of the specification.

9.3.2 Terms and Definitions

A good specification defines specific words and terms in order to clarify their meaning for that particular document. For example:

*The words **shall, will, shall not, will not, should,** and **may** are to be found in the body of this document and are used to signify the following:*

> *The words **shall** and **shall not** are used where a provision is mandatory, and the*

contractor must comply with that part of the specification as written.

*The word **should** is not obligatory and is used where a provision is preferred and indicates a strong recommendation to the contractor to fulfill that part of the specification.*

*The word **may** is used where alternatives are acceptable; the contractor has options and should choose his or her preferred option.*

*The words **will** and **will not** are used in connection with an action of the owner rather than of the contractor.*

Here is an example:

The contractor shall place a protective cover over all parts of the project engineer's Rolls-Royce during all phases of the coating project and shall remove this cover only at the request of the project engineer. The contractor should cover all other cars in the vicinity of the coating project. The contractor may use 8.0 mil plastic sheeting or 20 oz. canvas cloth to cover the project engineer's Rolls Royce, etc. At appropriate intervals, the owner will determine whether the protective cover is in place.

Several other terms or definitions could be included in this section, including definitions of personnel, such as:

- *Owner of company means the registered owner of the facility in question or his or her designated representative.*
- *Applicator/contractor means the successful tender submitter responsible for doing the coating work.*
- *Foreman means the applicator's representative on site who is the responsible party for the contractor.*
- *Inspector means the person designated to carry out the inspection procedures according to the specification.*
- *Specifying engineer means the person who can resolve non conformance issues or make changes to the specifications. It may also be the person who drafted the specifications. (The specifying engineer may also be known as the project engineer or just engineer.)*
- *Specifier means the person who drafted the specifications. The person may or may not also be the specifying engineer.*
- *Coating supplier means the manufacturer (or a designated representative) of the coating materials used on the project.*

9.3.3 Reference Standards

The specification generally includes a list of published standards referenced by particular sections or parts of the document. Any part of a referenced standard may be as binding on all parties as the entire standard, unless an exception is noted.

9.3.4 Safety

Many specifications begin this section with a catch-all phrase, such as:

Work shall be done in a safe manner in accordance with all applicable federal, state, and local safety codes.

Generally, the owner has his or her own safety manual, which cites specific safety requirements, such as:

- *Wearing hard hats*
- *Use of breathing apparatus (owner may require respirator fitting for all contract personnel)*
- *Use of protective clothing, usually in contrasting but identifying colors as to class of personnel, such as:*
  - *Refinery personnel (owner's*

personnel) ***blue***
- — *Paint contractor's personnel* ***orange***
- — *Other contract personnel* ***yellow***

- *Requirements for special permits for certain plant areas, such as confined spaces; such permits usually are valid only for an 8-hour shift and may require a standby worker outside the confined space at all times*
- *Other plant requirements, such as identification of safe havens to be used in the event of emergencies*

Some companies require contract personnel to attend a company-sponsored safety school and successfully pass an examination in order to work in the plant. In such a school, much attention is directed to site-specific safety issues.

9.3.5 Pre-Job Conference

A good specification will require a pre-job conference so that all parties — the owner, contractor, coating supplier, and inspector — can convene to review standards and work procedures for the project. Discussion should include all aspects of the specification but is most likely to focus on:

- Scope
- Safety practices
- Pre-cleaning inspection
- Cleaning operations
- Coating materials and handling practices
- Application procedures
- Inspection (tools, methods, and sequence)
- Contractor submittals
- Change orders, if any

No coating specification is ever perfect. Problems are likely to occur. Even the best prepared document is likely to contain errors or ambiguities, which should be resolved in this type of forum. Methods to resolve problems the contractor might encounter as the job progresses should be agreed on in the pre-job conference.

More importantly, it is here that the inspector (independent, in-house, or the contractor's) determines his or her authority and responsibilities. As one inspector put it: "*If a contractor is going to get mad, it is better that he gets mad up front rather than later in the job.* Issues should be resolved as early as possible and preferably without anyone getting mad! The ability of the inspector to participate in objective discussions and help to achieve a fair resolution is one valuable part of the inspectors' role.

9.3.6 Surface Preparation

It is generally believed that 60 – 80% of all premature coating failures are attributable to inadequate or improper surface preparation. This section of the specification becomes a vital part of the document, and the specifier should be particularly clear and concise in the intent and wording of this element of the specification.

Requirements vary with the project, but this section should deal with all parts of the cleaning process, which should include such items as:

- Pre-inspection: a procedure to inspect for, mark, and correct all fabrication defects
- Pre-cleaning: removal of such contaminants as oil, grease, dirt, etc. by solvent cleaning to a known standard, e.g., SSPC-SP 1, "Solvent Cleaning;" this step must be done before any other surface preparation can proceed

- Cleaning operations to referenced standards

An example of surface preparation text might say:

*After all fabrication defects have been duly corrected and approved by the engineer and all surfaces to be coated have been solvent cleaned and approved by the engineer, the contractor shall proceed with the cleaning process as follo*ws:

Prepare the clean, dry surfaces by abrasive blasting using DuPont StarBlast #6 in accordance with Surface Preparation Standard NACE No. 1/SSPC-SP 5, "White Metal Blast Cleaning." Blast cleaning shall achieve a surface profile (also called anchor profile) of 1.5 to 3.0 mil (38 to 75 µm) as determined by NACE Standard RP0287, "Field Measurement of Surface Profile of Abrasive Blasted Steel Using Replica Tape."

Note: An alternative standard which can be specified is ISO Sa3 (ISO 8501: 1) "Blast Cleaning to Visually Cleaned Steel."

After surface preparation of the substrate, grit, dust, etc. shall be removed and a coat of primer applied before any detrimental corrosion or recontamination occurs.

Other parts of this section could deal with abrasives, equipment, techniques, and restrictions. For example:

Blast cleaning shall not be done when the steel temperature is less than 5°F (3°C) above the dew point or when relative humidity is 85% or greater, etc. Venturi nozzles shall be discarded when worn such that the internal diameter is 20% or more greater than when new or when the nozzle has worn one size from the original diameter size, e.g., if a #6 nozzle in use wears to a #7, it shall be discarded.

It is important that specification statements are detailed and specific. In the statement immediately above, the contractor may object to being told what nozzle to use. *Without such instructions, however, inspectors cannot make objective judgments.* It might be suggested that equipment should be properly sized for the project, and equipment that is not in good condition shall not be used. Such statements do not define any criteria that could be used to measure whether equipment is fit for the purpose. Inspectors would have to use their own experience and judgment, as would the contractor, and clearly there is potential for disagreement.

9.3.7 Coating Materials

Selecting coating materials involves matching a coating with the environment and in-service conditions that it serves. The specifier must be able to access each area to be coated and rank each according to the anticipated operating conditions; then he or she determines which coating to use in each environment. As a guideline, the engineer could use the table titled *Typical SSPC Painting Systems for Environmental Zones,* which lists various environmental zones of usage and recommends corresponding generic coatings.

Selecting coatings for atmospheric exposure where there is opportunity for periodic inspection and maintenance, may not be as critical as selecting coatings for buried or submerged surfaces, or as a lining for a vessel.

The specifier has several options available when selecting coatings for the project. Examples of some options are:

- Selecting according to generic formula, such as SSPC Paint #20, AWWA C-204 Interior System #8, MIL Spec. C-15203, etc.
- Selecting materials based on performance criteria, such as percent solids by weight and volume, viscosity, weight per gallon, gloss, dielectric strength, permeability, abrasion resistance, pencil hardness, pass 4,000 in a salt fog apparatus, etc., all according to test methods listed in such publications as those issued by ASTM
- Single source selection — the adoption of a specific coating or coating system, usually based on known field performance, generally supplied by a single manufacturer or approved equal. It could also include a list of approved systems with manufacturers and products defined for each.

Sometimes a specifier determines that coating materials from one manufacturer are acceptable but is open to considering other products. When this is the case, the specification lists one manufacturer's coatings by name and indicates an approved equal. The contractor is then free to select an alternative coating, provided the owner (or specifier) is satisfied the alternative materials are equal.

Each user has a preferred method of specifying coatings and may employ one of the above methods or some combination of them. Other issues found in this section may include handling, storage, mixing, and thinning of coatings used on the project.

9.3.8 Coating Schedule

In most instances, when the project is relatively simple, coating schedule information is included in the scope of the specification. When the coating project is more complex, coating schedule information may be listed separately, either as a section of the specification or as a separate appendix. It identifies each area to be coated and each area to be protected, covered, and **not** coated.

9.3.9 Workmanship

A coating specification may include a catch-all phrase like the following:

All work shall be performed in strict accordance with these specifications and with the coating manufacturer's current printed instructions for materials to be used on this project. Work shall be performed by skilled workmen in a safe and workmanlike manner.

This is an open-ended phrase, subject to interpretation and often much misunderstanding. The specification should define what is meant by good workmanship, for example:

Application shall be in accordance with the principles of good workmanship described in SSPC-PA 1.

A more detailed approach is to require operators to be qualified according to ASTM Standards D 4227 and 4228 or to NACE International's Guide to Qualification of Tradesman Industrial Maintenance Painters.

Requirements for operator training are increasingly used in industry. Applicators must establish some type of craft assessment to determine the level of work competence.

9.3.10 Application

This section defines approved methods for coating application:

- Brush
- Roller (hand- or power-type)
- Air spray
- Airless spray
- Plural-component spray

- Air-assisted airless spray, etc.
- Thickness (wet film, dry film)

Although measuring WFT and DFT are not application methods, they are critical steps in the application process and thus are included in the specification.

A good specification states the minimum and maximum dry-film thickness (DFT) of each coat of the coating system and total minimum and maximum allowable DFT. In addition, a specification may call for stripe coating then identify areas to be striped and the appropriate procedure to follow.

The DFT of stripe coats cannot easily be specified or controlled in the field. References to stripe coat thickness may include statements such as "*apply a full-bodied stripe coat*" or "*achieve full and complete coverage.*" It may also mention that stripe coats "*shall be color contrasting and must be dry before any overcoating takes place. Measurements of stripe coat DFT are likely to be unreliable due to the proximity of edges, sharp corners, or weld seams. Stripe coats shall be color contrasting, and be over coated dry.*"

9.3.11 Work Schedule

It is generally the responsibility of the contractor to establish his or her own work schedule and submit it to the engineer for approval prior to starting the job. Owners are generally reluctant to tell contractors how to schedule their work.

The owner may, however, set limits for starting and completing the job and require the contractor to submit a written work plan or schedule. The schedule times should include these items:

- Pre-inspection
- Pre-cleaning
- Repair of fabrication defects
- Surface preparation
- Application
- Inspection intervals and hold points
- Repair and remedial coating work
- Documentation and reports

The owner or specifier may, in this section, identify access points to the plant and job site and the allowable working hours for the contractor. It would be unfair, for instance, to let the contractor believe that work could start at 7 a.m. when the gates do not open until 9 a.m. If this were the case, the contractor would have a valid claim for 2 hours of standby time. Other known restrictions and limitations should also be designated.

9.3.12 Repair and Remedial Coating Work

Repair work is almost guaranteed on any new coating installation. The specification should identify procedures for repair work and require the contractor to repair any damage to the coating work, as well as describe the procedure to use. Consider, for example:

Contractor shall identify damage to the coating and shall feather-edge the coating around the damaged area a minimum of three (3) in (75 mm) from the center of the damaged area in all directions. Contractor shall use 80-grit abrasive-coated paper to expose each coat of the coating system, including the primer. Using the finish coating material as the repair material, the contractor shall apply, by brush, the same number of coats as is found in the repair area. Total thickness of the repair shall be no less than 90% of the total thickness of the adjacent undamaged coating.

9.3.13 Inspection

As stated earlier, coating specifications vary and are usually tailored to meet the requirements of a particular job. The inspection plan should vary also. Owners may choose to specify their own inspector, an independent inspector, or the contractor's inspector (in which case, the completed job is subject to review and acceptance by the owner). Specifiers should address specific elements of inspection, such as:

- Measuring ambient conditions at the work site throughout the job (dew point, relative humidity, air and steel temperatures, etc.)
- Pre-inspection (fabrication defects, steel condition, presence of surface contaminants, etc.)
- Pre-cleaning (removal of oil, grease, dirt, etc.)
- Surface preparation (equipment, abrasives, cleanliness, profile, etc.)
- Coating materials (storage, identification, mixing and thinning, etc.)
- Application (equipment, thinners, WFT, DFT, recoat times, etc.)
- Inspection (hold points, visual, holiday detection, etc.)
- Documentation (record keeping, reports, etc.)

In the best case, the specification outlines inspection procedures, defines the inspector's tasks and includes pertinent criteria such as:

- When, where, and how many measurements to take
- Pass/fail criteria for all measurements
- What inspection tools to use
- Guidelines for completing and submitting reports
- A comprehensive statement of the inspector's responsibilities and authority
- An organizational chart showing the chain of command and the inspector's position

If guidelines do not exist, inspectors should establish their own procedures containing the same elements. These elements should relate to the various sections of the specification just mentioned.

9.4 Owner's Relationship to the Coating Inspector

9.4.1 The Coating Specification and the Coating Inspector

It is important to realize that almost every user of coating inspection has their own ideas of the duties and responsibilities of an inspector. There seems to be no general agreement within the industry on the day-to-day activities of an inspector and the inspection itself. An independent inspector, particularly, will find the job changes according to the client.

Some owners regard the inspector as a project supervisor and assign duties like supervising safety issues or labor, keeping track of and ordering materials, and normal quality control testing.

Other owners may instruct the inspector simply to observe the work, make tests and measurements, and report directly to the owner without any dialogue with contractors or their workers. Conceivably, at some point an inspector may be called on to represent either extreme.

For the purposes of CIP, NACE has defined the inspector's role as that of **a quality control technician who is primarily responsible for observing and reporting the technical aspects of a coating project.**

Supervision and health, safety and the environment (HSE) oversight are **not** considered to be part of the inspector's role unless specifically designated.

With this in mind, Section 9.5 examines various parts of the specification and considers the role of the inspector, particularly duties and responsibilities in relation to the specification.

Documentation

Documentation is included with the section on inspection and refers to all record keeping and reports of the inspection process.

Inspectors should remember that the documentation they prepare may be the most significant record of the work performed on a project. It should be accurate and easy to understand, for readers who may not have specific knowledge of the job or the project location.

9.5 Inspector's Responsibilities Regarding the Specification

9.5.1 Inspector's Responsibilities Regarding the Job Site

Inspectors should walk through the job site to become thoroughly familiar with the surroundings (Figure 9.1). On the walk-through, note each item to be coated or left uncoated (as described in the specification's scope of work section or in a separate coating schedule) and obtain any maps or drawings that would be helpful. If necessary, on complex projects, make a specific list of exactly what items are to be coated and what items are to be kept free of coatings.

Check that all items to be left uncoated are properly covered and protected during the coating operations, including:

- Identity plates
- Breather holes
- Electrical equipment
- Metering and monitoring instruments
- Gauge glass covers

Also check from time to time to see that the necessary protection remains in place until the job is completed.

If there is more than one inspector on the job, each one should know exactly the items for which he or she is responsible, and the supervising inspector should ensure that each item to be inspected is assigned to someone.

Figure 9.1 Inspectors at Work

9.5.2 Inspector's Responsibilities Regarding Standards and Codes

Generally, the specification requires the contractor to work in a safe manner in accordance with all applicable federal, state, and local codes, etc. It is the contractor's responsibility to observe and follow such codes, and he is liable if he fails to do so. However, a prudent inspector determines what codes are applicable and acquires a working knowledge of them.

Coating specifications also frequently reference various published standards that relate to particular parts of the document. *Since a referenced standard (or part thereof) becomes part of the specification*, the inspector must obtain, study, and become familiar with each and every part of the standard and its relationship to the project (Figure 9.2).

Figure 9.2 Code of Federal Regulation re. Labor

9.5.3 Inspector's Responsibility Regarding Safety

Safety is the responsibility of all workers involved at the job site. The employer has the primary liability for safety. Inspectors should know enough to recognize safety violations because they involve their own personal safety and the safety of the crew on the job.

An inspector is not a safety engineer or supervisor but is responsible for:

- His or her own safety (Figure 9.3)
- Reporting any unsafe conditions or practices to the safety engineer or supervisor
- Following all specific safety requirements as set forth in the specification and by the safety engineer or supervisor

For their own safety, inspectors should also know:

- Safe practices for working with solvents, coatings, spray equipment, scaffolding, abrasive blasting, etc.
- Location of first aid stations
- Location of the nearest telephone and emergency telephone numbers (ambulance, fire department, safety engineer)

Figure 9.3 Inspector Wearing Breathing Apparatus

9.5.3.1 Material Safety Data Sheets (MSDS)

In many countries, including the US, MSDS are required on the job. These data sheets are required by legislation to provide workers with information regarding the hazards they face in their working environment.

Inspectors and other workers should be informed of any hazardous substances associated with the work they perform, and they should receive appropriate training in minimizing risk of personal injury or medical

consequences that might result from performing the work. MSDS are discussed in more detail in Chapter 18.2.

9.5.4 Inspector's Responsibilities Regarding Pre-Job Conference

Inspectors should study the specifications *before* the meeting and *prepare a list of questions* regarding any phase of the job that is not clear. They should not leave the meeting without a crystal clear understanding, preferably in writing, of:

- The specification and changes, modifications, or waivers, if any
- Their authority on the job
- Their specific responsibilities on the job

9.5.5 Inspector's Responsibilities Regarding Surface Preparation

9.5.5.1 Standards

Standards (Figure 9.4, Figure 9.5) are an essential part of the quality control of coating operations and are discussed in many other portions of the CIP program.

When following surface preparation standards, an inspector should:

- Ensure specified cleanliness standard is used
- Ensure surface is prepared as specified
- Not ask for cleaner surface than specified
- Verify that only specified materials (e.g., grit, cleaning solvents) are used

Figure 9.4 SSPC-VIS 1 Surface Preparation Standard

Figure 9.5 SSPC-VIS 3 Surface Preparation Standard

9.5.5.2 Anchor Profile

Know exactly what anchor pattern tolerances are allowed. If the specification states a minimum 1.5 mil (38-µm) anchor pattern (surface profile), 1.3 mil (33 µm) is not acceptable.

A well-written specification requires a surface profile range, such as between 1.0 to 2.0 mil (25 to 50 µm), or will express surface profile with a variable, such as 1.5 mil ± 0.5 mil (38 µm ± 12.7 µm). **Be sure to clarify this point at the pre-job meeting**.

More is not necessarily better. An anchor pattern that is too deep is as out of specifica-

tion as one that is too shallow. It is unfair to the client to allow the contractor to get by with substandard cleaning. It is also unfair to the contractor to require a higher degree of cleanliness than that specified. Cleaning is expensive and the contractor is contractually bound to clean the work to a specified degree, **not more**.

Insist on the standard of cleanliness specified; ask for no more and accept no less. Know what cleaning materials are to be used, and determine that the actual materials are clean and as specified.

9.5.6 Inspector's Responsibilities Regarding Coating Materials

Make sure that the coatings and allowable thinners used are those specified. Know where the coatings are stored on site. Ensure storage conditions are in accordance with specifications and the manufacturer's latest instructions. Check containers for any sign of damage.

Know how the coatings are to be mixed, thinned, and agitated, and then ensure that this happens. Be sure all pigments are worked into the liquid coating. If the coating is a two-pack or three-pack product, be sure the correct components are stirred properly, combined as specified and then mixed thoroughly. Make sure the workers observe manufacturer's recommended pot life and induction or sweat-in times. Know the volume of solids, wet-film and dry-film thicknesses specified and allowable tolerances, dry, and re-coat times, and times for proper cure.

Figure 9.6 Coating Materials in Packaging

9.5.6.1 Sampling Coatings

The specification may require the contractor or inspector to take samples of the coatings on the project, spelling out the sampling procedure, number of samples taken, labeling procedures, and storage requirements, etc.

The sampler should use only clean containers when taking partial samples to avoid contaminating the sample. Samples may be partial 0.5 pint to 1 qt. (250 mLto 1 L) or unopened containers, 1 to 5 gals (5 to 20 L). The inspector may be required to visit the manufacturer's plant to take samples of the coating.

Inspector's Responsibilities Regarding Sampling Coatings

Alternatively, the coating specification may require the inspector to take samples of the coating materials on site. The inspector should follow the specification carefully, as well as the following:

- Select coatings to be sampled at random
- Ensure coatings are thoroughly mixed
- Place the amount specified in the correct container
- Label the sample container with the following data:
    - — Product name and number

- Color
- Batch number
- Date the sample was taken
- Inspector's name

The inspector should ensure that each sample container is correctly sealed and is stored under safe and appropriate conditions. To avoid sampling error, some clients prefer that an unopened coating container be sent to the testing lab, where the material can be mixed and sampled under more controlled conditions.

9.5.7 Inspector's Responsibilities Regarding Workmanship

Inspectors must understand the nature of the work to be done. Have a copy of the manufacturer's latest instructions and understand them thoroughly. At the pre-job conference, ensure that workmanship performance expectations are clearly understood by all participants.

Observe the workers and report any unacceptable work to the supervisor, the owner's representative, or to the contractor for correction (Figure 9.7). Stay safe. You are responsible for your own safety and for personally following all safety requirements established for the job. Report any questionable conditions or practices to the safety engineer immediately.

Figure 9.7 Proper Application of the Specified Coating is Critical to it's Performance and life Cycle

9.5.8 Inspector's Responsibilities Regarding Application

Ensure that the coating application is done as specified (in a proper "workmanlike" manner) and is free from defects. Know exactly what thickness tolerances are allowed. A good specification states a minimum and a maximum DFT for each coat and for the total system: for example, 4–6 mils (100–150 µm) per coat and 12–18 mils (300–450 µm) for the total system. If this is not the case, then insist in the pre-job conference that clear, practical DFT standards be established, understood, and agreed upon by all parties.

It is important to understand that the inspector's responsibility is to ensure the specified DFT range is achieved (Figure 9.8). It is a disservice to both the client and the contractor if an inspector insists on an extra topcoat just to make sure that any thin spots or defects possibly missed in inspection are covered.

If the contractor fails to meet the specifications to any substantive degree, and the inspector has made a reasonable effort to gain compliance, then it is important that

this information is brought to the attention of the supervisor or the owner's representative for determination of appropriate remedial actions. By making a clear, accurate, and objective report and recommendation, the inspector may have an important bearing on the decisions made.

In extreme cases, an owner could cancel the contract, seek legal redress, or bring various influences to bear to gain better cooperation. In some cases, it may be more economical to waive compliance with the specifications, finish the work, and accept the inevitable lower coating performance. Such a judgment, however, must be made **only** by the designated supervisor or owner's representative, not by the coating inspector.

Figure 9.8 Applicator Must Have Good Access to the Surface Being Coated to Ensure the Coating is Properly Installed

9.5.9 Inspector's Responsibilities Regarding Work Schedule

- Understand the work schedule
- Ensure that all phases of the job are done in the manner outlined by the contractor and approved by the client
- Inspect at the specified intervals (or nominated hold points)
- Prepare and submit reports as specified

9.5.10 Inspector's Responsibilities Regarding Coating Repair and Remedial Work

The procedure for coating repair (Figure 9.9) should be addressed in the specification and discussed in the pre-job conference.

- Ensure the areas to be repaired are clearly identified and the coated surface properly prepared (e.g., feather edged by sanding) as specified
- Monitor the number of repair coats applied, observe recoat times, and check WFT and DFT as specified
- Document the work

Figure 9.9 Runs and Sags

9.5.11 Inspector's Responsibilities Regarding Inspection

To summarize, some typical responsibilities of the inspector include:

- Before the job:
  - — Obtain, read, study, and comprehend the specification, referenced codes, and standards
  - — Study coating material data sheets, checking for any conflict with the specification
  - — Visit site
- At the pre-job conference:
  - — Resolve questions about the specification, including specific reports, test instruments, and procedures

  - If no specific tests, reports, etc. are specified, be prepared to state exactly what tests, reports, etc. are planned
  - Determine responsibilities and authority
- During work (Figure 9.10):
  - Perform quality control tasks in accordance with the position's responsibility and document all activities
  - Verify that work complies with the requirements of the specification
  - Report non-compliant work and deviations from written specified requirements, including modifications agreed at the pre-job conference or any similar meeting

Figure 9.10 Inspection

9.5.11.1 Specification Critical Examination

The coating project specification is a significant tool for coatings inspectors. It provides "the road map to completion" of the coatings project. It is crucial that it is a well-thought-out and well-written document since inspectors verify that the coatings are installed "per the specification."

It is important that the specification adequately and accurately addresses coatings project issues such as:

- Coating material suitability for intended service
- Existing conditions and service environment
- Surface preparation
- Coatings application

Otherwise, the coatings may be installed "per the specification" and fail miserably. Inspectors should utilize their experience and knowledge to conduct a critical examination of the specification and verify that the specification criteria are suitable for the specific project. Do not be afraid to ask questions of the specifier to validate the requirements of the specification.

Study Guide

1. List five (5) of the formal sections usually contained in a good specification.

_____
_____
_____
_____
_____

2. What are two (2) of the inspector's responsibilities as they relate~~s~~ to the specification?

_____
_____

Chapter 10: Surface Preparation

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Design and fabrication defects
- Steel surface defects
- Fabrication errors
- Pre-cleaning
- Soluble salts
- Hand tool cleaning
- Power tool cleaning
- Abrasive blasting
- Typical abrasives
- Crushed slags
- Nozzle size
- Centrifugal blast
- Abrasives
- Waterjetting
- Water blasting
- Inspector's checklist

Key Trade Terms

- Faying surfaces
- Surface lamination
- Inclusions
- Weld spatter
- Gouges
- Pre-cleaning
- Organic solvents
- Alkaline cleaners
- Acidic cleaners
- Detergents
- Dry grit blasting (air blasting)
- Crushed slag
- Ceramic grit
- Venturi nozzle
- Water blasting
- Water jetting
- Surface profile

10.1 Introduction

For virtually every coating process, the first step — *the initial surface cleaning and preparation* — is **the** key step to the success of the coating system. Modern coatings require both a clean *and* roughened surface if they are to have long-term stability. The only exception is if they are specifically designed for application to poor surfaces. It has been estimated that approximately 75% of all premature coating failures are caused either completely or in part by inadequate or improper surface preparation.

Surfaces where protective coatings are applied may include:

- Steel (Figure 10.1)
- Galvanized surfaces (Figure 10.2)
- Aluminum (Figure 10.3)

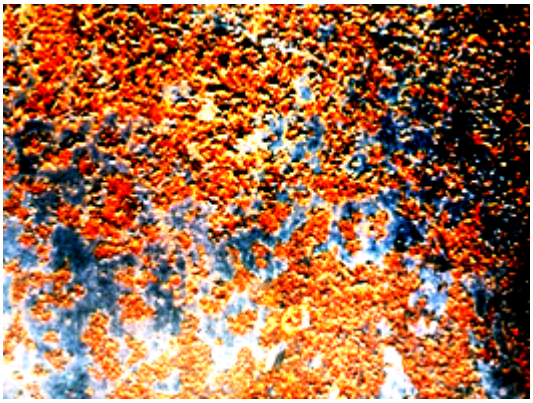

Figure 10.1 Mild Steel

Figure 10.2 Galvanized Steel

Figure 10.3 Aluminum

The following sections cover each of the three surfaces named above; however, recognize that steel is the most common surface prepared and coated for protection. Surface preparation activities prior to coating application may include:

- Assessment or inspection of surface conditions, including design and fabrication defects
- Pre-cleaning, or removal of visible surface deposits such as oil and grease
- Work to remedy or alleviate design or fabrication defects
- Inspection and documentation of the pre-cleaning process and cleaning defects, if any
- Surface preparation by any appropriate method to remove detrimental surface contaminants

Many factors in surface preparation affect the life of a coating, including:

- *Residues of oil, grease, and soil* can prevent adhesion or mechanical bonding of the coating to the substrate
- *Residues of (non-visible) chemical salts* can induce corrosion after coating
- *Rust on the surface* interferes with adhesion
- *Mill Scale:*
  - *Loose or broken mill scale*: can cause early coating failure
  - *Tight mill scale*: can cause later coating failure
- *Rust scale* cannot be protected by any coating and cannot maintain adhesion to steel
- *Anchor pattern issues* (formed by surface preparation actions):
  - May be so rough that peaks are formed, which are difficult to adequately protect with coating
  - May not be rough enough, possibly causing coating failure because of a loss of adhesion
- Sharp ridges, burrs, edges, or cuts from mechanical cleaning equipment can prevent adequate DFT

- *Surface condensation* if coated over, may result in blistering and delamination failure
- *Old coatings* may have poor adhesion or may be too deteriorated to re-coat
- *Existing coatings* may be incompatible with and affected by application of a maintenance coating

Surfaces to be coated require some precleaning. Inspecting for contamination, including heavy deposits of grease, soil, dust, dirt, or cement splatter, is an important component of the coating process. Remove all debris, and ensure the surface is completely available for coating application. Inspecting for surface cleanliness is a continuous process and should take place at least three times during the coating process:

- Before any surface preparation activities
- After surface preparation, and before coating begins
- Between each application of coating in a multi-coat system

The first essential step of surface preparation is to consider the specific substrate to be coated. Among metal surfaces that are often coated, the factors that affect the choice of surface preparation method and the coatings vary. Such substrates include:

- New or unpainted steel
- Steel with mill scale
- Corroded steel
- Corroded zinc or zinc-galvanized
- Corroded aluminum

Surface preparation of concrete is discussed elsewhere in the CIP program.

10.1.1 New Steel Surfaces

New steel is relatively easy to clean if it is new and unpainted, provided the surface is not exposed to corrosion in a chemical or marine environment. The biggest problem is likely to be removing mill scale deposits. Blast cleaning, using either shot or grit, or a mix of the two, can easily remove most mill scale. An advantage of using grit for blasting is the simultaneous creation of an *angular surface profile* that is suitable for good adhesion. Tightly adhered mill scale can be difficult to remove without blast cleaning.

Mill scale is formed on new steel by a reaction between the hot steel and oxygen in the environment during the production process. As a result, the surface of newly produced hot-rolled steel is generally covered with blue-black deposits of mill scale.

Adhesion of mill scale to steel is unpredictable and varies from tightly adherent to lightly adherent. Overcoating mill scale can cause the mill scale to delaminate, thus causing coating failure.

Mill scale is also relatively smooth, a factor that is significant for today's high-build, fast-drying coatings. Adhesion of coatings to smooth mill scale may be poor, resulting in failure through loss of adhesion.

Mill scale is cathodic relative to bare steel. When steel is partially covered in mill scale and exposed to corrosion, the cathodic mill scale does not corrode, being protected by the anodic steel. Corrosion does take place at the anodic surface, and base steel is lost. This effect is the opposite of what is generally required.

When most of the surface is covered by mill scale, corrosion at the anodic areas may be accelerated by the unfavorable area effect.

Large cathode + Small anode = Rapid corrosion at the anode

For best results, clean mill scale from new steel by abrasive blasting (Figure 10.4); this provides an anchor pattern for optimum coating adhesion.

Previously Coated Steel

When previously coated steel needs to be re-coated, remove the old coating by sanding, abrasive blasting, or stripping any existing coatings that (Figure 10.5, Figure 10.6):

- Have poor adhesion
- Are too deteriorated to recoat
- Are incompatible with or affected by a subsequent maintenance coatings
- Are peeling or degraded in any way

Figure 10.4 Mill Scale

Figure 10.5 Delamination and Peeling of Maintenance Coating

Figure 10.6 Incompatible Coating Applied over Existing Coating System

If the previous coating is completely intact, clean the surface with a strong detergent or solvent and scuff sand to remove the gloss. Perform the simple tests as listed below:

- *Spot test:* apply a small amount of coating over old paint. The old finish may wrinkle or lift within 30 minutes; this indicates the need to remove the old coating. Since this test can be destructive, seek permission before actually testing the surface.
- *Adhesion test:* if the coating does not lift or wrinkle after the spot test, do an adhesion test. Cut an "X" into the coating, place tape firmly over the cut, then pull with a hard, fast pull (ASTM D3359). If the coating fails, either remove it or consider an appropriate barrier coating.

10.1.2 Galvanized/Zinc

Coat freshly galvanized steel (Figure 10.7) within 24 hours or allow it to oxidize sufficiently, then prepare the substrate prior to coating per the specification. Atmospheric exposure develops a passive film of oxide and/or zinc carbonate on the surface. If the film layers adhere tightly to the substrate they help coatings adhere because of their relative roughness. Remove any loosely adherent or powdery salts before coating.

Water washing effectively removes most loosely adherent oxides/zinc salts when

using a pressure wash technique, with plenty of clean, fresh water available. This technique is less effective than blast cleaning.

Figure 10.7 Galvanized Steel

When blast cleaning, lightly blast clean (brush blast) the surfaces to roughen them prior to coating, or treat with an acid-based solution (e.g., acid-etch primer or acid-wash solution) to provide a clean surface with a profile. Either of these treatments enhance a coating's adhesion to the substrate. Current thinking suggests blast cleaning before coating produces better results rather than relying on etch primers to provide good adhesion.

Oil-based coatings such as alkyds or epoxy esters perform poorly on galvanized or zinc-coated surfaces because of a reaction between the coating and the zinc surface called *saponification*. This reaction, a formation of *soap*, causes degradation of the oil-based binder and consequent loss of coating adhesion to the zinc surface. Inspectors need to know ASTM D 1731, *Preparation of Hot Dip Aluminum Surfaces for Painting*.

10.1.3 Aluminum

New aluminum surfaces may develop a protective oxide film that exhibits low adhesion to the substrate. If coated with an organic coating, this oxide film could detach from the surface. However, with *anodized* aluminum the oxide film adheres strongly to the substrate and can be coated with an organic coating, requiring a light abrasion of the surface before application. In some cases only degreasing and water rinsing are sufficient surface preparation. In other situations it may be necessary to prepare the surface by wet- or dry-abrasive blasting with a fine-particle sand or plastic abrasive. Avoid a high profile on aluminum.

Check corroded aluminum surfaces for oxidation. Aluminum, like zinc and zinc-coated surfaces, forms a passive film of aluminum oxide in atmospheric exposure. Lightly blast or wire brush the surface to remove powdery or loosely adherent aluminum salts before coating. A special aluminum surface treatment (e.g., etch primer) may be required before coating. Select a primer with known compatibility and strong adhesion to a clean surface. Be familiar with standard ASTM D 1730, *The Preparation of Aluminum and Aluminum Alloy Surfaces for Painting.*

10.1.4 Stainless Steel

Uncoated stainless steel reacts with the atmosphere to produce a protective film which is an essential part of its corrosion protection. However, prior to coating, remove any film during the surface preparation. The coating may detach from the substrate if not removed. In general, these protective films formed on stainless steel are tough and adherent.

Some types of stainless steel tend to become rust-spotted when exposed to an unsuitable environment. If this occurs, it may be necessary to either totally or partially remove the

rust, dry- or wet-abrasive blasting using a nonmetallic abrasive, or by vigorous scrubbing with water and a stiff-bristle brush or scrubber.

10.2 Design and Fabrication Defects

Many structures are not designed with the coating process in mind. Design flaws and fabrication faults can easily complicate surface preparation and application of a successful coating system. Neither the applicator, the inspector, nor even the coatings can be blamed for problems engendered by the work of designers, engineers, and/or fabricators. In some cases, specialized blasting nozzles (e.g., 45 and 90 degrees) or partial disassembly of these members can take care of this problem.

The inspector may be able to provide valuable insight by identifying design and/or fabrication problems that make the job highly difficult to do well.

Some common design defects that affect the coating process include:

- Hard to reach or inaccessible areas
- Rivets, bolts, or other connectors
- Welds
- Gaps (particularly skip welds or surfaces close together)
- Overlapping surfaces (e.g., roof plates in water tanks)
- Angle iron badly oriented or in complex arrangements
- Threaded areas
- Dissimilar metals
- Sharp edges, particularly on corners or rough cut plate
- Construction aids

10.2.1 Hard to Reach Areas

Hard to reach areas are difficult to coat properly and need special attention to ensure proper coating (Figure 10.8, Figure 10.9). For example, stiffening members on the inside of a vessel create areas that are difficult to reach, clean, or coat. Many tall vessels are built with little thought given to how the interior surface can be maintained.

Because maintenance of all kinds, including corrosion prevention methods, are so vital to the life of facilities and structures, designers should incorporate supports for cleaning, coating, and repair tools, i.e., cradles for tools, ladders, foot- and hand-holds, and built-in scaffolding, to allow easy access to the area and to stow equipment and materials while working.

Figure 10.8 Design Problem: Hard-to-Reach Area

Figure 10.9 Design Problem: Hard-to-Reach Area

10.2.2 Rivets and Bolts Construction

Designs that feature riveted and bolted areas (Figure 10.10, Figure 10.11) can leave gaps as well as very tight areas that are next to impossible to clean and coat. It is extremely difficult to protect bolts in these design configurations.

Figure 10.10 Design Problem: Bolts

Figure 10.11 Design Problem: Bolt Configuration

10.2.3 Welds

Welds generally present rough, discontinuous areas on a plane surface and may have many sharp edges. Too frequently welds are not cleaned properly (Figure 10.12, Figure 10.13) leaving weld spatter, slag, and acid flux residues. If these imperfections are not removed, corrosion may be encouraged.

Figure 10.12 Design Problem: Welds

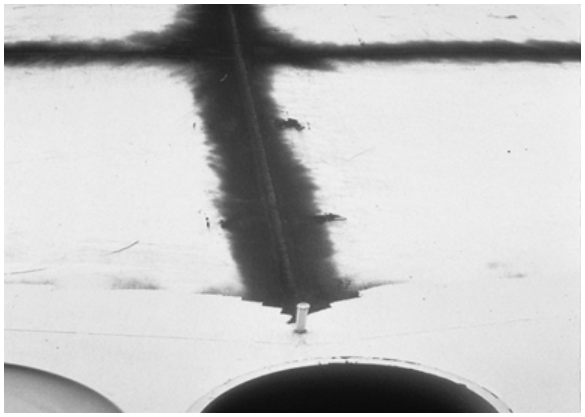

Figure 10.13 Design Problem: Welds

Clean weld areas, especially in tanks and vessels, grind them smooth or flush, depending upon the operating conditions, then stripe coat. Grinding welds, however, is not always advisable, so inspectors should **not** authorize grinding of welds without consulting the structural engineer.

When inspections are required, *the visual comparator* associated with *NACE Standard RP0178* may be useful. This plastic replica demonstrates a variety of finishes for butt welds and lap welds and allows inspectors to identify and report the weld condition according to a scale ranging from ***A*** to ***F*** in each case.

Welds are often tested for cracks with chemical test solutions (e.g., dye-penetrant solutions) that leave contamination on the surface. Coatings applied over this type of surface will not bond well and coating failure with subsequent corrosion is likely to occur. Removing such contamination is difficult. Apply a prescribed solvent as needed until any remaining traces cannot affect coating adhesion or bleed back into the coating.

10.2.4 Gaps

Skip welds, gaps (Figure 10.14), sharp edges, crevices, and back-to-back angles can also lead to early coating failures. These problems are common on older structures and may not be as common on newer structures today.

Figure 10.14 Design Problem: Gaps

10.2.5 Overlapping

Overlapping (Figure 10.15) plates and roof plates, generally skip-welded, create areas inaccessible for either cleaning or coating. Overlapping plates create crevices and moisture accumulation which makes corrosion occur often.

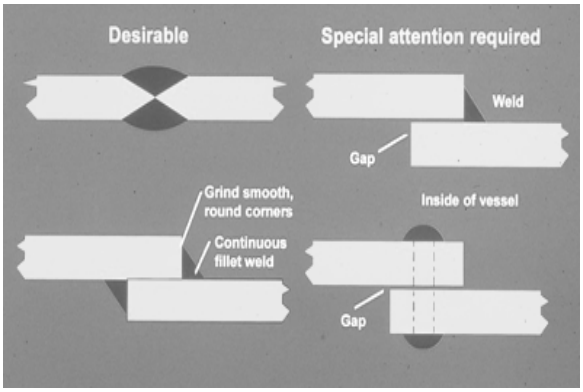

Figure 10.15 Design Problem: Overlapping Surfaces

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10.2.6 Angles

Angles are frequently used in construction (Figure 10.16, Figure 10.17). Often the back sides of these angles are not coated but are sometimes pre-coated with galvanizing or inorganic zinc. The area between the angles may be impossible to clean and coat. Seal the void space around the angles with caulking or mastic to prevent corrosion and the possible undercutting of coating at the edges. Other alternatives may include penetrating sealers.

Figure 10.16 Design Problem: Angles

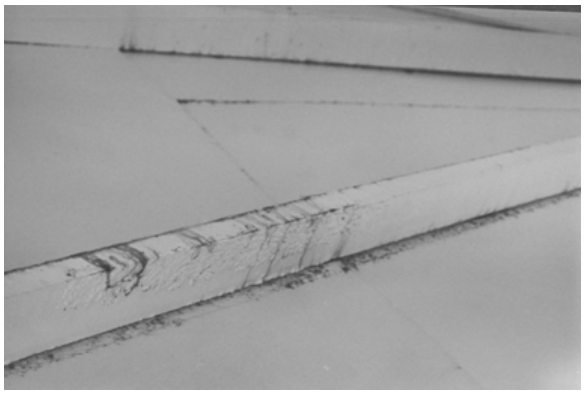

Figure 10.17 Design Problem: Angles

10.2.7 Threaded Areas

Threaded areas (Figure 10.18, Figure 10.19) are very difficult to coat; take care to ensure workers adequately clean and coat all surfaces. There are many crevices and sharp edges with threads that can encourage initiation of corrosion. Since threads are difficult to clean and coat properly, replace threaded outlets, when possible, by flanged or pad-type outlets, which are generally more easily accessible.

Figure 10.18 Design Problem: Threaded Areas

Figure 10.19 Design Problem: Threaded Areas

10.2.8 Dissimilar Metals

Dissimilar metals that come in contact with each other create a galvanic cell, which can start corrosion resulting in coating failure (Figure 10.20). Whenever dissimilar metals

must join, coat all connected dissimilar metals.

Figure 10.20 Design Problem: Mild Steel Bolts/ Stainless Steel Piping

Where dissimilar metals connect, a metallic pathway forms, opening the possibility for bimetallic corrosion. In this case, an unfavorable anode-to-cathode relationship may exist. When the anode is relatively small compared to the cathodic area, the corrosion effect concentrated at the anode may be severe, leading to rapid corrosion and probably pitting at the anodic area.

10.2.9 Edges

A typical structure may contain edges that are many linear feet long, most of which have no rounded edges (Figure 10.21, Figure 10.22). Sheared edges and flame-cut edges created during fabrication are likely to be sharp and very problematic in the coating process. Coatings generally have a tendency to shrink and pull back from edges, leaving a thin, less protective coating.

Figure 10.21 Design Problem: Edges

Figure 10.22 Design Problem: Edges

Stripe coat edges at least once during the coating process, preferably once for each regular coat to provide additional coating thickness at the edge.

10.2.10 Construction Aids

Construction aids (Figure 10.23) such as hold-downs, brackets, etc., are often welded to a structure with skip welds or with only one side of the joint welded. These temporary aids, designed to be removed after construction, are sometimes left in place and over coated along with the original coating application. When this happens, surface preparation or coating application may be less than ideal and early coating failures occur.

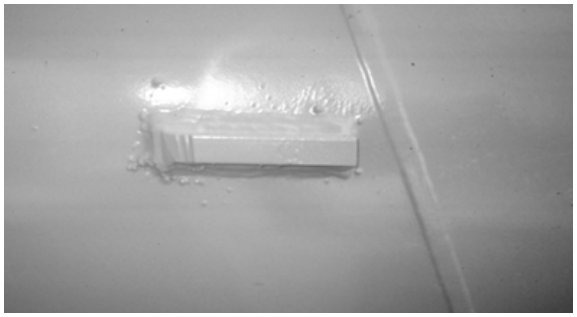

Figure 10.23 Design Problem: Construction Aids

Though they create a potential problem, do not remove construction aids in the field without engineering approval. However, prepare the surface per the specification and apply a proper coating to avoid premature failure of the surrounding coating.

Other design problems that could lead to early coating failure include:

- Depressions in outer surfaces can accelerate corrosion by restricting run-off flow, water drainage, or by collecting dirt or other trash
- Crevices that trap water or corrosive liquids
- Poor ventilation which slows evaporation of condensing moisture

10.2.11 Corners (Exterior and Interior)

Remember, corners behave like sharp edges and the same tendency for corrosion occurs (Figure 10.24). Stripe coat them as a matter of good practice. Interior corners present two potential problems:

- Coatings applied over interior corners will shrink in much the same way sharp edges do, by forming a bridge with poor contact to the substrate. This is sometimes known as the *wallpaper effect*.
- Corners may allow accumulation of dirt or trash, and the coating may then be applied over the contaminated surface. Like other surfaces, inside corners should be clean, free of dirt, dust, etc., and, preferably, stripe coated before application of the main coating.

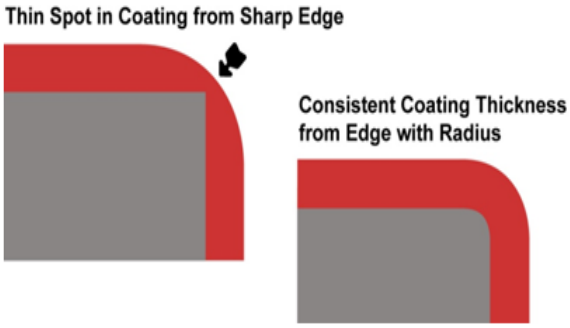

Figure 10.24 Design Problem: Corners

10.2.12 Faying Surfaces

Faying surfaces (i.e., surfaces joined to create a friction grip) are a special case (Figure 10.25). Clean and leave uncoated or clean and coat with a tested and approved coating. ASTM and British standards describe tests to establish coating suitability for faying surfaces. Inorganic zinc coatings are probably the most commonly used.

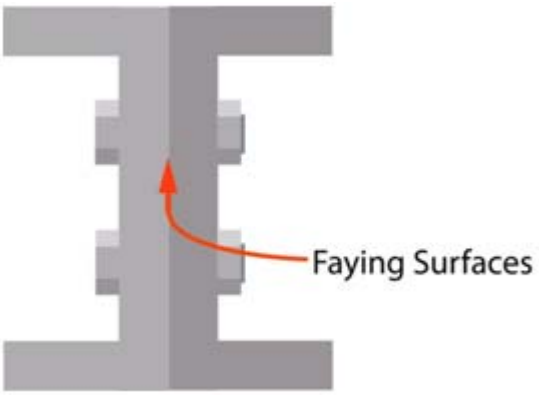

Figure 10.25 Design Problem: Faying Surfaces

10.3 Steel Surface Defects

Surface preparation for coating includes suitable preparation of the steel substrate to remove all surface defects that could break

through the coating film or prove difficult to adequately protect with coatings. It is not widely understood that surface preparation does not just mean the removal of mill scale, rust, and contaminants. Typical example defects include:

- Surface laminations
- Inclusions

Remember, where defects are exposed by blast cleaning and subsequently removed by grinding, *it is necessary to re-prepare the immediate area to* ***retain the surface profile***.

10.3.1 Surface Lamination

Surface lamination is the most common surface defect on steel substrates. It is typically caused by rolling the steel. These defects **must** be removed by grinding since no coating system can effectively protect the surface if they are left intact. Small surface laminations (even if they do not yet project above the surface) may later curl upward and penetrate or disrupt the coating system.

10.3.2 Inclusions

Remove **inclusions** (Figure 10.26) in all forms, such as rolled-in mill scale. Methods include chipping and/or grinding. Sometimes weld filling can restore the surface.

10.4 Fabrication Errors

Fabrication errors should be addressed in the job specification and discussed at the pre-job meeting. Inspectors should ensure these defects are corrected *in accordance with the specification*. If correction is not called for by the specification, make sure the workers prepare and coat the defects as well as possible. Find and document each defect's precise location in the daily inspection report. This information will be quite useful to the owner for future maintenance and help determine if premature failures loom.

Figure 10.26 Lamination

If the specification calls for repair of the defects, then complete the repairs before further work proceeds. Fabrication defects fall into several broad categories. Some of them are very similar to design defects in terms of the proper way to repair and document them.

10.4.1 Imperfect Welds

10.4.1.1 Weld Spatter

Weld spatter, also known as weld splatter, (Figure 10.27 and Figure 10.28) describes particles of molten metal from welding that are thrown onto the surface adjacent to the weld. Sometimes weld spatter removes easily with an impact tool such as a chipping hammer, but generally removal requires grinding down with a disc or angle grinder in order to remove it successfully.

Weld spatter may be up to 20 mils (500 µm) or more in height over the substrate and is difficult to cover using only a coating of appropriate thickness. The resulting thin coating film over the weld spatter may break down early in service and allow corrosion

Figure 10.27 Fabrication Defect: Weld Spatter

Figure 10.28 Fabrication Defect: Close-Up of Weld Spatter

to develop, which can later spread beneath the coating film. Consequently, treatment of weld spatter is important. Remove by mechanical means before blasting according to the specification. In tanks and vessels, where coatings are in immersion service and where frequent inspection is impractical, it is most critical to remove all weld spatter to minimize or eliminate the opportunity for corrosion to occur.

10.4.1.2 Skip Welds

Proper welding technique is also important to avoid skip welds (Figure 10.29). The welding should be continuous rather than spot or intermittent. Continuous welding is more expensive than spot welding; however, extending the life of the coating generally more than offsets the extra cost of continuous welding. Report any cracks in welds to the owner for further evaluation before coating.

The *best* method to seal the area is to make a continuous weld, clean and grind it smooth, then follow by stripe coating along with the regular coating. If continuous welding is not possible, use penetrating sealer or caulking in the overlap joints. Use a caulking compound that is compatible with the coating system over the prepared joint before stripe coating. Epoxy and silicone-based caulks have both been used with success.

Figure 10.29 Fabrication Defect: Skip Weld

10.4.1.3 Rough Welds

Grind rough welds (Figure 10.30) smooth (Figure 10.31) or repair them to remove sharp edges and other irregularities to prevent the coating from bridging over voids in the weld. Sharp ridges and spikes are difficult to coat; the coating pulls back from edges of the ridge and is much thinner at those points. Grind or repair all welds to create a smooth surface. Also fill undercuts and pinholes with welding.

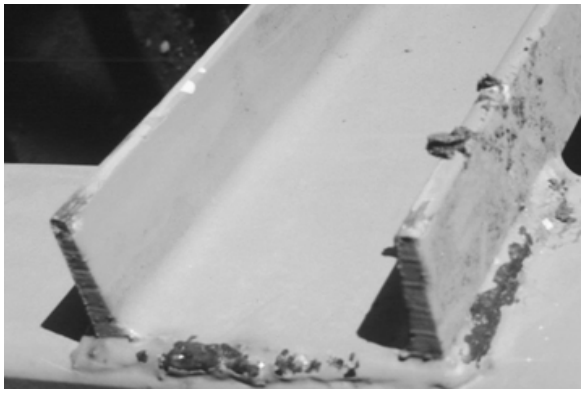

Figure 10.30 Fabrication Defect: Rough Weld

Figure 10.31 Welds Ground Smooth Prior to Coating

10.4.2 Laminations

Correct laminations, scabs, rollovers, and other defects of this type (Figure 10.32) to expose areas that are otherwise inaccessible for cleaning and coating. Be sure to remove slivers, laminations, and other defects that may penetrate the coating.

10.4.3 Gouges

Gouges or sharp indentations (Figure 10.33) of any kind limit the effectiveness of coating films. Applying coating over gouges may merely bridge over the gouge, creating voids where corrosion can occur. Round these indentations so that the entire surface can be evenly and completely coated.

Figure 10.32 Fabrication Defect: Lamination

Figure 10.33 Fabrication Defect: Gouge

10.4.4 Sharp Corners and Edges

Sharp corners and edges cause surface tension which causes coatings to pull back, particular during drying and/or curing. Round all sharp edges. (Figure 10.34, Figure 10.35.)

10.4.5 Sharp Bends or Angles

Sharp bends or angles can also cause the coating to bridge over areas of the substrate, creating voids which can trap moisture and cause corrosion. This condition is not easy to correct or change, so take extra care during coating application. Applying a brush stripe coat may help ensure adequate coverage. NACE publishes the standard recommended practice RP0178, *Fabrication*

Figure 10.34 Fabrication Defect: Sharp Corners/ Edges

Figure 10.35 Sharp Corners/Edges

Defects, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service. The design engineer, working jointly with the coatings engineer or specifier, can use this illustrated standard along with an accompanying weld replica as a valuable guide to avoid many common design faults and fabrication defects that can adversely effect the entire coating system.

The same standard may be quoted in the specification, providing a visual guide to the acceptable conditions after the pre-cleaning stage of surface preparation. A companion replica is available to help inspectors, which shows various degrees of weld preparation and examples of rounded edges.

Neither the inspector nor the painter can easily control aspects of the design that create areas difficult or impossible to coat. However, both should pay close attention to these hard-to-coat areas when they inspect or prepare for work. Document these areas in writing and bring them to the attention of the supervisor or owner's representative.

It is important to identify fabrication defects that could lead to inadequate coating performance. Identify, document, and correct defects. Responsibility for remedial action is often a subject of dispute, but repairing defects before or during surface preparation ensures coating performance is much better (and more economical in the long term).

Note that **NACE SP0178**, *Written Standard and Visual Comparator* is available for specifiers to communicate the welded surface preparation requirements.

It addresses the following:

- Written standard is precedent
- Addresses: design, fabrication, and surface finishing (i.e., smoothing welds and rounding edges)
- Specification must define the weld grade designation (A-E)
- Cost benefit generally based on corrosion rate of base steel when exposed to vessel contents (i.e., potable water tank v. low pH acids)

Its companion Visual Comparator (Figure 10.36) provides the following information:

- Aid to interpret written standard
- Weld finish designations (butt, lapped, and corners)
- Radiused corners and edges

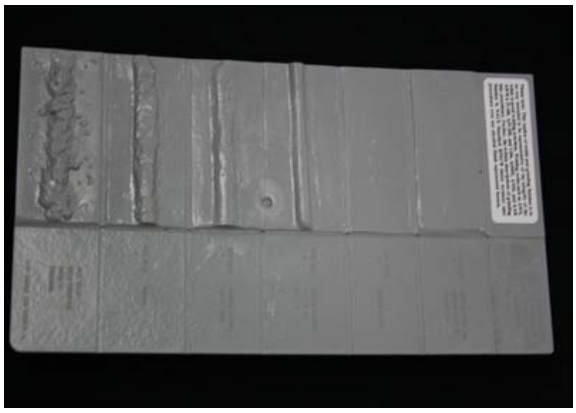

Figure 10.36 Visual Comparator

10.5 Pre-Cleaning

The degree of required cleaning is closely related to the type of coatings chosen, although, in general, a better standard of cleaning provides better long-term protection for *any* coating system. Cleaning methods and cleanliness standards for **pre-cleaning** are in this section of the chapter.

10.5.1 Contaminated Surfaces

Inspectors should always check surfaces for contamination before surface preparation begins. Listed below are some of the things to be aware of in the pre-cleaning stage (Figure 10.37).

10.5.2 Oil and Grease

Solvent cleaning is a method to remove all visible oil, grease, soil, drawing and cutting compounds, and other soluble contaminants from steel surfaces. Solvent cleaning is for use prior to coating application and in conjunction with the surface preparation methods specified to remove rust, mill scale, or old coatings.

10.5.3 Standards

SSPC-SP 1 is the only commonly used standard that formally governs solvent cleaning to remove oil, grease, dirt, soil, drawing compounds, and other similar organic compounds. Inspectors must also understand that contaminants addressed in the standard must be “visible.”

Figure 10.37 Pre-Cleaning

10.5.4 Test Methods

Oil present in small quantities on blast cleaned surfaces may be detected by these tests:

- Pour solvent across the surface; the solvent should form a continuous flow and ***not*** *break* into droplets
- Use an ultraviolet light to illuminate the surface to reveal traces of certain hydrocarbon oils, grease, fingerprints, etc.
- Ultraviolet light also may reveal other materials on the surface, which may or may not be detrimental to the coating

Use only approved ultraviolet lamps. Looking directly into unshielded ultraviolet lamps may cause severe eye damage including blindness. Consult the safety engineer or other knowledgable person about any ultraviolet lamp you may consider using.

10.5.5 Removal

SSPC-SP 1 defines a variety of pre-cleaning methods, including:

- Solvent wipe with cloth or rag
- Immersion of the substrate in solvent
- Solvent spray
- Vapor degreasing
- Steam cleaning
- Emulsion cleaning
- Chemical paint stripping
- Alkaline cleaners

A variety of solvent cleaning materials may be used for SSPC SP-1 cleaning; some examples are:

Organic solvents, such as kerosene, turpentine, naphtha, mineral spirits, toluol, xylol, etc., clean the metal by dissolving and diluting the oil and grease contamination on the surface. Some organic solvents in use for solvent cleaning may be considered hazardous to health and are generally likely to be a fire risk. In particular, toluol is subject to health and safety restrictions in many countries.

Inorganic materials such as chlorides, sulfates, weld flux, and mill scale **are not removed** by organic solvents.

Use clean solvent for the last wash or rinse to remove the slight film of oil or grease that may be left on the surface. This film, if left in place, may interfere with coating adhesion to the surface.

Some solvents (e.g., xylol and toluol) will also dissolve some paint films so they can be removed from the surface. Nonconvertible coatings (e.g., chlorinated rubber, vinyl) are most likely to be softened or removed by solvent washing.

Petroleum based mineral spirits with a minimum flash point of 100°F (38°C) may be used as a general purpose solvent under normal conditions. In hot weather use high-flash-point mineral spirits, 80–90°F (26–32°C), with a minimum flash point of 120°F (50°C).

Because solvents are potentially hazardous and may be inhaled during solvent cleaning, monitor working spaces for solvent fumes. Concentrations in workers' air should be below threshold limit values (TLV) defined by federal, state, or local regulations. Use appropriate fresh air masks in confined spaces and whenever the safe concentration is exceeded. Ensure the fresh air supply is free of carbon monoxide (CO) or other contaminants from other sources such as engine exhausts, etc.

Also ensure the concentration of solvents in air does not exceed the lower limit of flammability, known as the *lower explosive limit* (LEL), so a fire or explosion does not occur. Such concentrations are most likely to occur in confined spaces, such as tanks, pipes, or vessels.

In general, cost considerations and regulations restricting the use of organic solvents are so stringent they discourage the use of

these materials except in highly controlled special situations.

Alkaline cleaners, such as trisodium phosphate (TSP) and sodium hydroxide, saponify most oils and greases, and their surface-active components wash away other contaminants. These cleaners may also saponify certain coating vehicles. Manufacturers often combine alkaline cleaners with surfactants (wetting agents), inhibitors, and detergents to form proprietary products; use these according to the manufacturer's recommendations. These products are often used at elevated temperatures.

After cleaning, a slightly soapy film may remain on the surface. Remove this film (as usually done) with a high-pressure, hot-water rinse. Residues that remain on the surface tend to compromise adhesion of the coating to the metal. Administer a pH paper test to determine the effectiveness of the wash. In general, the pH of the washed surface should not exceed the pH of the wash water. In some cases, the owner may elect to use an acidic wash, such as 0.1%-by-weight chromic acid, sodium dichromate, or potassium dichromate, to neutralize traces of the alkali on the surface.

Follow safety precautions for use of alkaline cleaners and chromic acid. Both can cause burns and/or dermatitis. Ensure workers wear rubber gloves, safety goggles or eyeglasses, and respirators when spray applying these materials.

Acidic cleaners are usually composed of fairly strong acids, such as phosphoric acid (H_3PO_4), with small quantities of surfactants, water-miscible solvents, and organic wetting and emulsifying agents. Acidic cleaners remove soil by chemical attack and by dissolving the reaction products. They may be used to remove corrosion products and for other special purposes.

Disposal of alkaline or acidic cleaners is often a problem, so ensure the waste or used materials are properly collected and disposed of. Workers cannot wash contaminants onto the ground, into the normal drainage system, into adjacent watercourses, or allow the contaminants to run off into the general water system.

Detergents are increasingly monitored via strict regulations concerning the use of organic solvents. The safety considerations associated with using alkaline or acidic cleaners have led to an increased use of detergents, especially the biodegradable types, to remove oil, grease, and other similar contaminants from the surface.

Generally, these cleaners are composed of buffering salts, dispersants, soaps, and inhibitors. They function by wetting, emulsifying, dispersing, and solubilizing the contaminants, which can be washed away using water (usually hot) or steam. They are frequently used at temperatures ranging from 150–212°F (65–100°C).

Emulsion cleaners are typically proprietary products and should be used only in accordance with the manufacturers' instructions. These cleaners may contain oil-soluble soaps or emulsifying agents, buffering salts, dispersants, and inhibitors, along with kerosene or some type of mineral spirits. Emulsion cleaners are generally sprayed onto the surface where they function by wetting, emulsifying, dispersing, and solubilizing the contaminants.

Generally, the emulsion cleaners leave a thin film of oil on the surface which must be

washed away with hot water, steam, solvents, detergents, or some type of alkaline cleaning agents.

Fresh water is a common, if not powerful, solvent and may effectively clean a surface. However, it is important to test the water for pH and conductivity before being used for surface preparation. This topic is discussed further in the sections about waterjetting and wet abrasive blast cleaning. Any cleaning method requires the use of appropriate safety precautions.

Also, it is important to thoroughly rinse surfaces, particularly when alkaline or acidic materials are used. This minimizes the amount of soil (contaminants) remaining and removes residues of cleaning materials that could adversely impact coating performance.

10.6 Soluble Salts

In marine and industrial environments where the air contains particles of chemical salts, it is well known that these salts may deposit on the work piece. If this occurs after blast cleaning but before coating, it may be necessary to wash and re-blast the surface. Determine the presence of certain chemical salt deposits, such as ferrous sulfate, or ferrous hydroxides, by means of test papers or chemical test kits.

Steel that has developed corrosion in the presence of certain contamination (e.g., sulfates, chlorides) may be difficult to clean adequately. Even though the surface may appear to be properly blast cleaned and free of corrosion products, it may contain enough *non-visible* contamination to create a surface unsuitable for coating.

In extreme cases, heavily contaminated areas will, after blasting, absorb moisture from the air, change to a dark color, and rapidly deteriorate. This effect can sometimes be seen within minutes of completing blast cleaning, particularly when humidity is relatively high — it is a clear indication that the surface is contaminated.

10.6.1 Standards

The standards below are some used for various test methods:

- SSPC-Guide 15
- ISO 8502-2
- ISO 8502-5
- ISO 8502-6
- ISO 8502-9

These standards are discussed in detail in later chapters of CIP1 and in greater detail in CIP2.

10.6.2 Test Methods

The test methods to determine the presence of soluble salts on the surface (Figure 10.38) are discussed in later chapters with hands-on practice with instruments during the class.

Figure 10.38 CSN Test Kit - Chlorides, Sulfates and Nitrates

10.6.3 Removal

To remedy the problem of soluble salts on the surface, the surface should be cleaned more thoroughly. Further blast cleaning may be effective in some cases, but it may be better to wash using high-pressure wash equipment. Waterjetting may also be effective to remove heavy contamination. In these cases, follow surface preparation with tests for soluble iron (ferrous) salts and/or chlorides. This ensures that remaining contamination is below critical levels.

10.6.4 Inspection Considerations

There are some things inspectors should be constantly aware of during pre-cleaning. The following are some items to consider:

- Visually check the substrate to determine if contaminants are present
- If contaminants are visible on the substrate, follow the removal process described above
- After solvent cleaning, if required, ensure that no cleaning substance remains on the surface

10.6.5 Inspector's Checklist

Some of the items on an inspector's checklist prior and after cleaning are to check the substrate for:

- Damage from fabrication
- Damage from design
- Contaminants
- Residual contaminants after solvent cleaning

10.7 Hand Tool Cleaning

Hand tool cleaning is a method to prepare steel surfaces using non-powered hand tools. Hand tool cleaning removes all *loose* mill scale, rust, paint, and other detrimental foreign matter. *Adherent* mill scale, rust, and coatings cannot generally be removed by this process in a high production environment. Mill scale, rust, and paint are considered adherent if they cannot be removed by lifting with a dull putty knife.

Both standards dealing with hand tool cleaning (ISO St2 and St3) specify the use of a dull putty knife to determine whether or not contaminants are firmly adherent.

Tools (Figure 10.39) used in hand cleaning include:

- Wire brushes
- Scrapers
- Chisels
- Knives
- Chipping hammers

Figure 10.39 Hand Tool Cleaning

10.7.1 Surface Cleanliness Standards NACE-SSPC/ISO

The written standard commonly used to control the hand tool cleaning process is **SSPC-SP 2**, *Hand Tool Cleaning* (Figure 10.40).

Figure 10.40 Surface Cleanliness Written Standards

Common hand tool cleaning standards are:

- SSPC-SP2
- ISO 8501-1, St2, or St3

Common power tool cleaning standards are:

- SSPC-SP3
- SSPC-SP11
- SSPC-SP15
- ISO 8501-1, St2, or St3

A common standard used for solvent cleaning is:

- SSPC-SP1

10.7.2 Cleaning Methods

When hand tool cleaning operations commence, certain procedures are necessary:

- Inspect the surface to determine its condition, the presence of heavy layers of rust, or to detect any foreign substances, such as oil, grease, or dirt
- Specify or require solvent/emulsion cleaning to remove oil, grease, or dirt. Remove heavy layers of rust by chipping

Figure 10.41 Surface Cleanliness Visual Standards

- Clean the surface with any of the hand tools previously mentioned; then inspected prior to coating. Apply the coating within the time period required by the specification

Manual (hand tool) cleaning is the slowest and perhaps least satisfactory method of surface preparation. Normal tools used are wire brushes, scrapers, or chipping hammers. The process is slow, labor intensive, and costly, with the end result still far from satisfactory. It is practically impossible to remove all rust and mill scale by this method.

A complicating factor can be the reluctance of labor to engage in arduous manual tasks. Slow progress and deteriorating labor relations can lead to significant increases in the cost of achieving a clean surface by these methods.

Hand tools have the advantage of being portable and not requiring power to operate. They are most suitable for use when small areas need to be prepared in the vicinity of other workers or when access is difficult, such as when maintenance is performed on communication towers 300 ft (100 m) in the air.

Use manual cleaning only when weather or some other factor precludes using more efficient methods. Hand cleaning is one of the oldest methods of surface preparation and is most often used when:

- Power-operated equipment is unavailable.
- The work is inaccessible to power tools.
- The job is too small to warrant use of power tools.
- Hand tool cleaning may be used extensively and with good effect when properly implemented in a maintenance painting program. It may be more effective when used in conjunction with power tool cleaning.

10.7.3 Inspection Considerations

Some of the things inspectors should consider are:

- The substrate condition prior to cleaning
- The solvent cleaning prior to hand tool cleaning
- The area the hand tooling is required
- The coating to be applied to the existing surface
- The edges after the hand tool cleaning is completed
- The ambient conditions during cleaning and prior to coating

10.7.4 Inspector's Checklist

An inspectors checklist prior to and after hand tool cleaning should include but not be limited to the following:

- Check the pre-cleaning before hand-tool cleaning begins
- Check the surface to ensure that hand tool cleaning is the required surface preparation
- Understand the specification concerning hand tool cleaning
- Know the areas that require hand tool cleaning
- Check the equipment to ensure that the proper tools for the job are at hand
- Check the substrate after the hand tool cleaning to ensure there are no lifting edges
- Ensure that the transition of the coating has been feathered in to ensure adhesion of the coatings

10.8 Power Tool Cleaning

Power tool cleaning uses power-assisted mechanical cleaning tools. These tools are essentially similar to the tools used for hand tool cleaning, but with a power source, such as electricity or compressed air.

This process can remove loose mill scale, rust, paint, and other detrimental foreign matter, but is not intended to remove adherent mill scale, rust, and paint. As in SSPC-SP 2, mill scale, rust, and paint are considered adherent if they cannot be removed by lifting with a dull putty knife (Figure 10.42). The standards most commonly used to govern the power tool cleaning process are SSPC-SP 3 or ISO 8501-1 St 3 (or St 2). Power tool cleaning is frequently used in maintenance operations. In addition to removing loose mill scale, rust, and paint, this method may be used to remove weld flux, weld spatter, and laminations, and to smooth rough welds and round out gouges before abrasive blast cleaning.

Figure 10.42 "Dull Putty Knife"

10.8.1 Surface Cleanliness Standards

Written standards for power tool cleaning are:

SSPC-SP 3 *Power Tool Cleaning* (Figure 10.43) calls for power tool cleaning to remove all loose mill scale, loose rust, loose paint, and other loose detrimental foreign matter. This method is not intended to remove adherent mill scale, rust, or paint. Mill scale, rust and paint are considered adherent if they cannot be removed by lifting with a dull putty knife.

SSPC-Vis 3 illustrates four initial rust grades (Figure 10.44) before surface preparation:

- Rust Grade A: Steel surfaces completely covered with adherent mill scale; little or no rust visible
- Rust Grade B: Steel surface covered with both mill scale and rust
- Rust Grade C: Steel surface completely covered with rust; little or no pitting visible
- Rust Grade D: Steel surface completely covered with rust; pitting visible

SSPC: The Society for Protective Coatings

SURFACE PREPARATION SPECIFICATION NO. 3

Power Tool Cleaning

Figure 10.43 Power Tool Cleaning Written Standards

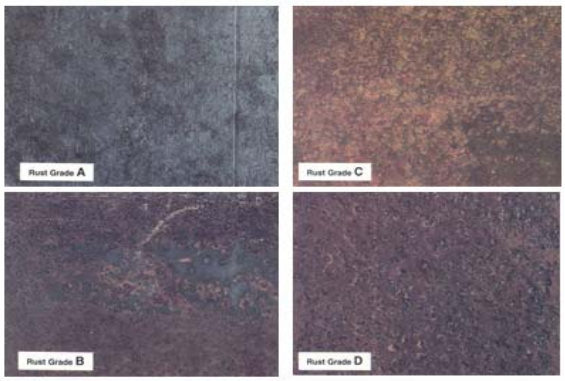

Figure 10.44 SSPC-Vis 1 Rust Grades A, B, C, and D

In **ISO 8501-1**, four rust grades are defined by written description and representative photographs (Figure 10.45, Figure 10.46):

- A: Steel surface largely covered with adhering mill scale but little, if any, rust
- B: Steel surface which has begun to rust and from which the mill scale has begun to flake
- C: Steel surface on which the mill scale has rusted away or from which it can be

scraped, but with slight pitting visible under normal vision

- D: Steel surface on which the mill scale has rusted away and on which general pitting is visible under normal vision

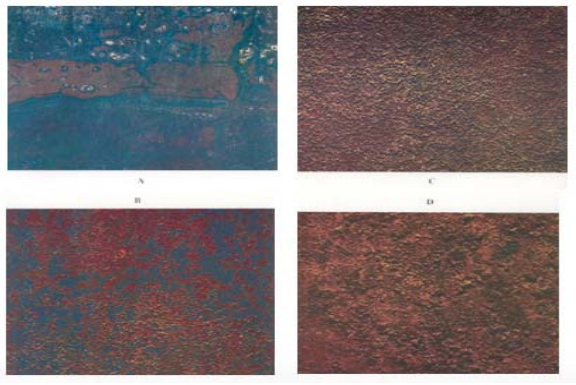

Figure 10.45 ISO Rust Grades A, B, C, and D

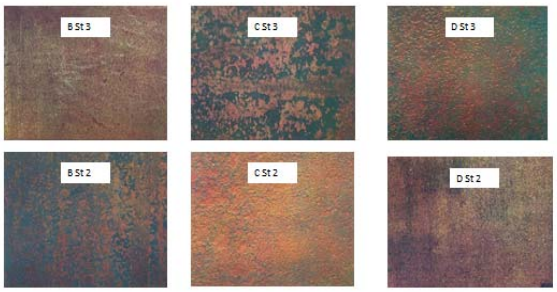

Figure 10.46 ISO 8501-1: Hand and Power Tool

SSPC-SP 11 *Power Tool Cleaning to Bare Metal* calls for power tool cleaning to produce a bare metal surface, and retain or produce a profile, when a clean, roughened, bare metal surface is desired but when abrasive blast cleaning is not feasible or allowed. Metallic surfaces prepared according to SSPC-SP 11, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter. Slight residues of rust and paint may be left in the bottom of pits if the original surface is pitted. If painting is specified, the surface must be roughened to a degree suitable for the paint system, with a profile not less than 1 mil (25 µm).

Visual standards for power tool cleaning are:

- SSPC VIS 3 (Figure 10.47)
- ISO
  - **Visual**
    - ISO 8501-1 (St 3 or St 2)
- Other acceptable standards must be agreed on by all parties involved in the surface preparation.

Figure 10.47 Power Tool Cleaning Visual Standards

10.9 Surface Cleaning Methods: Power Tools

This section presents some of the tools used for power tool cleaning, as well as their advantages and limitations.

10.9.1 Rotary Wire Brushes

Rotary wire brushes (Figure 10.48) are available in two general types:

- Straight (in-line)
- Vertical (right-angle)

Overworking the surface with a wire brush can be detrimental because excessive burnishing develops a polished surface, which is a poor anchor for most coatings. Rotary

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power wire brushes can also easily spread oil and grease over the surface; therefore, solvent cleaning is an essential step before power wire brushing.

Using rotary wire brushes is considered less desirable than other forms of power tool cleaning because issues stemming from achieving a polished rather than roughened surface are more likely.

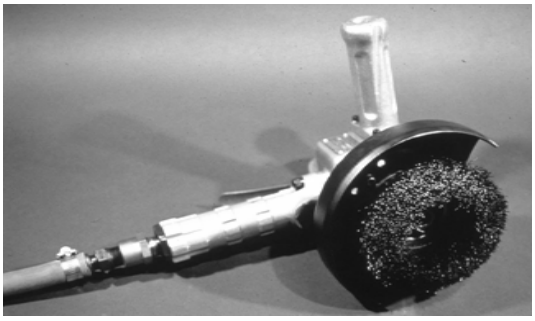

Figure 10.48 Rotary Wire Brush

10.9.2 Impact Tools

Chipping or scaling hammers are the most widely used impact tool. A chisel is inserted into a power tool; air-operated or electrically operated pistons transmit impact to the chisel then to the surface. The chisels come in different shapes and materials.

Scrapers and specialty chisels are also used. Use of scaling or chipping hammers is generally a slow, costly method to clean surfaces, but when considerable rust scale or heavy paint formation is present, they prove to be economical.

Please note: using these tools requires ***extreme care*** because it is too easy to cut into the surface excessively, removing sound metal and leaving sharp burrs where the coating will fail prematurely. **To repeat:** impact tools may be used to remove some tight mill scale and surface rusting, but this generally is not the most practical or economical method because of the high possibility of gouging the metal, which then requires smoothing so coatings will not fail prematurely. The tools must be kept sharp, or they can drive rust and scale into the surface.

10.9.3 Needle Scaler

Needle scalers (Figure 10.49) or needle guns, consist of several hardened steel rods that vibrate against the surface. Needle scaling is slow and, similar to other power tools, it burnishes while producing a relatively clean surface. It does, however, produce a surface profile. Needle scalers are effective on welds, corners, and irregular surfaces. When removing lead-based paint, they can be fitted with vacuum devices to comply with lead abatement regulations. Other power tools in use to remove similarly hazardous coatings may be fitted with dust containment and collection devices.

Figure 10.49 Needle Scaler

10.9.4 Rotary Scalers

Rotary scalers can be used effectively on large areas to remove rust and scale. These require careful use to avoid cutting the metal to such an extent that metallic points extend far above the surface causing early coating

failure due to insufficient coverage. Rotary scalers produce a very rough surface; take care to ensure that all peaks of the anchor pattern are covered by the coating.

10.9.5 Piston Scalers

Piston scalers (Figure 10.50) operate similarly to scaling hammers, but the piston itself acts as the impact tool. A hammer piston takes the place of the chisel. It is a circular shaft with the cutting end cross-shaped, somewhat like a star chisel. These scalers are available with one, two, or three pistons operating in one tool. Large assemblies with as many as 15 pistons are also available for use on flat, horizontal surfaces such as steel decks.

Figure 10.50 Piston Scaler

10.9.6 Grinders and Sanders

Grinders and sanders (Figure 10.51) are often used to prepare surfaces for coating. The machines powering these tools may be the same as those used for power wire brushing, with suitable sanding discs or grinding wheels substituted for the wire brushes. The abrasive grit size used with these tools is critical. A grit that is *too coarse* can creates a deep anchor profile that may be unsuitable for good coating performance. An abrasive that is *too fine* can cause the grinding wheel or sanding disc to clog early in the process making the process inefficient. Grinding is appropriate to remove weld spatter, smooth weld seams, or round off sharp edges or corners. Power grinders and sanders are frequently used to repair minor fabrication defects. The anchor profile *can be* extremely good, with complete removal of rust and mill scale; *however,* cleaning large areas with these tools is very expensive.

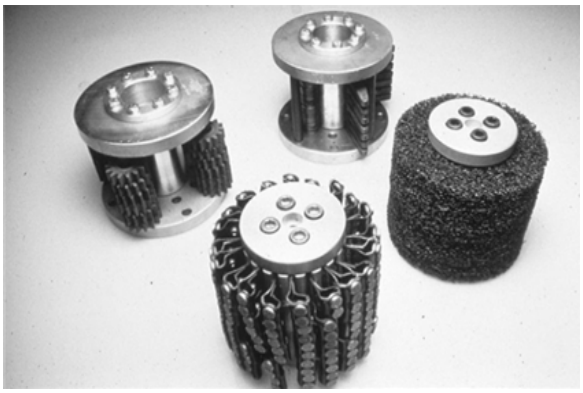

Figure 10.51 Grinders and Sanders

10.9.7 Disc Sanders

Pneumatic- and electrically-operated disc sanders are also available. They have a flat pad or abrasive surface in contact with the metal to be cleaned. Some motor-driven sanders have an orbital motion. The anchor profile varies by selection of the sanding disc used with the equipment. A rougher grit disc affects a rougher surface profile on the substrate. Consequently, a finer grit affects a less rough surface.

10.9.8 Vacuum Connections

Vacuum connections are used to eliminate dust from the removal of old coatings, and are required by many authorities. For that reason, many power tools now have collectors and vacuum lines to gather most of the dust as the tool operates. The effects of the

power tools on the surface remains the same, but the equipment is heavier and more difficult to handle. Even so, acceptable results can be achieved.

10.9.9 New Tools

There are some new power tools on the market that leave an anchor pattern as well as clean the surface. The MBX Bristle Blaster™ is one of the new tools.

Figure 10.52 MBX Bristle Blaster

10.9.9.1 Power Tool Cleaning to Bare Metal SSPC-SP 11

In 1989, SSPC adopted a new standard, SP 11, *Power Tool Cleaning to Bare Metal*. When the highest levels of surface preparation are required or specified (e.g., SSPC-SP 11), production of a surface profile is a mandatory part of the surface preparation operation. A surface profile can also be achieved using special power tools designed for the purpose.

Power tool cleaning in accordance with this standard produces a greater degree of cleaning than SSPC-SP 3; however, surfaces prepared according to SSPC-SP 11 should not be considered equal to surfaces prepared by abrasive blast cleaning. Although power tool cleaning to bare metal produces surfaces that *look* like near-white or commercial blast, they are not necessarily equivalent to abrasive blast cleaned surfaces.

10.9.10 Inspection Considerations

Some of the things inspectors should consider are:

- The substrate condition prior to cleaning
- The solvent cleaning prior to power tool cleaning
- The area where power tool cleaning is required
- The coating to be applied to the existing surface
- The edges after the power tool cleaning is completed
- The ambient conditions during cleaning and prior to coating

10.9.11 Inspector's Checklist

The inspector's checklist prior to and after power tool cleaning should include but not be limited to:

- Check the pre-cleaning before power tool cleaning begins
- Check the surface to ensure that power tool cleaning is the required surface preparation
- Understand the specification concerning power tool cleaning
- Know the areas that require power tool cleaning
- Check the equipment to ensure that the proper tools for the job are at hand
- Check the substrate after the power tool cleaning to ensure there are no lifting edges
- Ensure that the transition of the coating has been feathered in to ensure adhesion of the coatings

10.10 Abrasive Blasting

10.10.1 Introduction

In this section, blast cleaning methods are examined. The following are some of the methods inspectors need to know in order to perform a good inspection:

- Centrifugal blasting
- Sand-injected water blast
- Slurry blast
- Wet abrasive blast
- Dry grit blast cleaning (air blasting)

10.10.2 Methods

10.10.2.1 Dry Grit Blasting (Air-Blasting)

The most generally established method of surface preparation for coatings application is **dry grit blasting**. Dry grit blasting (Figure 10.53) uses a highly concentrated stream of grit projected at a surface to remove rust, mill scale, or other contaminants, and to create a rough surface good for adhesion. Indeed, when modern coatings are applied, there is no truly satisfactory or economically-equivalent alternative process.

The fundamental principle of grit blasting is to remove rust, mill scale, or other surface contaminants and to obtain a suitably roughened surface. This is done by projecting a highly concentrated stream of relatively small abrasive particles at high velocity against the surface to be cleaned. The high-velocity impact of the abrasive particles abrades the surface. Blast cleaning removes rust, mill scale, and old coatings along with some of the base metal (Figure 10.54).

Figure 10.53 Dry Abrasive Blasting

The basic components of an abrasive blasting system are illustrated in Figure 10.55.

Figure 10.54 Blast Cleaning Booth

10.10.2.2 Equipment Overview

As mentioned, abrasive blasting is the most commonly used method of surface preparation. The abrasive is forced from the pressure vessel (blast pot) under pressure through the blast hose and onto the substrate (Figure 10.56). It is a high-production method for heavy-duty jobs, i.e., in shipyards, refineries, and chemical plants, and for cleaning railroad cars and buildings.

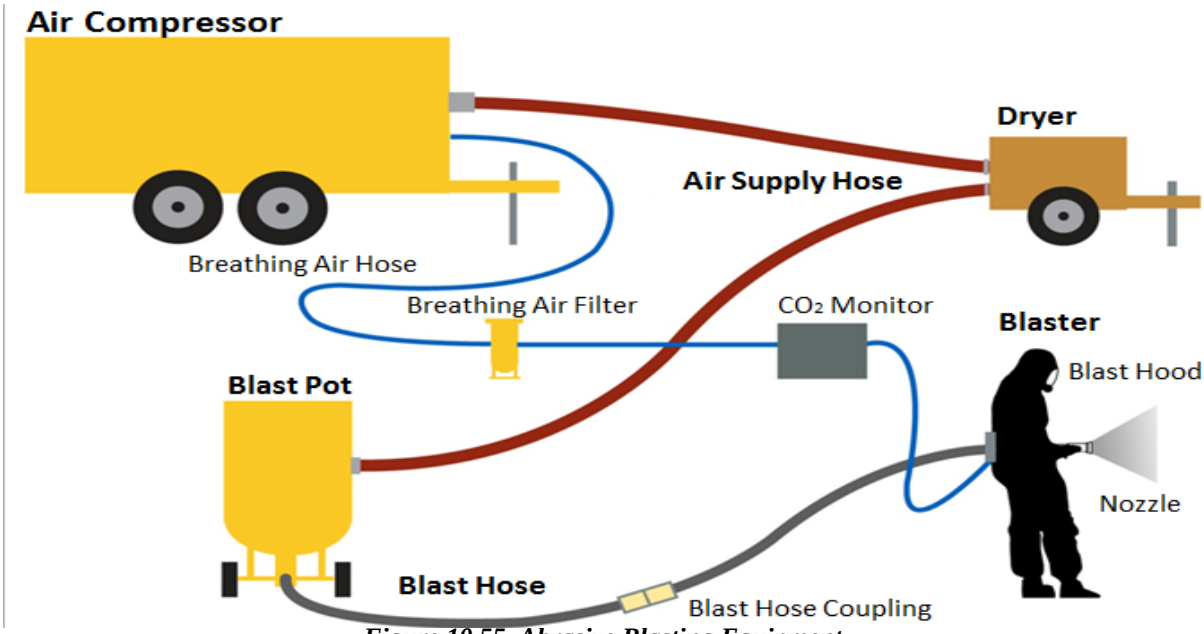

Figure 10.55 Abrasive Blasting Equipment

Figure 10.56 Blast Cleaning Equipment

10.10.2.3 Blast Pot

The care, safety, and efficient use of the blast pot can save money in both man-hours and abrasives. On-going maintenance is needed to eliminate leaks and pressure losses. In most countries, the vessel (blast pot) must be inspected annually and hydro tested to 1½ times the design pressure to ensure safe and effective functioning.

Blast cleaning is a potentially hazardous operation. With abrasives and equipment both under pressure, safety is very critical. Remember that abrasives and air leave the nozzle at great speed (at a rate close to 450 mph (720 kph); that is 660 ft/s, or about *half the speed of a shotgun charge*). At that velocity, abrasives can strike surfaces or other workers a considerable distance from the operation.

Although the attached blast hoses are "static dissipating," **it is essential to ground the entire system**, including hoses, operator, and work piece, **to prevent injury due to electrical shock**. Grounding is particularly important when the operator is working at heights (when shock may lead to a fall) or when blasting in a hazardous environment.

10.10.2.4 Air Supply Hose

The air supply hose carries air from the compressor to the abrasive blast unit. Generally, the larger the air line, the better; no smaller

than 1.25 inches (31 mm) internal diameter (ID) is recommended. The recommended hose size is three to four times the nozzle orifice. On lines longer than 100 ft. (30 m), the hose ID should be four times the blast nozzle orifice size. The larger hose size eliminates loss of air pressure through the air hose because of friction.

10.10.2.5 Blasting Hose

There are two types of abrasive supply hoses:

- **Four-ply -** use when the hose is subject to external abuse or when there is danger of the operator pulling it at right angles
- **Two-ply** - a lighter hose some blasters prefer because of its greater flexibility

The size and length of abrasive blast hoses are related to their efficiency. A rule of thumb is: *the hose ID should be three to four times the size of the nozzle orifice*.

The *whip length* section is the last section of the blast hose. It gives the operator (blaster) better handling and enhances his ability to handle the hoses under high pressure. It is usually 10-15 ft (3-4.5 m) long and a smaller diameter than the rest of the blast hoses. The smaller ID causes a drop in pressure so it is recommended that operators use a whip attachment only when necessary.

Most blast hoses are now made with an internal ground; loading the hose rubber with carbon black allows static electricity to drain to earth. Sometimes an additional external ground is necessary. Use only grounded hoses to ensure operator safety.

Couplings (Figure 10.57) connect the hose sections. Using *only* externally fitted couplings is highly recommended. Internally fitted couplings reduce hose ID and air capacity significantly. In addition, a turbulent condition may occur at the point where the air and abrasives hit the leading edge of the nipple inside the hose, resulting in pressure drop and heavy wear at that point.

Figure 10.57 Coupling

Couplings are held in place with external screws that penetrate into the *wall* of the hose. Ensure the screws do not penetrate the tube causing air leaks and loss of pressure.

Maintain grounding through the coupling. Because of inevitable pressure drops within air lines, keep pressure hoses as short as possible. Preferably, the blast hose (from pot to blast nozzle), should not be more than 20 ft (6 m) long. When longer lengths are unavoidable, keep the hose straight; ensure any bends are wide and have a smooth radius.

During blast cleaning, the air compressor must be able to deliver and maintain the required air volume and pressure at the nozzle. Related equipment, including the following, must be of the correct size and type to match the compressor output (Figure 10.58):

- Air and abrasive hoses
- Hose couplings
- Blast nozzles

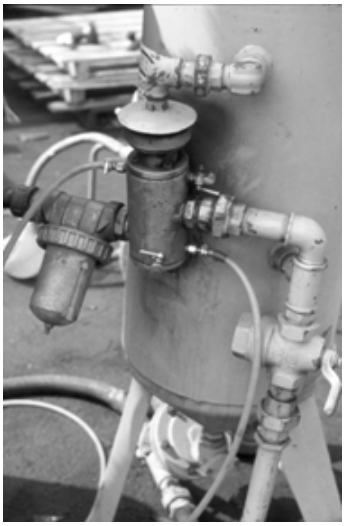

Figure 10.58 Air Compressor to Pot Connection

The compressed air must be free of contaminants, including oil and water. *First*, since air-supplied breathing equipment is required when abrasive blast operations are done, it is critical that the breathing air meets safety and legal requirements. This is the responsibility of the applicator unless otherwise designated. *Second*, it is important that the blast air is clean to ensure that the blasting does not add contaminants to the surface.

The blasting contractor is responsible for complying with all requirements of the specifications, such as size of hose, type of nozzle, and air volume. The coating inspector may check each of the requirements specified to ensure compliance by the contractor.

Compressed air is a common source of power for blast machinery, paint spray equipment, power tools, etc. It is favored on site because it is relatively safe (less dangerous than electrical power). To produce the needed quantities of compressed air, it is necessary to use a compressor. A compressor draws in atmospheric air, pressurizes it, and feeds the air into a pressure vessel (known as a receiver) or directly to the item that requires it.

Producing compressed air presents two problems to the surface preparation process. These are:

- Any change in atmospheric pressure can result in the release of water vapor from the air.
- Because compressed air in the receiver is stored by pressurizing an oil reservoir, it is possible that oil vapor remains in the air as it is released.

Both of these factors require fitting adequate vapor traps to blast cleaning equipment to remove oil and water contaminates.

10.10.3 Compressors

Compressors are rated for both air pressure and capacity.

Air pressure is measured in pounds per square inch (psi), Pascals (Pa), or bar. Air pressure is normally set a little above the intended working pressure, normally a maximum of 100 psi (690 kPa, 7 bar) for portable compressors. This pressure, if successfully maintained, produces efficient blast cleaning. *Use air pressure no more than safety considerations and regulations allow.* This figure may vary in different countries.

Adequate pressure is critical to effective blasting. If the abrasive is not propelled at sufficient pressure, the job takes extra time to complete. Measure pressure at the nozzle with a hypodermic needle gauge described later.

Select a compressor that is able to supply more air than is required. This provides a reserve capacity for peak loads or additional equipment. The same compressor that pow-

ers blasting often also powers air-operated spray guns and other equipment. No other surface preparation process requires such large quantities of compressed air as the blast cleaning operation.

It is estimated that with one 3/8 in (9.5 mm) nozzle operating, there is a 5 lb (35 kPa) drop in pressure for each 50 ft (15 m) of hose in use. This pressure drop compounds depending on the number of operating nozzles, the nozzle sizes, and the lengths of hose in use. Undersized compressors create inefficiencies that directly impact cost and schedule. Their use may lead to:

- Wasting time waiting for a lower-capacity compressor to build up the required pressure
- Placing undue strain on the compressor during peak loads
- Loss of time from inefficiently operating air-starved equipment
- Inability to add new tools to the system
- Greater possibility of breakdowns or shutdowns
- Excessive running to supply the quantity of air needed
- Excessive heat and condensation

Water and oil separators are essential to maintain surface cleanliness during the blast cleaning process. Without them, the air from the compressor can carry oil vapor or moisture droplets entrapped in the high-pressure air, or from residual dust arising during blast cleaning.

Take precautions to ensure that compressed air supplies are oil and moisture free. Install suitable oil and moisture traps, after-coolers and filters in the air lines, and make sure they receive adequate maintenance. Most oil and moisture traps operate with drain plugs in a partly-open position, allowing accumulated moisture to disperse.

Moist air can also cause abrasives to clog the abrasive lines or blast pot and may cause rusting of the blast cleaned surface. Some of the accessories (Figure 10.59) for the operation are listed below:

- Filter units that contain charcoal and supply-purified air to the blast hood. They also have monitors to detect the presence of carbon monoxide (CO).
- Drier units to remove water from the compressed air and prevent the abrasive from becoming wet.
- Absorbent filters to absorb moisture in compressed air and prevent condensation on the work piece.
- Refrigerant to remove water by cooling and extracting moisture from the air stream, thereby preventing condensation on the work piece. Cooler air holds less water than warmer air.
- Centrifugal separators to remove water through centrifugal force.
- Water-cooled heat exchangers to cool hot compressor air thus removing moisture from the air stream.
- An auxiliary receiver or storage tank. These act as reservoirs of compressed air. One or more compressors feed air into the auxiliary tank until it is needed to power the tools and operations connected to the tank.

Figure 10.59 Abrasive Blasting Hopper

10.10.4 Surface Cleanliness Standards

There are various degrees, or standards, of surface cleanliness achievable by abrasive blasting. The abrasive blast cleaning standards for new steel in most common use are from NACE, SSPC, and ISO (Figure 10.60).

NACE / SSPC JOINT STANDARDS	NOT	ISO STANDARDS
NACE No. 1/SSPC-SP 5 White Metal Blast Cleaning		ISO 8501-1, Sa 3 Blast-Cleaning to Visually Clean Steel
NACE No. 2/SSPC-SP 10 Near-White Metal Blast Cleaning		ISO 8501-1, Sa 2½ Very Thorough Blast-Cleaning
NACE No. 3/SSPC-SP 6 Commercial Blast Cleaning		ISO 8501-1, Sa 2 Thorough Blast-Cleaning
NACE No. 8/SSPC-SP 14 Industrial Blast Cleaning		ISO 8501-1, Sa 1 Light Blast-Cleaning
NACE No. 4/SSPC-SP 7 Brush-Off Blast Cleaning		

Figure 10.60 Abrasive Cleaning Standards

10.10.4.1 NACE-SSPC

In October 1994, NACE and SSPC jointly issued the following surface preparation standards for abrasive blast cleaning (Figure 10.61):

- NACE No. 1/SSPC-SP 5, *White Metal Blast Cleaning*
- NACE No. 2/SSPC-SP 10, *Near-White Metal Blast Cleaning*
- NACE No. 3/SSPC-SP 6, *Commercial Blast Cleaning*
- NACE No. 4/SSPC-SP 7, *Brush-Off Blast Cleaning*

Standard	Random Staining	Cleanliness
NACE No. 1/SSPC-SP 5 White Metal Blast Cleaning	None	Free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter
NACE No. 2/SSPC-SP 10 Near-White Metal Blast Cleaning	5%	
NACE No. 3/SSPC-SP 6 Commercial Blast Cleaning	33%	
NACE No. 4/SSPC-SP 7 Brush-Off Blast Cleaning	Tightly adherent mill scale, rust, and coating may remain	
NACE No. 8/SSPC-SP 14 Industrial Blast Cleaning	Traces of tightly adherent mill scale, rust, and coating residues are permitted to remain on 10 percent of each unit area	

Figure 10.61 Abrasive Cleaning Standards

NACE No. 1/SSPC-SP 5, *White Metal Blast Cleaning*

A white metal blast cleaned surface, when viewed **without** magnification, shall be free of all visible:

- Oil
- Grease
- Dust
- Dirt
- Mill scale
- Rust
- Coating
- Oxides
- Corrosion products
- Other foreign matter

Acceptable variations in appearance that do not affect surface cleanliness include variations caused by:

- Type of steel
- Original surface condition
- Thickness of steel
- Weld metal
- Mill or fabrication marks
- Heat treatment
- Heat-affected zones
- Blasting abrasive
- Differences in the blast pattern

NACE No. 2/SSPC-SP 10, *Near-White Metal Blast Cleaning*

A near-white metal blast cleaned surface, when viewed **without** magnification, shall be free of all visible:

- Oil
- Grease
- Dust
- Dirt
- Mill scale
- Rust
- Coating
- Oxides
- Corrosion products
- Other foreign matter except for staining

Staining shall be limited to no more than **5%** of each unit area of surface approximately 9 in^2 (6,400 mm^2), i.e., a square 3 x 3 in (80 x 80 mm) and may consist of:

- Light shadows
- Slight streaks or minor discolorations caused by:
  - — Rust
  - — Mill scale
  - — Previously applied coatings

Acceptable variations in appearance that do not affect surface cleanliness include variations caused by:

- Type of steel
- Original surface condition
- Thickness of steel
- Weld metal
- Mill or fabrication marks
- Heat treatment
- Heat-affected zones
- Blasting abrasive
- Differences in the blast pattern

NACE No. 3/SSPC-SP 6, *Commercial Blast Cleaning*

A commercial blast cleaned surface, when viewed **without** magnification, shall be free of all visible:

- Oil
- Grease
- Dust
- Dirt
- Mill scale
- Rust
- Coating
- Oxides
- Corrosion products
- Other foreign matter except for staining

Random staining shall be limited to no more than **33%** of each unit area approximately 9 in^2 (6,400 mm^2), i.e., a square 3 x 3 in (80 x 80 mm) and may consist of:

- Light shadows
- Slight streaks or minor discolorations caused by:
  - — Stains of rust
  - — Stains of mill scale
  - — Stains of previously applied coating

Acceptable variations in appearance that do not affect surface cleanliness include variations caused by:

- Type of steel
- Original surface condition
- Thickness of the steel
- Weld metal
- Mill or fabrication marks
- Heat treatment
- Heat-affected zones

- Blasting abrasive
- Differences in the blast pattern

NACE No. 4/SSPC-SP 7, *Brush-Off Blast Cleaning*

A brush-off blast cleaned surface, when viewed **without** magnification, shall be free of all visible:

- Oil
- Grease
- Dirt
- Dust
- Loose mill scale
- Loose rust
- Loose coating

Tightly adherent mill scale, rust, and coating may remain on the surface. Mill scale, rust, and coating are considered *tightly adherent* if they cannot be lifted with a dull putty knife.

The entire surface shall be subjected to the abrasive blast. The remaining mill scale, rust, or coating shall be tight**.**

NACE No. 8 / SSPC-SP 14, *Industrial Blast Cleaning*

An industrial blast cleaned surface, when viewed **without** magnification, shall be free of all visible:

- Oil
- Grease
- Dirt
- Dust

Traces of tightly adherent mill scale, rust, and coating residues are permitted to remain on 10% of each unit area of the surface if they are evenly distributed. The traces of mill scale, rust, and coating are considered to be tightly adherent if they cannot be lifted with a dull putty knife. Shadows, streaks, and discolorations caused by stains of rust, stains of mill scale, and stains of previously applied coating may be present on the remainder of the surface.

10.10.5 Visual Standards

Surface profile coupons are available in 0.5 mil (12 µm) increments from 0.5–3 mils (12–75 µm). The coupons allow for determination of surface profile through comparison (ASTM D 4417, Method A).

10.10.5.1 SSPC-VIS 1

After discussing the wording of the NACE/SSPC joint surface preparation standards, it is time to consider the visual standards that support written standards. The first visual standard is SSPC-VIS 1, *Visual Standard for Abrasive Blast Cleaned Steel* (Figure 10.62).

Figure 10.62 Visual SSPC-VIS 1

This visual standard contains reference photographs for steel surfaces prepared by abrasive blast cleaning using **sand** abrasive (Figure 10.63). They are intended to supplement the written SSPC blast cleaning surface preparation specifications and are not meant to be used as a substitute for these specifications. In reviewing the standard and the slides, specific descriptions will be identified.

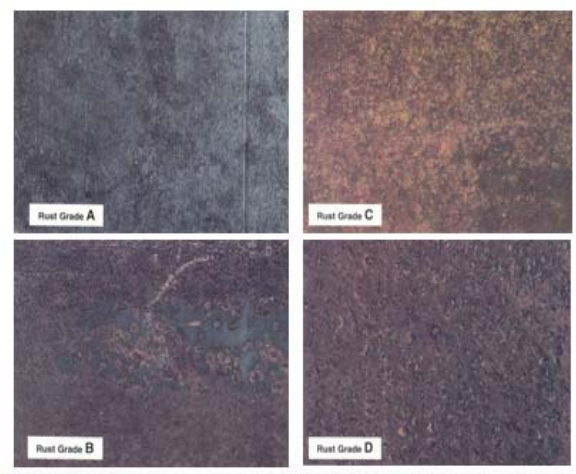

Figure 10.63 SSPC-Vis 1 Rust Grades A, B, C, and D

Rust Grade A

For example, note the designation A SP 10. This indicates surface rust grade A (100% adherent mill scale) blast cleaned to a near-white metal finish. If grade D were substituted for grade A, the designation would be D SP 10.

Figure 10.64 shows rust grade **A** (100% adherent mill scale) blast cleaned to **SP 10** (near-white) and to **SP 5** (white metal), with the designations **A SP 10** and **A SP 5**.

Also note, there is no photograph for **A SP 7** because of the wide variations in appearance when brush-off blast cleaning adherent mill scale is done. There is also no photograph for **A SP 6** because this condition cannot normally be obtained when removing adherent mill scale.

Figure 10.64 Rust Grade A - blasted

Rust Grade B

Figure 10.65 and Figure 10.66 illustrate rust grade B (mill scale and rust) blast cleaned as follows:

- **B SP 7** Brush-Off Blast
- **B SP 6** Commercial Blast
- **B SP 10** Near-White Metal Blast
- **B SP 5** White Metal Blast

The difference in appearance of the steel after each blast cleaning method on different initial rust grades is easily seen.

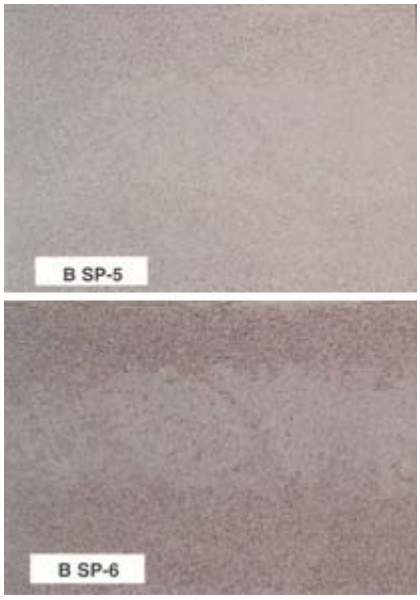

Figure 10.65 Rust Grade B - blasted

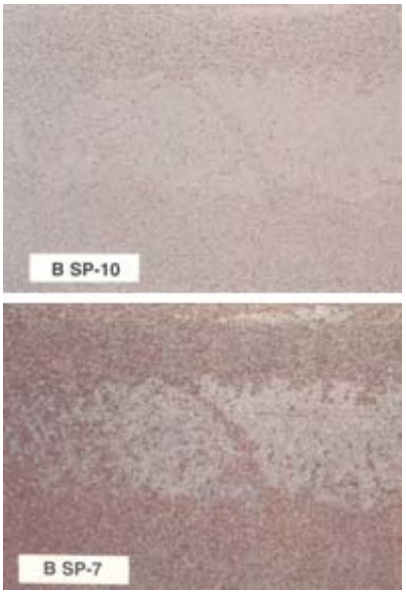

Figure 10.66 Rust Grade B - blasted

Rust Grade C

Rust grade C (100% rust) is blast cleaned to the four standards:

- **C SP 7** Brush-Off Blast
- **C SP 6** Commercial Blast
- **C SP 10** Near-White Metal Blast
- **C SP 5** White Metal Blast

Again, note the contrast in appearance due the different initial rust grades in Figure 10.67 and Figure 10.68.

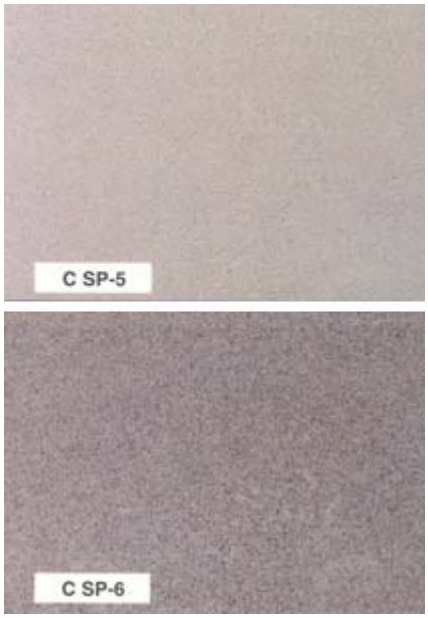

Figure 10.67 Rust Grade C - blasted

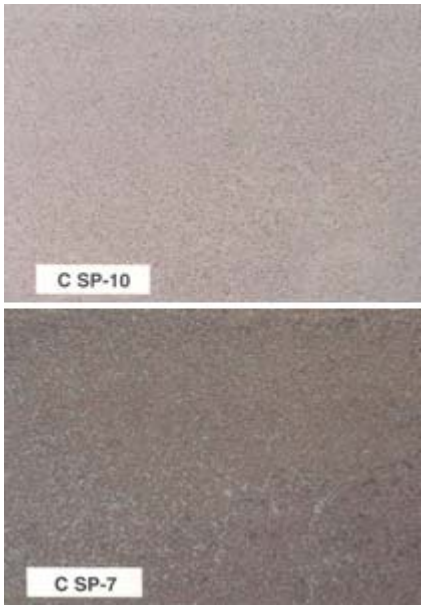

Figure 10.68 Rust Grade C - blasted

Rust Grade D

Figure 10.69 and Figure 10.70 illustrate rust grade D (100% rust with pits), blast cleaned as follows:

- **D SP 7** Brush-Off Blast
- **D SP 6** Commercial Blast
- **D SP 10** Near-White Blast Metal
- **D SP 5** White Metal Blast

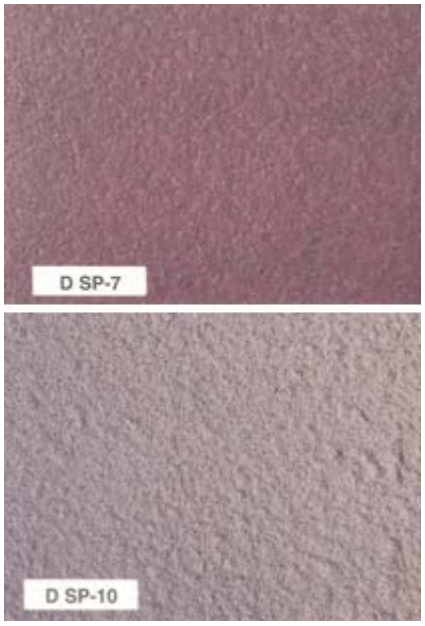

Figure 10.69 Rust Grade D - blasted

Figure 10.70 Rust Grade D - blasted

10.10.6 ISO

Modern ISO standards are roughly equivalent to the ISO standards that were developed from the original Swedish standards. ISO 8501-1 was published in 1988 and contains four standards:

- **Sa 3** *Blasting to Visually Clean Metal*
- **Sa 2½** *Very Thorough Blast Cleaning*
- **Sa 2** *Thorough Blast Cleaning*
- **Sa 1** *Light Blast Cleaning*

Each organization's system of visual standards represents a progressive scale of visual appearance only, the best grade shown first in each. The quality of blast cleaning is determined visually, and photographic standards are generally used only for comparison purposes. There is no correlation between the degree of blast cleaning used and the surface profile produced and no specific correlation with removal of chemical contamination (or non-visible salts). For these issues, written standards and other measuring techniques must be used.

10.11 Typical Abrasives

The degree of surface roughness and the rate of cleaning depend primarily on the characteristics of the abrasive grit used. Although blasting abrasives range widely from crushed walnut shells, glass, and crushed slags to various metallic shots and grits, and even ceramic grits, there are a limited number of abrasive types in common use to prepare a surface for coating. These include:

- Crushed slag
- Naturally occurring mineral grit
- Ceramic grit

Despite the widespread use of the term "sand blasting," sand is not listed as a grit blasting abrasive. Sharp sand is a cheap and effective but it is increasingly not used throughout most of the world (nor any abrasive containing free silica) due to the health hazards of *silicosis.* Workers exposed to hazardous levels of free silica dust—such as that released during blast cleaning — may develop silicosis, a very serious lung disease.

It is important to note that there is *some* naturally occurring silica-free sand that can be used for abrasive blasting. These sands do not release silica in a harmful form (i.e., free silica) when broken up in the blasting process. Permission to use sand may occasionally be given for *site work* in the open air, but only when operators and other personnel are carefully protected from the dust and the site and blasting conditions are approved by the local health authorities.

10.12 Crushed Slags

Crushed slag from metallurgical processes or combustion are relatively cheap abrasives. Copper-, nickel-, coal-, and aluminum-slag are common. There are quite effective grits for ***once-only use***, but they are not generally suitable for grit reclamation and reuse because they rapidly break down to dust. These materials are often called *expendable abrasives*.

A typical analysis of copper-slag abrasive may show the chemical content to be similar to the content shown in Table 1.

Table 1: Analysis of Copper-Slag Abrasive

SiO_2	38.40%	Silicon Oxide
Al_2O_3	3.35%	Aluminum Oxide
TiO_2	0.35%	Titanium Oxide
FeO	41.55%	Iron Oxide (II)
Fe_2O_3	3.15%	Iron Oxide (III)
MnO	0.27%	Manganese Oxide
CaO	5.86%	Calcium Oxide
MgO	2.15%	Magnesium Oxide
K_2O	0.53%	Potassium Oxide
Na_2O	0.40%	Sodium Oxide
CuO	0.47%	Copper Oxide
PbO	0.04%	Lead Oxide
ZnO	1.68%	Zinc Oxide
S	0.96%	Sulfur
Total	**98.84%**	

Notice there is very little copper content since the slag is a byproduct of the copper extraction process. Also notice that most of the contents are oxides of one metal or another.

10.12.1 Ceramic Grit

Ceramic grits (aluminum oxides and silicon carbides) are relatively expensive abrasives, but their use is sometimes justifiable because of their special properties. Ceramic grits are particularly effective because their particles retain sharp cutting edges even on

hard-base materials (which may resist effective blasting by chilled cast iron grit).

Additionally, ceramic grits achieve effective cutting at lower blasting pressures than normally used for other abrasives. Because of this, ceramic grits are particularly well suited to blast thin metal surfaces which can *buckle* or distort if blasted with chilled iron grit at conventional blast pressures. Finally, because ceramic grit is virtually inert to normal corrosive influences, it can safely blast stainless steel or nonferrous material surfaces without causing rust staining, discoloration, or bimetallic corrosion.

10.13 Nozzle Size

Other factors being constant, the speed of blasting and the air consumption are directly related to the size of the nozzle. Accordingly, the maximum nozzle size that can be used depends upon the capacity of the compressor feeding it (Table 2). Table 3 shows the volume of air required at various pressures to feed different sizes of nozzles.

Maintaining nozzle size is of considerable importance. This can be a problem with normal cast iron nozzles which wear quite rapidly. More efficient blasting can be maintained with nozzles made of wear-resistant alloys, tungsten carbide, or ceramics. Although the initial cost is higher, these nozzles are more economical over time.

Table 2: Maximum Nozzle Size Relative to Compressor Capacity

Blast Nozzle Orifice Size		Volume of air required (ft^3/min)				
		60 psi	70 ps	80 ps	90 ps	100 ps
¼	#4	67	76	85	94	103
3/8	#6	151	171	191	211	232
½	#8	268	304	340	376	413

Table 3: Volume of Air Required at Appropriate Pressure to Feed Nozzles of Differing Orifice Sizes

Blast Nozzle Orifice Size		Volume of Air Required (L/min)				
		4.1 bar	4.8 bar	5.5 bar	6.2 bar	6.9 bar
6.3 mm	#4	1900	2150	2400	2660	2920
9.45 mm	#6	4280	4840	5410	5980	6570
12.6 mm	#8	7590	8610	9630	10650	11700

The *internal profile* of the blast nozzle is also extremely important. Venturi nozzles are generally preferred to the parallel-bore nozzles formerly used. They last longer, have higher grit velocity at a more economical air consumption, and result in an increase in overall blasting efficiency.

10.13.1 Nozzle Designs

10.13.1.1 Venturi vs. Straight Bore

There are two types of blasting nozzles used in the industry today:

- Straight bore
- Venturi

When and where the various nozzle types are used depends on several factors. The **straight bore** nozzles have an outlet abrasive velocity of about 217 mph (349 kph), or 315 ft/s. In addition, they tend to spread the abrasive in a large blast pattern, with more concentration in the center and less at the edges.

The **Venturi** nozzle (Figure 10.71) has a large entrance throat, tapers gradually into a short straight section in the middle, and then flares at the outlet end. The Venturi shape permits abrasive velocity up to 450 mph (720 kph), or 660 ft/s and an almost equal impact over the entire surface. Venturi nozzles are the most effective shape for tough cleaning jobs. Periodically, the user should:

- Check nozzle type
- Venturi types provides higher abrasive velocity than straight-bore types the same size. When venturi nozzles wear, they lose their efficiency.
- Check for cracked and/or worn nozzles. Do not use cracked nozzles because they can create a severe safety hazard. Also worn nozzles decrease blasting effectiveness.

Figure 10.71 Venturi Nozzle

Use a nozzle orifice gauge (Figure 10.72) to measure wear. Some users specify that nozzle wear should not exceed one nozzle number, $\frac{1}{16}$ in (1.6 mm); other users may require nozzle replacement when wear reaches 50% of the original size. The nozzle aperture test is described on the following pages.

Test for nozzle pressure of the optimum 90–100 psi (620–690 kPa) using a hypodermic needle pressure gauge *during* the blasting operation.

Obtain the blaster's agreement. Either the inspector or operator measures the pressure by inserting the needle into the hose as close as possible behind the blast nozzle and while the hose is blasting with abrasive. The nozzle air pressure test, or hypodermic-needle test (Figure 10.73), is described in detail on the following pages.

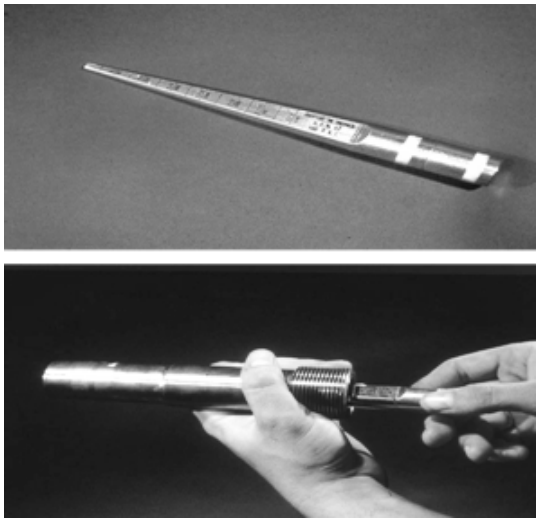

Figure 10.72 Nozzle Aperture Test

Choice of nozzle size is affected by the:

- Type of work to be done
- Volume of compressed air available
- Amount of pressure available
- Type of blast unit being used
- Velocity needed:
  - — Longer nozzles
    - More velocity
    - More concentrated blast pattern
    - Preferable on tough cleaning jobs
  - — Nozzle too large for work may waste power from undue blasting

Ensure workers do not use nozzles as hammers, tap signals from inside tanks, or drop. Checked regularly for cracks and wear.

10.13.2 Safety

For the safety and comfort of the blast cleaning operator, good quality working clothes are essential. Typically, these include (Figure 10.74):

- Safety boots (with steel insert toe cap)
- Coveralls
- Strong leather gloves
- Air-fed blasting helmet, incorporating a replaceable visor and leather cape
- Hearing protection

Figure 10.73 Needle Pressure Gauge

Figure 10.74 Blast Operator Safety Gear

It is important that the operator has a good supply of clean, fresh air for breathing. Two common ways to achieve this are:

- Deliver a supply of air at low pressure from the blast pot via a filter. Disadvantage: the air is the same quality (often poor) in use for blasting.
- Feed in a separate supply of air, also at relatively low pressure, from a remote air-driven pump well away from any contaminated or dust laden atmosphere.

*Abrasive blast cleaning at high pressure is a **dangerous** operation*. It is essential to take the appropriate steps to protect both the operators and any spectators or other site personnel. Some considerations are:

- Allow no one but the operator in the vicinity of the blast cleaning operation
- Display warning notices
- Post a look-out (or *pot-man*) to watch for hazardous activity
- Test all equipment for operational safety
- Ensure fitting and use of a *Deadman's Handle* cut-out device
- Ensure a *deadman* (remote control) *valve* (allows the machine to be controlled at the nozzle by the operator) is part of this unit
- Ensure that the deadman safety feature is always operable and is used during blast operations

Several accessories are in common use with the blast pressure pot, including:

- Abrasive metering valve to monitor the proper balance of abrasive to the air flow and nozzle size
- Remote control (deadman) valve

The operator must hold the remote control valve (*deadman valve*) in the closed position to pressurize, and therefore activate, the blast pot. When the valve is released, the blast machine is shut down, thus safeguarding the operator. If the operator becomes ill, faints, trips and drops the hose, he or she is not in danger of being hit by flying abrasives or the blast hose whipping around in the work area.

Figure 10.75 Deadman Valve (Note: This is the "off" position)

Many consider the deadman valve cost effective because it can eliminate the need for a pot tender (or blaster's helper). Figure 10.75 shows an operator holding the blast nozzle with his hand under the Deadman's handle. Remote control valves may operate by compressed air or electricity. Compressed-air-operated valves do not require any other power source than the compressor, but may be slow to react, particularly when the blast hoses and nozzle are a significant distance from the blast pot. Electrically-operated valves operate instantaneously but require a power source, they are not intrinsically safe, so they cannot be in use in a hazardous environment.

Ensure workers wear the required filtered and regulated air-supplied respirators for all dry abrasive blast cleaning. Not only the operator but all personnel in the contaminated area must wear approved breathing apparatus. Also, ground all equipment to prevent electrical shock.

All participants in the surface preparation process, including coating inspectors, should use common sense in detecting potential hazards. Everyone has a responsibility to report any lighting, scaffolding, or equipment malfunctions that are safety hazards to the appropriate person. Knowledgeable and responsible workers ensure the safety of staging, spiders, or swing scaffolding before using them for work or for inspection.

Never get in the path of an abrasive blast. The abrasive particles can travel as fast as 450 mph (724 kph), with the effect of a shotgun blast. Coating inspectors must follow all safety and health rules as established by the safety engineer or the person responsible for safety on the contract.

Coating inspectors should be familiar with and, when appropriate, make use of the following protective equipment:

- Hoods
- Respirators
- Heavy protective clothing and gloves
- Eye and hearing protection
- Operators may be required to ground equipment, and the coating inspector may also be required to verify that the equipment is properly grounded.
- Site safety must conform to applicable worker protection rules and regulations. In the US, Occupational Safety and Health Administration (OSHA) regulations provide necessary guidelines.
- In other countries, governmental bodies have similar regulations that must be observed.

A more detailed appraisal of appropriate regulations is provided in the safety module of this course.

10.13.3 Inspection Considerations

Ambient conditions may have an effect on the abrasive blasting process as well as on the blast cleaned surface before coating. Ambient conditions include:

- Air and substrate temperatures
- Relative humidity
- Dew point temperature
- Environmental exposure (e.g., marine, industrial, etc.)

10.13.3.1 Air Temperature

It is unwise to abrasive blast if the steel surface is much colder than the surrounding air. Moisture can condense on the blasted surface causing the surface to flash rust. Use a steel surface thermometer to check the substrate temperature.

10.13.3.2 Relative Humidity

During blast cleaning operations high humidity (moisture) can result in the rapid deterioration of the cleaned surface. Do not conduct final dry abrasive blasting in wet or damp conditions, i.e., when raining or when the relative humidity is very high (generally greater than 90%). *Relative humidity* (RH) is defined as the amount of moisture (water vapor) in air, compared with the maximum possible in the air (i.e., saturation level). If RH reaches 100%, then the air will not support any more water vapor; any surplus water vapor will appear as condensation.

10.13.3.3 Dew Point Temperature

Dew point is defined as the temperature at which condensation occurs. If the ambient temperature falls below the dew point, or if some or all of the structure has a temperature below the dew point, then condensation will occur.

Coatings applied over a wet surface generally do not adequately adhere to the substrate. If abrasive blasting is done when environmental conditions are close to the dew point, condensation is likely and flash rusting may occur.

For this reason, coating specifications normally require that coatings application not take place while the temperature of the steel or the surrounding air is less than 5°F (3°C) above the dew point. To calculate the dew point, like relative humidity, make temperature measurements with a hygrometer.

10.13.3.4 Masking

In blast cleaning projects, it is common that some areas must remain un-blasted. Typical examples include surfaces that are already painted or sensitive equipment such as valves or instruments. To protect these areas, *mask them off* using suitable templates of metal or rubber, or suitably tough masking tapes firmly secured to the surface. Fix masking materials in place before *any* blast cleaning begins in the immediate area. Check the masking on a regular basis during blasting to ensure that adequate protection is maintained. At the conclusion of the blasting and coating operation, remove the masking carefully.

10.13.3.5 Surface Cleanliness

Surfaces must be free of oil and grease before blast cleaning. Blast cleaning does not remove oil, grease or non-visible contaminants. Inspect all surfaces after cleaning to ensure they comply with the specification. Cleanliness after preparation is important, so ensure residual traces of abrasive are blown off, vacuumed, or swept away before primer coating.

If lead is present in the coating waste or blast debris, do not blow off the surface. The contractor must follow all regulations regarding lead removal.

Clean any scaffolding, staging, or support steel above the surface to prevent abrasives from dropping onto the freshly cleaned surface or onto the newly primed surface.

10.13.3.6 Blow-down

After blast cleaning, clean the blasted surface to remove residual dust and abrasive. Possible cleaning methods to remove all traces of residual dust or grit include: blowing down with a high-pressure jet of clean dry air, vacuum cleaning, or brushing with a clean dry brush. The surface should closely resemble the visual standard of surface finish specified (e.g., *NACE No. 2/SSPC-SP 10, Sa 2½*, etc.). Dust or grit is not always completely removed — it often remains hidden in crevices or corners. The high pressures of the spray coating stream can disturb and distribute it into the coating film, causing a poorly adherent paint layer or incomplete film formation.

10.13.3.7 Surface Condition at Time of Coating

Do not allow surfaces prepared for coating to deteriorate or to be contaminated in any way between the end of the cleaning phase and the beginning of the coating application. Clean grit-blasted surfaces should not be handled or touched unless clean protective gloves are worn. Do not expose cleaned surfaces for prolonged periods or expose them at all to high humidity either in the open or

in storage. Under such conditions, oxidation and rusting may proceed very rapidly.

As far as practicable, storage after blast cleaning should provide a warm, dry environment. Apply coating as soon as possible after blasting. Commonly observed rules indicate a maximum delay of four hours after blasting and require that *if visible deterioration has occurred, the surface preparation shall be repeated*.

Inspectors should be aware of and consider all the air supply issues that can lead to inadequate surface preparation and surface condition at the time of coating. Some of the things to be aware of are:

- **Inadequate air supply**. Theoretically, a #6 nozzle (3/8 in [9.4 mm]), a popular size, requires 232 cfm (6,570 L/min). To provide the necessary quantity of air, a compressor of at least 300 cfm (8,600 L/min) is normally used. A larger nozzle requires more air and a proportionally bigger compressor.
- **Too small air hoses**. Resulting friction losses are expensive.
- **Internal hose couplings.** Can cause up to 15% efficiency loss of the working pressure. External couplings and nozzle holders are a must.
- **Badly designed machines**. May have significant pressure losses.
- **Too small piping on the machine.** Causes friction losses.
- **Compressed air lines not kept straight** and **as short as possible**.

Other important factors affecting blasting performances are:

- Correct choice of nozzles. Venturi nozzles are much more efficient than straight-bore nozzles.
- Clean, dry air.

There are so many variables that influence cleaning that rates of cleaning cannot be stated definitively. These variables include, but are not limited to:

- Air availability
- Nozzle size and type
- Type of equipment used
- Condition of surface to be cleaned
- Surface cleanliness standard required
- Limitations on operator maneuverability
- Lighting quality
- Distance of nozzle from surface
- Skill of operator
- Type and size of abrasive

10.13.4 Inspector's Checklist

Always have a checklist that indicates the proper inspection procedure items. The following list includes some of what to focus on and monitor during dry abrasive surface preparations:

- Ambient conditions
- Conditions of substrate (rate or amount of corrosion)
- Pre-blast surface cleanliness (oil, grease, dirt, etc.)
- Shot/grit size selection (IAW specification)
- Shot/grit cleanliness
- Condition of abrasive blasting equipment
- Surface profile (IAW with specification/standards)
- Surface cleanliness after abrasive blasting (dirt, airborne contaminants, etc.)
- Operator qualifications (know the operators and their abilities)
- Safety

10.14 Centrifugal Blast Cleaning

The most complex of the centrifugal blast cleaning cabinets (Figure 10.76) are designed to blast large quantities of steel on a regular basis, such as all plate received by a shipbuilding yard. These machines, often known as *wheelabrators*, are designed to work on a continuous basis and include a conveyor system to carry items through the cabinet continuously. It is typical for these cabinets to use a system of rotating wheels with vanes to propel the abrasive. (The term *wheelabrator* has been adapted for general use.) These cabinets usually also have an abrasive recovery and recycling system and are capable of very high rates of cleaning.

Blasting with a wheelabrator machine is often highly automated and is best suited to repetitive blasting tasks at a fixed location. Typical locations include shipyards or steel structure fabrication facilities, such as those used for building oil production platforms and their ancillary equipment.

Figure 10.76 Centrifugal Blast Machine

This method of cleaning is used:

- In a stationary setup, when work can be brought to the equipment
- For large, flat surfaces, when a portable wheelblast unit can be driven across the surface, such as on the flight deck of an aircraft carrier, or on concrete surfaces, such as floors, pits, etc.
- To eliminate the need for compressor set-ups including air/blast hoses, an abrasive pot, and a pot attendant
- For lower production costs
- On work pieces such as pipe, piling, reinforcing steel, beams, flat plate, etc., with a series of centrifugal blast wheels housed in a blast enclosure, arranged so all sides of the work are cleaned as it travels through the equipment.

Wheel blast operations are described in more detail in CIP Level 2.

10.14.1 Equipment Overview

Inspectors should be aware of the various kinds of centrifugal blasting units in operation today. The plant operation unit, in general, consists of the following:

- Roller tables (Figure 10.77)
- Dust collectors
- Pre-heating ovens
- Blast cabinet
- Paint booths
- Drying booth
- Handling equipment

Figure 10.77 Roller Table Unit

Figure 10.78 Portable Centrifugal Unit

Figure 10.79 Portable Tank Unit

10.14.2 Surface Cleanliness Standards

The surface cleanliness standards are the same as those used in dry abrasive blasting. The standards are *very* important and will be briefly discussed again. As with abrasive blasting, the centrifugal blasting operation should use the SSPC SP 1 preparation standard before blasting begins.

10.14.3 NACE-SSPC

Written surface preparation standards include NACE/SSPC joint standards and ISO standards. These standards are considered similar but are ***not equivalent***:

- NACE No. 1/SSPC-SP 5, *White Metal Blast Cleaning* — ISO Sa 3, *Blasting to Visually Clean Metal*
- NACE No. 2/SSPC-SP 10, *Near-White Metal Blast Cleaning* — ISO 2½, *Very Thorough Blast Cleaning*
- NACE No. 3/SSPC-SP 6, *Commercial Blast Cleaning* — ISO Sa 2, *Thorough Blast Cleaning*
- NACE No. 4/SSPC-SP 7, *Brush-Off Blast Cleaning* — ISO Sa 1, *Light Blast Cleaning*

10.14.4 Safety

Each person is responsible for his or her own safety around any plant during centrifugal blasting operations. Some dangers to be aware of include:

- Overhead cranes moving plate or pipe
- Dust and debris in the air (use proper PPE)
- Roller tables moving during inspection of the work piece
- Pre-heated plates or pipe when checking the temperature of the piece
- Use caution when between the blast cabinet and the paint booth while checking the anchor pattern
- Roller conveyor movement when checking the DFT
- Overhead movement when load-out is in progress
- Always wear the proper PPE

10.14.5 Inspection Consideration

The steps for centrifugal blasting inspection are basically the same as those discussed in the air blasting section of this chapter.

10.14.6 Inspector's Checklist

Always have a checklist that indicates the proper steps for the appropriate inspection procedures. The following are some of the things to be aware of and monitor during dry abrasive surface preparations:

- Ambient conditions
- Conditions of substrate (rate or amount of corrosion)
- Fabrication defects
- Pre-blast surface cleanliness (oil, grease, dirt, etc.)
- Shot/grit size selection (IAW specification)
- Shot/grit cleanliness
- Equipment
- Surface profile (IAW with specification/ Standards)
- Surface cleanliness after centrifugal blasting (dirt, airborne contaminants, etc.)
- Operator qualifications (know the operators and their ability to perform)
- Safety

10.15 Abrasives

There are many types of abrasives used in the industry today. This section discusses some of these abrasives and their use, especially those used most often and in the most common situations inspectors encounter.

10.15.1 Shot & Grit

Some examples of shot and grit (metallic) abrasives include:

- **Cast steel** is a hard metallic abrasive used to remove scale and other hard surface deposits.
- **Steel grit** abrasives have irregular shapes and are effective in cutting away surface deposits or imperfections. Steel grit is expensive and is generally used only in recycling systems and when cheaper abrasives are unavailable. Because steel grit can be recycled, it reduces the overall waste stream.
- **Steel shot** is spherical; it can be produced accidentally as a byproduct or intentionally for blast cleaning. Steel shot is good for heavy brittle deposits. Because of its spherical shape, it ricochets in enclosed areas and causes multiple impacts. Steel shot may stretch light materials and drive mill scale and other impurities into the surface.
- **Cast iron** is the hardest metallic abrasive and is used to remove scale and other hard surface deposits. Hardness should not be confused with toughness; hard abrasives sometimes have high breakdown rates because of their brittleness. This product should not be used in corrosive environments; it has a high initial cost, but can be recycled.
- **Malleable iron** is a relatively hard metallic abrasive used to remove scale and other hard deposits.

These abrasives are often heat treated to different hardnesses to increase their life and the rate of cleaning. Hard abrasives, 62–65 HRC (HRC = Hardness, Rockwell C), are often used for etching, but they break down rapidly. Softer abrasives, 35–40 HRC, may be used for easier cleaning jobs. These materials may round up after use. The average hardness of metal abrasives is 45–50 HRC, which works well as an air blast abrasive.

10.15.2 Crushed Slag

Refractory slag is manufactured from byproducts of burning coal, refining copper, and nickel. It is fast-cutting with medium durability. SSPC-AB 1, *Mineral and Slag Abrasives*, defines the requirements for selecting and evaluating mineral and slag abrasives which are used for blast cleaning steel and other coating surfaces. This specification mainly covers abrasives intended for one-time use without recycling; reclaimed materials must be retested before reuse.

10.15.3 Ceramic Grit (Aluminum Oxides and Silicon Carbides)

Ceramic Grits are relatively expensive abrasives, but their use is sometimes justifiable because of their special properties. Because the particles retain sharp cutting edges, their cutting action can be particularly effective, especially on hard-base materials which may resist effective blasting by chilled cast iron grit.

Additionally, their effective cutting action is achieved at lower blasting pressures than other abrasives normally require. Ceramic grits are particularly well suited to blast preparation of thin metal surfaces, which *buckle* or distort if blasted with chilled iron grit at conventional blast pressures.

Finally, as these ceramic grits are essentially inert to normal corrosive influences, they can be used safely to grit blast stainless steel or nonferrous material surfaces without causing rust staining, discoloration, or bimetallic corrosion.

10.15.4 Silica Sand

Sand is still used in the US because it is cheap. The high breakdown rate of sand may tend to counter its original low cost and usually no attempt is made to reclaim it. However, it is often considered (particularly in the US) to be the most economical abrasive used in industrial field applications. Sand-blasted surfaces may require a final cleaning with air to remove dust remaining on the surface.

10.15.5 Garnet

Almandine garnet is the heaviest and hardest of garnets and can withstand higher cutting speeds while maintaining low dust levels. With its crystalline shape, fast cutting action, and longer life span, garnet is a highly efficient and effective abrasive.

10.15.6 Agricultural Abrasives

In addition to other abrasives discussed, use agricultural abrasives when the dust from other abrasives may harm sensitive equipment. When stainless steel or other high-purity alloys are blasted, it is important that the abrasive does not embed metallic particles in the surface. An example is using crushed walnut shells to blast clean components of the space shuttle to preserve the integrity of the special alloy materials.

10.15.7 Specialty Abrasives

Specialty abrasives include abrasives such as dry ice, plastic beads, sponge, soda bicarbonate, and ice:

- **Dry ice** is carbon dioxide frozen solid. It may be produced on site by cooling liquid carbon dioxide then compressing the resulting flakes into pellets, or by grinding and screening blocks of dry ice. **Caution**: Dry ice generates very low temperatures. Its boiling point is -110°F (-79°C) and can cause immediate frostbite if it comes in direct contact with exposed skin. Use dry ice to remove certain types of surface contaminants and existing organic coatings successfully. Dry ice does not change the surface roughness of metal surfaces and produces little or no dust, usually leaving the substrate dry and cold. Dry ice is a single-use abrasive because it evaporates immediately after use. The CO_2 abrasive pellets are produced in close proximity to the blasting site (within a few meters) and are used immediately.
- **Ice** is frozen water produced either on or off site. The ice is crushed and sieved to produce the blast abrasive. Ice removes certain types of surface contaminants and

existing organic coatings. It does not change substrate roughness or produce dust, but does leave the substrate wet. Ice is a single-use abrasive.

- **Plastic bead abrasives**; these small plastic beads (about the size of the holes in a plastic button) remove coatings with minimal roughness change to the substrate. Plastic beads are almost always used in recovery (recycling) systems. They are extensively used for strip coatings from aircraft. *Note:* the dust produced may be combustible. Plastic bead blasting operators require extensive training because the abrasive flow, work-to-nozzle distance, and blast air pressure are different for different coating types. These variables are usually determined by the blast operator. Plastic bead abrasive leaves the surface dry, but it may be dusty.
- **Baking Soda** (sodium bicarbonate) is usually used in a water slurry driven by compressed air and cannot be recycled. It removes surface contamination and existing coatings with minimum substrate change. Although it produces little or no dust, rinse the substrate with fresh water as a final step. The operator requires special training.
- **Sponge**: Synthetic sponge particles remove surface contaminants and create a surface profile suitable for recoating. Compressed air propels the sponge particles to the surface where, upon contact, they expand and abrade the surface. The sponge particles clean the surface by absorbing contaminants and trapping them within the sponge particles. The result is a very clean surface with suitable abrasion to remove corrosion and provide an anchor profile for industrial coatings. Sponge particles may be discarded after one use or used repeatedly to reduce waste and disposal needs. Sponge blasting creates very little dust, is extremely worker friendly, and can provide a variety of profiles, since abrasives may be encased within the sponge particles to achieve the desired results.

10.15.8 Inspection Considerations

Inspectors and operators should ensure that:

- Operators use both the type and size of abrasive specified.
- Everyone follows the specified recycling procedure. Most metallic abrasives, such as iron and steel shot and grit, and expensive abrasives, such as glass beads, may be recycled. Make sure contaminants, including dust, paint, and mill scale are removed from the abrasive materials if they are to be recycled.
- Abrasives are clean and free of moisture and oil.
- Abrasives are stored off the ground, away from moisture and the elements.

10.15.9 Abrasive Selection and Size

Consider some or all of the following when selecting a blasting abrasive:

- The kind of surface to be cleaned
- Size and shape of object to be cleaned
- Type of cleaning facility: outdoor, indoor with cabinet, or blast room
- Existing surface conditions
- Conditions desired after cleaning
- Desired surface profile and whether or not the abrasive is to be recycled
- Types of coating to be applied

Each type of abrasive is generally available in more than one size. Abrasives are graded according to how fine a mesh or sieve screen they can pass through without one particle of abrasive remaining on the mesh (Table 4, Table 5, and Table 6). When in doubt about whether a given abrasive is the correct size, perform a mesh or sieve test. Equipment required for the test includes:

- An accurate balance
- A set of US National Bureau of Standards (NBS) screens
- A convenient quantity of abrasive to weigh (2.2 lbs [1,000 g] is a handy weight)
- Pour the abrasive into the top of the nested screens. The screens are nested so that the screen with the largest openings is on top, grading down in screen opening size to the screen with the smallest openings on the bottom, for example: from top to bottom, #8, #15, #16, #40, #50, etc..

Table 4: SAE Shot Specifications

SAE Shot No.	Max. % Retain-ed	Screen No. and Aperture	Max, % Retain-ed	Screen No. and Aperture	Min. % Retain-ed	Screen No. and Aperture	Max. % Retain-ed	Screen No. and Aperture	Max % to Pass
S-1320	0	4 (0.187)	—	—	90	6 (0.132)	7	7 (0.111)	3
S-1110	0	5 (0.157)	—	—	90	7 (0.111)	7	8 (0,0937)	3
S-930	0	6 (0.132)	—	—	90	8 (0.0937)	7	10 (0.0787)	3
S-780	0	7 (0.111)	—	—	85	10 (0.0787)	12	12 (0.0661)	3
S-660		8 (0.0937)	—	—	85	12 (0.0661)	12	14 (0.0555)	3
S-550	0	10 (0.0787)	—	—	85	14 (0.0555)	12	16 (0.0469)	3
S-460		10 (0.0797)	5	12 (0.0661)	85	16 (0.0469)	11	18 (0.0394)	4
S-390		12 (0.0661)	5	14 (0.0555)	85	18 (0.0394)	11	20 (0.0331)	4
S-330	0	14 (0.0555)	5	16 (0.469)	95	20 (0.0331)	11	25 (0.0280)	4
S-280	0	16 (0.0469)	5	18 (0.0394)	85	25 (0.0280)	11	30 (0.0232)	4
S-230		18 (0.0394)	10	20 (0.0331)	75	30 (0.0232)	12	40 (0.0165)	3
S-170	0	20 (0.0331)	10	25 (0.028)	75	40 (0.0165)	12	50 (0.0117)	3
S-110	0	30 (0.0232)	10	35 (0.0197)	70	50 (0.0117)	10	80 (0.007)	10
S-70	0	40 (0.0165)	10	45 (0.0138)	70	80 (0.007)	10	120 (0.0049)	10

Table 5: SAE Grit Specifications

SAE	Max. Limit Screen		Nominal Screen		Min. Limit Screen	
Grit No.	Maximum Grit Retained %	Screen No. and Aperture	Minimum Grit Retained %	Screen No. and Aperture	Maximum Grit to Pass %	Screen No. and Aperture
G-10	0	7 (0.111)	80	10 (0.0787)	10	12 (0.0661)
G-12	0	8 (0.937)	80	12 (0.0661)	10	14 (0.0555)
G- 14	0	10 (0.0787)	80	14 (0.0555)	10	16 (0.0469)
G- 16	0	12 (0.0661)	75	16 (0.0469)	15	18 (0.0394)
G-18	0	14 (0.0555)	75	18 (0.0394)	15	25 (0.0280)
G-25	0	16 (0.0469)	70	25 (0.0280)	20	40 (0.0165)
G-40	0	18 (0.0394)	70	40 (0.0165)	20	50 (0.0117)
G-50	0	25 (0.0280)	65	50 (0.0117)	25	80 (0.0070)
G-80	0	40 (0.0165)	65	80 (0.0070)	25	120 (0.0049)
G-120	0	50 (0.0117)	60	120 (0.0049)	30	200 (0.0029)
G-200	0	80 (0.0070)	55	200 (0.0029)	35	325 (0.0017)
G-325	0	120 (0.0049)	20	325 (0.0017)	—	

Table 6: Screen Sizes According to Openings

Mesh Size	Opening in Inches (in.)	Opening in Micrometers (µm)	Opening in Millimeters (mm)
4	0.187	4,760	4.76
5	0.157	4,000	4.00
6	0.132	3,360	3.36
7	0.111	2,830	2.83
8	0.0937	2,380	2.38
1	0.0787	2,000	2.00
12	0.0661	1,680	1.68
14	0.0555	1,410	1.41

Table 6: Screen Sizes According to Openings

16	0.0469	1,190	1.19
18	0.0394	1,000	1.00
20	0.0331	840	0.84
25	0.0280	710	0.71
30	0.0232	590	0.59
35	0.0197	500	0.50
40	0.0165	420	0.42
45	0.0138	350	0.35
50	0.0117	297	0.297
60	0.0098	250	0.250
70	0.0083	210	0.210
80	0.0070	177	0.177
100	0.0059	149	0.149
120	0.0049	125	0.125
140	0.0041	105	0.105
170	0.0035	88	0.088
200	0.0029	74	0.074
230	0.0024	62	0.062
270	0.0021	53	0.053
325	0.0017	44	0.044
400	0.0015	37	0.037

The choice of abrasive is generally determined by the specification and may be the subject of coating manufacturer guidelines provided on application instructions or technical data sheets for a specific product.

10.15.10 Abrasive Cleanliness

Test abrasives for cleanliness with the simple *vial test*. Drop some of the abrasive into a small vial of water with known pH (preferably distilled or deionized water with a pH of 7) and shake. Typically, the ratio should be one volume of abrasive to two volumes of water. Inspect the top of the water for a film of grease or oil. Check the water for visible turbidity (cloudiness due to sediment) which is usually a sign of excess dirt, dust, or clay in the abrasive.

Use a litmus or pH paper test in the vial of water to tell whether the abrasive is acid or alkaline. pH paper indicates the actual value of acidity or alkalinity. If the abrasive is dirty, an acid or alkaline, document these

results and immediately report them to the owner's representative.

Litmus and pH papers indicate the presence of chemical salts dissolved in water that form an acidic or basic solution. Litmus and pH papers will **not** detect the presence of chlorides. If red litmus paper changes to blue, the solution is basic. If blue litmus paper changes to red, the solution is acidic. If, however, the litmus paper does not change, it indicates the solution is neutral.

Even if the solution is neutral, it does not indicate the absence of soluble chemical salts because some chemical salts, such as sodium chloride (common sea salt), form a *near-neutral* solution. Specific test papers may indicate the presence of soluble chemical salts.

10.15.11 Abrasive Sieve Analysis (Sieve Test) ASTM C 136

ASTM C 136 is the test method for sieve analysis of fine and coarse aggregates (Figure 10.80). Typically a 2 lb (1 kg) representative sample of abrasive is sieved through a series of screens (such as 12/40 or 16/40) and the percentage retained on each screen size is recorded. This test enables the inspector to compare the particle size and distribution of the abrasive with the data furnished by the abrasive supplier.

Shake the screens over a retaining pan; the abrasive particles remain on the screens whose hole size is just smaller than the abrasive particle. The finest abrasive particles pass all the way through and are caught on the pan.

The next step is to weigh the particles that remain on each screen and calculate the percentage retained. This is why using 35.273 oz (1,000 g) of abrasives as the starting weight is convenient. If 8.395 oz (238 g) of abrasive is retained at a given level, it is clear that 23.8% of the abrasive was retained at that level without doing a lot of extensive arithmetic.

Figure 10.80 Abrasive Sieve Analysis

10.15.12 Air Supply Cleanliness

Blotter Test ASTM D 4285

Check compressed air for blast cleaning operations for the presence of oil or water by a simple blotter test. Hold a white absorbent paper in the air stream discharging from the compressor.

ASTM D 4285, *Standard Test Method for Indicating Oil or Water in Compressed Air*, requires an absorbent collector, such as white absorbent paper, cloth on a rigid backing, or a non-absorbent collector 1/4 in (6 mm) made of transparent plastic. Center the collector in the discharging air stream within 24 in (61 cm) of the discharge point for one minute. Conduct the test on the discharging air as close to the use point as possible and after the inline oil and water separators.

Use the blotter test to check for any visible traces of oil or water in compressed air for abrasive blasting or spray coating application. When performing this test, the tester should:

- Allow the compressed air system to reach operating conditions
- Allow air to discharge at operating conditions to remove accumulated condensation in the system
- Fasten the collector material to a rigid backing, avoiding personal contact with the air stream

According to ASTM D 4285, any indication of oil discoloration on the collector shall be cause for rejection of the compressed air for use in abrasive blast cleaning, air blast cleaning, and coating application operations. Any indication of water contamination on the collector shall be cause for rejection of the compressed air for use in those applications where water is detrimental, such as abrasive blast cleaning, air blast cleaning, and coating applications.

To distinguish hydrocarbon oils from water, use an ultraviolet (UV) light or detect the characteristic odor of oil. Also, thoroughly inspect the surface being cleaned for any sign of oil or water.

10.16 Water Blasting and Waterjetting Overview

Using water as the principal ingredient to prepare surfaces for coating application is a relatively recent development. It was developed for two principal reasons.

First, water dampens dust emissions and allows use of abrasive blast cleaning techniques in places where blasting dust is considered a nuisance or hazardous.

Second, the water can wash away soluble contamination, which dry blast cleaning cannot remove easily. The significance of soluble contaminants (not easily seen on a dry blast cleaned surface) has been increasingly recognized as a reason why coatings fail to provide long-term performance. Their removal is now considered to be an essential element of successful surface preparation for the best coating systems.

The waterjetting standard addresses both visible (WJs) and non-visible (NV) levels of cleanliness. NACE 5/SSPC-SP 12 is addressed in great detail in these sections to give inspectors a better understanding of the process.

10.16.1 Definitions

There are two forms of water blast cleaning:

- ***Water blasting***: uses abrasive combined with water
- ***Waterjetting:*** uses water alone

Over the past few years, when abrasive blasting was not feasible, industry has used high-pressure water to prepare steel and other hard surfaces for coating. Certain surface preparation standards, such as NACE Standard RP0172, incorporated the term *water blast* in the title and body of the document. This term confused many users, since it seems to imply that some type of abrasive in the water is always necessary.

Now NACE, SSPC, and other societies use the term ***waterjetting*** when water is the only cleaning medium and ***water blasting*** when an abrasive of some type is incorporated with water to form the cleaning medium.

The advanced CIP courses discuss waterjetting and water blasting in more detail, but for now, the following is a brief look at this

cleaning process as an alternative to abrasive blast cleaning.

10.17 Waterjetting

NACE, SSPC, etc. have divided waterjetting into types (categories) for the sake of accuracy and consistency. The current categories defined by NACE and SSPC are:

- **Low-Pressure Water Cleaning (LP WC)**: pressures below 5,000 psi (34 MPa)
- **High-Pressure Water Cleaning (HP WC)**: pressures of 5,000 to 10,000 psi (34 to 70 MPa)
- **High-Pressure Waterjetting (HP WJ)**: pressures of 10,000 to 30,000 psi (70 to 210 MPa)
- **Ultrahigh-Pressure Waterjetting (UHP WJ)**: pressures above 30,000 psi (210 MPa)

The advantages of high-pressure waterjetting include:

- Uses water as a cleaning material, since suitable water is generally available in inexpensive large quantities
- No abrasive particles to contaminate surrounding areas
- Absence of dust and spark hazard at the nozzle tip

10.17.1 Low-Pressure Water Cleaning (LP WC)

Low-pressure water cleaning is primarily a washing technique. At pressures below 5,000 psi (34 MPa), water removes soluble contamination and *some* loosely adherent surface contaminants. It reliably removes chalking of aged coatings, leaving the coating surface intact.

Dry docks often use low-pressure water cleaning to wash the undersides of ships in dry dock, removing marine growth and some deteriorated antifouling coatings prior to recoating.

10.17.2 High-Pressure Water Cleaning

Use high-pressure water cleaning to prepare concrete surfaces prior to coating application. A properly focused HP WC water nozzle can cut through concrete blocks, so the technique is both efficient and dangerous. When used for surface preparation for coatings over steel surfaces, the production rate is relatively low. In addition, only loose contamination can be successfully removed when preparing steel surfaces for painting.

10.17.3 High-Pressure Waterjetting

Surface preparation for coatings seldom uses high-pressure waterjetting equipment. It does not clean better than equipment operating at lower pressure, and the production rate is not cost effective.

10.17.4 Ultrahigh-Pressure Waterjetting

UHP WJ uses water at very high pressure: 30,000 psi (210 MPa) and above (up to 50,000 psi [340 MPa]). Because of the high pressures required, safe practice demands great care in controlling the waterjet nozzles, since a person struck by high-velocity water at short range could be injured seriously.

Most UHP WJ equipment operates with a rotating nozzle and dual water streams. The highly efficient nozzle design produces an effective cleaning pattern while using relatively little water, perhaps no more than 2 gal (8 L) per minute. Hold the nozzle close to the surface being cleaned since cleaning efficiency decreases rapidly when the nozzle

is held further than 18 in (50 cm) from the surface. The most effective cleaning is achieved when the nozzle is at a maximum distance of approximately 2 in (50 mm), though the blast pattern is then very narrow and production rates may decrease.

At this pressure, water removes most contaminants, such as chemical salts, dirt, grease, and rust scale. ***It will not produce a surface profile*** but can restore any previously existing surface profile if the equipment is designed to clean the surface to a high standard. Use the highest pressures, 35,000 psi (240 MPs) and above to achieve this high standard. An unexpected benefit of using very high pressures is the heat it generates. The heat limits rust deterioration, and the surface remains relatively clean (though with some *ginger* discoloration).

10.17.5 Waterjetting in Immersion Conditions

Pure waterjetting at pressures below 7,000 psi (48 MPa) is seldom used for surface preparation prior to coating, except as a wash technique. It is commonly used underwater, however, to remove marine growth on ships and oil-related structures. Use pressures between 2,900 and 7,200 psi (20 and 50 MPa, 200 and 500 bar) to clean marine growth from a ship's hull or offshore structure.

The performance depends upon these main factors:

- The maneuverability of the diver and visibility
- The density of the fouling and degree of barnacle or shell growth

On ships' hulls in dry dock, a cleaning rate of up to 2,000 ft^2/h (200 m^2/h) can be achieved with high-pressure waterjetting. Working under water, however, adds many other factors to consider, and these factors usually reduce performance. To better understand underwater jetting rates, consider this example: the legs of a drilling platform in the North Sea covered with weed and mussel growth up to 24 in (600 mm) thick (exceptionally heavy fouling) and were cleaned at the rate of 200 ft^2/h (20 m^2/h).

Because there is no reaction force with an underwater blast unit (the design compensates for reverse thrust), the operation is performed with considerably less physical effort when compared to similar work above the surface.

Underwater concrete cutting is another application for waterjetting; equipment has been used for this purpose at depths up to 450 ft (140 m). A section of damaged concrete coating on a 30 in (760 mm) steel pipeline beneath a rig in the North Sea was successfully cut and jet blasted away without damage to the underlying steel pipe. Pressures of 11,000 psi (76 MPa, 760 bar) were used, and one diver at a time from the team handled the gun and did the cutting.

When steel must be brought to a white metal finish underwater, use specially developed underwater equipment that injects abrasives into the water stream.

10.18 Water Blasting

There are three types of water blasting:

- Grit blasting with a shroud
- Sand injected water blast
- Slurry blast with grit/water mix

10.18.1 Grit Blast with Water Shroud

One of the advantages of using water in a blast cleaning operation is the reduction of the dust hazard. This aspect is particularly important when blast cleaning in a relatively public environment, such as city buildings. This is why equipment was developed to provide a protective shroud of water around the normal blast of abrasives in compressed air.

Other advantages of water-shrouded grit blasting include the ability to remove soluble contaminants from surfaces and the possible use of silica-bearing abrasives (e.g., sand). Hazardous components of the waste, including dust emissions, are much reduced. Up to 75% of dust cannot escape from the water stream and is, in theory, unable to enter the immediate surrounding environment.

Disadvantages include removal of the wet, used abrasive and the necessity of using an inhibitor in the water to prevent surface rusting on steel.

A water ring attachment is connected to a low-pressure water source, and the flow of the water is controlled by a small valve on the attachment. The water stream wets the abrasive stream outside and in front of the nozzle discharge, which helps keep dust to a minimum. Use this cleaning process when dust is objectionable. The resulting surface profile is similar to dry abrasive blasting but, of course, the surface is wet after blasting.

Blasting pressures are much the same as for dry blasting, up to 100 psi (690 kPa, 6.9 bar), and production rates are similar. Clean up time is greater because of the difficulty of removing wet abrasive sludge.

10.18.2 Sand-Injected Water Blast

This method uses the same basic equipment as high-pressure waterjetting plus several additional items, including:

- Abrasives injector and adapter
- Abrasive hose
- Abrasive container

The force of the water through the gun and gun lance draws the abrasive into the water stream by suction. The principal advantage of this method compared with waterjetting is that it ~~is~~ can create the desired surface profile. As in dry blasting, the surface profile depends largely on the combination of abrasive size and pressure used. In general, abrasive is less effective when mixed with water, and the surface profile less than that produced by the same dry abrasive.

Production cleaning rates are much better with abrasive injected into the water stream; up to 90% of dry blasting production rate can be achieved with this equipment. Typical water use is in the range of 2–15 gal/min (8–60 L/min). The production rate is around 50% of that achieved by dry blast cleaning.

10.18.3 Slurry Blasting with Water/ Abrasive Mix

In this method, the abrasive and water are mixed together at or near the blast pot with constant agitation to form a slurry. The slurry is then pumped through a single hose to the blast nozzle.

Because the abrasive/water mix is pumped as slurry, the pressure can be controlled easily. This means the cutting effect of the abrasive can be increased or reduced at will, and in fine increments, to allow special effects such as removal of only the top coating or feathering back the coating edges.

10.18.4 Equipment Overview

Waterjetting equipment (Figure 10.81, Figure 10.82, Figure 10.83, Figure 10.84, and Figure 10.85) used for water blasting surface preparation generally includes a:

- High-pressure water pump attached to a motor of suitable size
- High-pressure hose
- Special design nozzle

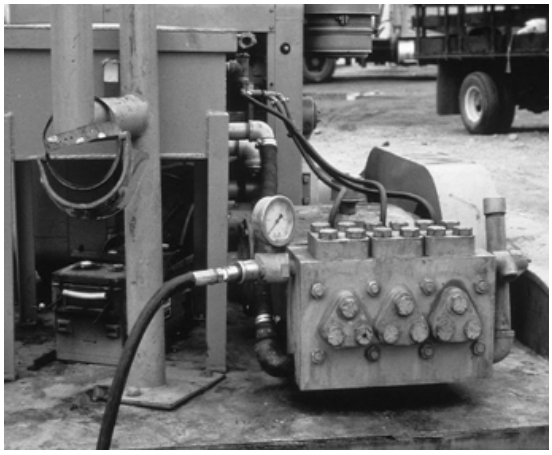

Figure 10.81 Waterjetting Equipment

Figure 10.82 Waterjetting Wand and Nozzle

Figure 10.83 Nozzle variety

Figure 10.84 Manual Waterjetting

Figure 10.85 Hose, Wand, Nozzle, and Safety Equipment

Inhibitors and moisture tolerant coatings are discussed in the remainder of this section, as well as a brief summary.

10.18.5 Inhibitors

In waterjetting and other similar cleaning operations using water, an inhibitor is sometimes added to the water to help prevent sur-

face rusting of the cleaned surface before a coating can be applied. This only applies, of course, when preparing steel (ferrous) surfaces. Possible potential issues stemming from adding inhibitors include:

- Inhibitor quantity
- Inhibitor deposits
- Inhibitor consistency

Inhibitor Quantity

Carefully control the quantity of inhibitors used. Excess quantities of inhibitor deposited on a surface will probably successfully prevent rust formation, but is also likely to interfere with coating adhesion. On the other hand, too little inhibitor deposited on a surface will fail to provide protection against rust formation.

Inhibitor Deposits

Inhibitor deposits are likely to interfere with long-term coating performance. Introducing a chemical layer between the coating system and the prepared surface is controversial and has been characterized by experts as *weakening* the protection given by the coating system.

Inhibitor Consistency

Inhibitors are generally added into the water container as soluble solids, or in a concentrated liquid metered through an injector into the blast stream. Successful use of inhibitors depends on the consistency of whichever method is chosen.

10.18.6 Moisture-Tolerant Coatings

A disadvantage of water blasting or waterjetting is that the quantity of water used creates a damp environment and a wet surface. In general, allow the surface to dry before applying coatings, or use special moisture-tolerant coatings.

Some coating manufacturers have coatings, often based on epoxy technology that can be applied directly to a wet surface. Using such coatings is a very convenient surface preparation method. Some of these specialty coatings are designated as tolerant of *damp* conditions, others as tolerant of *wet* conditions. Take care to determine how wet the surface will be at the time of application.

10.18.7 Water Blasting Summary

Water blasting has created a great deal of controversy. There is no doubt that both control of the system (with its ability to reduce pressure, etc.) and reduced contamination of the surface are important and valuable. On the other hand, drawbacks, i.e., the need to use inhibitors (which deposit on the steel surface), and the abrasive waste disposal problems may require considerable justification.

There is some doubt about the long-term performance capabilities of the new moisture tolerant coatings. There is not an expectation of coatings applied to wet surfaces to perform as well as coatings applied over an optimally prepared dry surface.

10.18.8 Surface Cleanliness Standards

Figure 10.86 Visual Waterjetting Standards

10.18.8.1 NACE-SSPC

The most commonly used ***waterjetting standards*** are SSPC-VIS 4 and NACE-VIS 7, and the most commonly used ***water blasting*** standards used are SSPC-VIS 5 and NACE-VIS 9. However, there are other guides/standards that may be referenced in a specification.

10.18.9 Safety

The protective equipment usually required for waterjetting includes:

- Waterproof suit
- Helmet and visor
- Protective heavy duty gloves and boots with steel toe caps and metatarsal protection
- Hearing protection
- Safety fluid shut-off valve (dead-man valve)
- A regulator to gradually increase pressure at start-up (helps operator adjust to spray nozzle back pressure)

10.18.10 Inspector Safety Considerations

Personal safety is everyone's responsibility. Do not do anything that could endanger anyone. Stay aware of the surroundings, individual role, location of nearest escape route, and how to get to it, etc. Know these things so well that they are automatic.

10.19 Inspector's Checklist

Items on the checklist include:

- Ensure the work site/environment is free of hazards such as moving equipment and/or vehicles.
- Check the condition of UHP hoses, pumps, wands, and nozzles
- Ensure sufficient air pressure is readily available
- If an inhibitor is specified, know how much is added when
- Know what the substrate is (steel, aluminum, stainless, etc.)?
- Know what substrate cleanliness level is specified
- Know the substrate condition: new steel, previously coated, etc.
- Know the operators' qualifications
- Ensure the blast area is roped off and no unauthorized people can enter
- Check for very fast flash rusting
- Monitor ambient conditions during surface prep and before coating application
- Know the specified anchor pattern

10.20 Anchor Profile

In addition to achieving cleanliness, abrasive blasting alters the substrate from a more or less smooth surface to a uniformly textured surface. This textured surface is the result of the sharp abrasive particles striking

the steel at high speed and leaving small impact craters or irregularities. This texture is called ***surface profile*** or *anchor pattern*.

Remember that abrasive sizes vary and a close inspection of size tolerance (measure to approximately +/-10%) should be maintained, especially where abrasives are reclaimed and reused. Reclaimed abrasives should be angular, not rounded, and free from oil, grease, iron oxide, etc.

Table 7: Choosing Abrasives for a Given Anchor Pattern

Anchor Pattern		How to Achieve
Mils	**Micrometers (µm)**	**Pressure Blast or Centrifugal Wheel**
0.5	12.7	80/120-mesh silica sand, 100-mesh garnet, 120-grit aluminum oxide, or G-200 iron or steel grit 12
1	25.4	30/60-mesh silica sand, 80-mesh garnet, 100-grit aluminum oxide, or G-80 iron or steel grit
1.5	38	20/50-mesh silica sand, 36-mesh garnet, 50-grit aluminum oxide, or G-50 iron or steel grit
2	50.8	16/40-mesh silica sand, 30-mesh garnet, 36-grit aluminum oxide, or G-40 chilled iron or steel grit
2.5	63.5	12/30-mesh silica sand, 20-mesh garnet, 24-grit aluminum oxide, G-25 iron or steel grit
3	76.2	8/20-mesh silica sand, 16-mesh garnet, 16-grit, aluminum oxide, or G-16 chilled iron or steel grit

Notes:
Pressure blast: normally around 620 kPa (90 psi) nozzle pressure 60 cm (2 ft) from surface. Steel shot is not normally recommended when a sharp anchor pattern is required; its round shot peens the surface.

These recommended abrasive sizes apply only to mild steel. As the hardness and type of metals vary, so will the anchor pattern.

10.20.1 Inspection Considerations

A well written coating specification will require a range of surface profile depths, expressed either in mils or micrometers (µm). For example, the specification may require a surface profile of 1.5–3.5 mils (37–87 µm). Surface profile is important because it increases the surface area and roughness to which the coating can adhere.

Too shallow a surface profile may result in premature coating failure due to lack of adhesion, identified by peeling, blistering, or delamination. Too high a profile may have peaks that are inadequately covered, resulting in *pinpoint rusting* or rust spots. This most likely occurs when primers are applied but left exposed without topcoats for some period of time. Good practice suggests applying at least two coats over the blast cleaned surface to ensure the surface profile is adequately covered.

In general, the greater the surface profile, the better coating adhesion will be. One exception to this rule appears to be inorganic zinc silicate primers, which tend to split (lose cohesion) when the anchor profile exceeds about 2.5 mils (67 µm).

This may be caused in part by attempts to increase coating thickness to cover profile peaks. Inorganic zinc silicate primers are well known to be sensitive to excess thickness. Follow the guidelines on the manufacturer's technical data sheets.

10.20.2 Test Methods

Several methods are available to measure surface profile:

- Comparator and coupons
- Replica tape
- Dial gauge depth micrometer (profilometer)

10.20.3 Replica Tape ASTM D 4417 Method C– NACE RP0287

Surface profile may be measured with replica tape (Figure 10.87), a proprietary product produced by the Testex® Corporation. Two types of tape are commonly used:

- Coarse for 0.8–2.0 mil (20–50 µm) surface profile
- Extra coarse for 1.5–4.5 mil (37–112 µm) surface profile

Figure 10.87 Replica Tape and Anvil Micrometer

Apply a piece of the tape (a small square of compressible foam plastic attached to a non-compressible plastic Mylar film) to the blast cleaned surface, dull side down. Use a hard, rounded object (burnishing tool), such as a swizzle stick (Figure 10.88), to crush the foam into the blast cleaned surface. This causes the foam to form an exact reverse impression (replica) of the actual surface profile.

Figure 10.88 Testex Tape and Swizzle stick

Figure 10.89 Replica Tape Procedure

Remove the tape from the surface. Use an anvil micrometer (Figure 10.89) to measure the thickness of the foam and the plastic. The thickness of the Mylar film, 2 mils (50 µm) is subtracted from the micrometer reading, and the result is the surface profile depth.

Two standards describe the working method for using replica tape: NACE Standard RP0287 and ASTM D 4417, Method C

10.20.4 Digital Profile Gauge ASTM D 4417

Rest the instrument base on the tops of the surface profile peaks; the spring loaded tip projects into the valleys. This is detailed in ASTM D 4417, Method B. This is a very sensitive test, and although it can be used in the field, it is best used in the laboratory (Figure 10.90).

Figure 10.90 Digital Surface Profile Gauge

Other surface profile instruments, such as depth measuring microscopes, or diamond-point tracking stylus gauges, are sophisticated laboratory methods not commonly used in the field (on site) or blast shop.

10.20.5 Inspection Considerations Summary

The term ***surface preparation*** (often shortened to *surface prep*) is broadly used to describe the process of preparing a surface for coating. As discussed earlier in this course, inadequate or poor surface preparation is the leading cause of premature coatings failure in today's industry. Hence, inspectors **must** take a comprehensive approach to inspecting the substrate prior to coating application. Regardless of the substrate, the inspector must be mindful of the fact ***that protective coatings performance warranties rely heavily on the surface preparation results achieved prior to application.***

10.20.6 Inspector's Checklist Summary

Checklists help inspectors perform inspections with excellence. Below is a summary checklist:

- Inspect equipment and materials to be used
- Pre-inspect the substrate
- Inspect during and after pre-cleaning process
- Perform specified tests to referenced standards
- Accept or reject pre-cleaned substrate
- Inspect and accept prepared substrate
- Perform additional testing if specified
- Document the process

Key Terms Definitions

Acidic Cleaners: Cleaners that remove soil by chemical attack; they dissolve the reaction products. They are usually composed of fairly strong acids, such as phosphoric acid (H_3PO_4), with small quantities of surfactants, water-miscible solvents, and organic wetting and emulsifying agents.

Alkaline Cleaners: Cleaners that saponify most oils and greases, and their surface-active components wash away other contaminants. These cleaners may also saponify certain coating vehicles.

Ceramic Grit: Relatively expensive abrasives that are justified by their special properties. Their particles retain sharp cutting edges, and are especially effective on hard-base materials which may resist effective blasting by chilled cast iron grit.

Crushed Slag: Relatively cheap abrasives that are formed from metallurgical processes or combustion. Copper-, nickel-, coal-, and aluminum-slag are common.

Detergents: Cleaners that are composed of buffering salts, dispersants, soaps, and inhibitors. They function by wetting, emulsifying, dispersing, and solubilizing the contaminants, which can be washed away using water (usually hot) or steam.

Dry Grit Blasting (Air Blasting): Blasting that uses a highly concentrated stream of grit projected at a surface to remove rust, mill scale, or other contaminants, creating a rough surface that is good for adhesion.

Emulsion Cleaners: Cleaners that are sprayed onto the surface where they function by wetting, emulsifying, dispersing, and solubilizing the contaminants.

Faying Surfaces: Surfaces joined to create a friction grip.

Gouges: Sharp indentations in the coating.

Inclusions: A non-metallic phase, such as an oxide, sulfide, or silicate particle in a metal.

Organic Solvents: Solvents such as kerosene, turpentine, naphtha, mineral spirits, toluol, xylol, etc., that clean the metal by dissolving and diluting the oil and grease contamination on the surface.

Pre-Cleaning: Check of the surfaces for contamination before surface preparation begins. Pre-cleaning involves removing all visible oil, grease, soil, drawing and cutting compounds, and other soluble contaminants from the surfaces

Surface Lamination: The most common surface defect on steel substrates. It is typically caused by rolling the steel.

Surface Profile (Anchor Pattern): The irregular peak and valley profile on a bare surface that can result from operations such as abrasive blast cleaning or power tool cleaning.

Venturi Nozzle: This blasting nozzle permits abrasive velocity up to 450 mph (720 kph), or 660 ft/s with an almost equal impact over the entire surface. Venturi nozzles are the most effective shape for tough cleaning jobs.

Water Blasting: Use of pressurized water discharged from a nozzle to remove unwanted matter from a surface.

Waterjetting: Use of standard jetting water discharged from a nozzle at pressures of

10,000 psig (70 MPa) or greater to prepare a surface for coating.

Weld Spatter: Particles of molten metal produced during welding and thrown onto the surface adjacent to the weld.

Study Guide

1. During surface preparation, surface cleanliness should be inspected (at a minimum) the following three (3) times:

2. Factors during surface preparation that may affect service life include:

3. Common design defects include:

4. Common fabrication defects include:

5. Four (4) typical SSPC-SP1 pre-cleaning methods include:

6. One standard to use with power tool cleaning is:

7. Four (4) examples of tools used for power tool cleaning are:

8. Two (2) abrasive blasting methods include:

9. Visual standards for abrasive blasting include:

_____
_____

10. SSPC-SP10/NACE 2 limits staining to _____ per each unit area.

11. SSPC-SP 5/NACE 1 limits staining to _____ per each unit area.

12. SSPC-SP 6/NACE 3 limits staining to _____ per each unit area.

13. The two (2) types of abrasive blasting nozzles include:

_____
_____

14. The specified level of surface cleanliness must be achieved and maintained:

_____
_____

15. Advantages of centrifugal blast equipment include:

_____
_____
_____

16. The inspector's checklist for surface preparation should include:

_____
_____
_____
_____
_____
_____

17. Abrasive media types include:

_____
_____
_____
_____
_____
_____
_____

18. Abrasive media typically used for recycling include:

_____

_____

19. List the pressure ranges that categorize:

- Low Pressure Water Cleaning: _____
- High-Pressure Water Cleaning: _____
- High-Pressure Waterjetting: _____
- Ultrahigh-Pressure Water Jetting: _____

20. Three (3) types of water blasting include:

_____

_____

_____

21. The NACE-SSPC waterjetting standard is:

_____

22. Three (3) test methods for surface profile include:

_____

_____

_____

Chapter 11: Surface Preparation Instrumentation

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Surface contamination
- Soluble salts
- Specification requirements
- Chloride contamination
- Bresle patch
- Sleeve test
- Soluble salts meter
- Conductivity
- Inspection considerations
- Inspector's checklist
- Anchor profile
- ISO comparators
- Replica tape
- Digital profile gauge

Key Trade Terms

- Soluble salts
- Chlorides
- Sulfates
- Nitrates

11.1 Surface Contamination

It is essential to measure the level of contaminants on a surface prior to coating to ensure that optimum coating quality and lifetime are achieved. If the coating is applied to a contaminated, improperly prepared surface, it could fail prematurely, resulting in costly re-coating and high maintenance costs. Surface contamination from salts such as chlorides, sulfates, and nitrates has been shown to lead to blistering of organic coatings, particularly in immersion conditions.

11.2 Soluble Salts

Soluble salts are non-visible and require tests to determine their presence. Although they are termed "soluble," they really are not very soluble at all. If they were, a simple wash could remove them. Water-soluble salts are deposited on steel surfaces by acid rain, marine spray, chemical processes, splash, spillage and immersion. If water-soluble salts remain on the bare substrate after surface preparation they can absorb moisture from the atmosphere and form corrosion cells. A corrosion cell can remain active on a substrate after the coating is applied and lead to premature coating failure. This can be even more critical if the steel is severely pitted requiring a combination of wet abrasive blasting and high-pressure waterjetting, followed by dry abrasive blasting to reduce the amount of contamination to a more desirable level.

Soluble salts can also be deposited on surfaces by contaminated blasting abrasives. This can *also* cause premature coating failure. Contamination can build up, especially if the abrasive is recycled several times. There are field tests available to identify abrasive contamination and help prevent costly failures.

Soluble salts' role as contaminants on coated surfaces is well established. Unfortunately, the industry has yet to reach a consensus on acceptable minimum contamination levels, and there is no industry developed standard procedure to detect and evaluate them. Currently, NACE, SSPC, and ISO, are developing a standard test method. It is also expected that as a part of this joint effort, they will recommend an acceptable minimum level of soluble salts contamination.

Types of soluble salt contamination:

- **Chlorides** are the salts of hydrochloric acid HCl. The chloride ion forms when the element chlorine picks up one electron to form the anion Cl- (a negatively-charged ion).
- **Sulfates** are the salts of sulfuric acid; the IUPAC-recommended spelling is *sulfate*; the British English spelling is *sulphate*.
- **Nitrates** are the salts of nitric acid with an ion composed of one nitrogen and three oxygen atoms (NO-3).

11.3 Specification Requirements

There are many variations in test methods, tolerances of different coatings, and opinions regarding soluble salts. For effective inspection, the specification should state very clearly:

- Limits of soluble salts to be accepted
- Specific salts to be limited on the substrate
- Test method to use
- Frequency of testing
- Where to administer tests

A typical specification clause may say:

"Blast-cleaned surfaces shall be tested for soluble salts prior to the application of coatings. Chloride levels shall be 10 ppm or less, as determined using the "Chlor-Test" method A for chlorides. At least 3 tests shall be performed in each area of 100 ft^2 (10 m^2). If any single test result is greater than 10 ppm, the area shall be water-washed and reblasted. It shall then be retested prior to coatings application, and the same limits shall apply."

If testing is meaningful, inspectors, owners, and contractors must all be familiar with the test methods and materials associated with soluble salts. Specified requirements that are not achievable, and inconsistent testing methods are likely to lead to confusion.

11.4 Soluble Salts Contamination

Soluble salts initiate and accelerate steel corrosion, and become deeply embedded within the iron corrosion products. If they deposit between coats, they can cause blistering and disbondment leading to coating breakdown. The salts stimulate corrosion through osmotic action, i.e., they draw moisture through the coating. The salts continuously draw moisture and form blisters that actually build up internal pressure. When the moisture combines with chlorides, it often forms a mild hydrochloric acid causing corrosion, undercutting of the coating, and coating failure. Often, a film of chlorides left on the surface is the cause of major disbondment.

It is not sufficient to measure only the cleanliness of the substrate. In a multi-layer coating process, it is necessary to monitor and record the cleanliness of each layer prior to applying the next coat.

11.4.1 Test Methods

- Potassium ferricynide
- Bresle patch
- Sleeve test

- Soluble salt meters
- Conductivity

11.4.1.1 Potassium Ferricynide: Qualitative Test for Water-Soluble Ferrous Salts

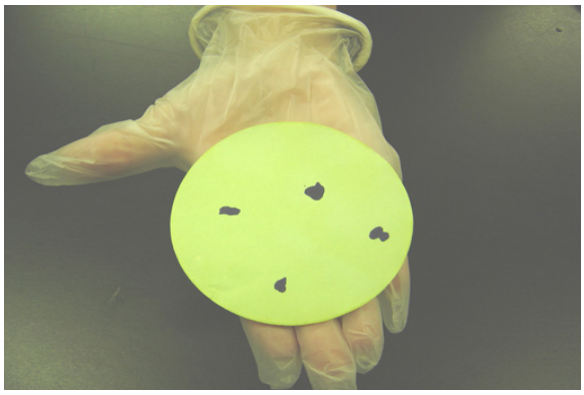

Figure 11.1 Indicator Paper

The qualitative test for water soluble ferrous salts (ions) is designed only to detect the presence of this substance on a steel substrate. It is not designed to measure the quantity of these ions.

Testing Procedure

The qualitative test procedure for water-soluble ferrous salts includes:

- Using prepared indication paper (Figure 11.1)
- Misting surface with distilled water
- Applying test paper to misted surface

A dark blue color indicates presence of soluble salts.

11.4.1.2 Bresle Patch Test

Proper Use

Before beginning any test method always refer to the manufacturer's instructions.

Figure 11.2 Elcometer 138 Bresle Kit & Patches

Specifications frequently direct inspectors to test surfaces in accordance with ***ISO 8502-6*** and ***ISO/DIS 8502-9,*** both of which specify use of the Bresle Patch method to extract soluble salts from the test surface and measure their concentration (Figure 11.2). In general, perform the Bresle Patch test as described below:

1. Select the section on the steel surface to assess the concentration of salts on the surface. Ensure the steel is dry and there is no loose adherent rust, dirt, or moisture (dampness), so the patch frame properly adheres to the surface. Bresle Patches work in almost every position: vertical, horizontal, slanting or on surfaces that are not completely flat.

Test more than one spot to catch the variations of the containment level!

2. Remove the backing and the foam circle from the test cell and adhere the cell tightly to the test area.
3. Insert the 5-mL syringe needle into the cell through the spongy foam perimeter. Pull back the plunger to remove the air from the test area.
4. Inject all of the reagent water (3 mL) into the cell taking care to keep air bubbles out. Make sure there are no leaks. (Figure 11.3)

Do not insert the needle into the transparent part of the patch ***or*** from the bottom; either location will leak!

Figure 11.3 Bresle patch injected with 15ml of water as in ISO 8502-6 Annex A

5. Remove the syringe needle from the center of the cell, but leave it in the spongy perimeter. Gently massage the top of the cell for 10 to 15 seconds. Withdraw and reinject the water a minimum of three times. Then retrieve as much of the water as possible with the syringe and place it in a clean vial or other container.

Test the solution using Kitigawa tubes, the quantab method, titrators, or a conductivity meter to find the concentration of soluble salts.

Figure 11.4 Conductivity Meter

Operating Parameters

Always refer to the manufacturer's data sheet for the operating parameters of specific Bresle patch test. The accuracy, precision, and repeatability of the test depends greatly on the individual administering the test and the method used to measure the salt concentration (Kitigawa tubes, quantab method, titrators, or conductivity meter, etc.). (Figure 11.4) The unit of measure is in mS (millisiemens) or µS (microsiemens).

If the test results are questionable, check the equipment, review the procedure, and redo the test. One of the most common Bresle Test errors is using contaminated test equipment which results in incorrect readings. Before the test, rinse all materials in clean distilled water, to ensure they are not contaminated and **NEVER touch any part that contacts the test water with your bare hands!**

Some common errors using the Bresle Patch include inaccurate readings due to:

- Test sample contamination
- Proper amount of test solution (reagent) not used

If using titrator tubes:

- Be sure to snap both ends of the tube and insert the tube properly.

If using the conductivity meter:

- Ensure batteries are good or the display may not function properly.
- Clean the measuring cell with a damp soft cloth or the value measurement may be unstable.

11.4.1.3 Sleeve Test

There are two variations of the test. One uses a titrator tube to determine the results of the test; the other uses a colorimeter to determine the results of the test. (Figure 11.5)

Figure 11.5 Salt Detection Kit

Figure 11.6 CSN Test Kit - Chlorides, Sulphates & Nitrates

Proper Use

Regardless of manufacturer, the tests are usually performed in a similar manner. Pour a pre-measured amount of solution into the sleeve provided in the test kit (Figure 11.6). Adhere the sleeve to the surface by its adhesive edges. Lift the sleeve and hold up to force the solution onto the surface. Massage the test solution against the surface through the test sleeve for 2 minutes. The sleeve from the surface.

If using the titrator tube:

- Place the sleeve in the hole provided in the lid of the test kit box.
- Snap off both ends of the titrator tube with the metal snapper provided.
- Insert the titrator tube into the sleeve with the smaller numbers and arrow at the bottom.
- Wait approximately 1.5 minutes or until the solution has wicked-up to the top of the titrator tube.
- Note: the cotton at the top of the titrator changes color to amber when fully saturated.
- Immediately remove the tube and read the number at the interface of the color change. Pink is normal: white is the chloride level. This number is µg/cm2, or parts per million.

> Parts per million readings are are a 1:1 ratio to micrograms per square centimeter. No mathematical calculations are necessary.

If using the colorimeter:

- Put the test solution into the test vial, then insert it into the colorimeter for analysis. The instrument has a digital display and the results are shown in parts per million.

- Use this testing method in accordance with ISO 8502-5, NACE 6G186, NACE 6, SSPC SP13, and SSPC Guide-15.

Calibration

Ensure manufacturer's instruments meet all coating thickness standards for quality and use, and are in accordance with ANSI/NCSL Z540-6 (National Calibration Standard).

If using the titrators tube:

- No calibration or calibration check is necessary.
- Choose a tube that measures in the appropriate range.

If using the colorimeter:

- Contact the gauge's manufacturer or supplier for checks and certification.
- Make regular calibration checks over the life of the instrument; this is a requirement of quality management procedures, e.g., ISO 9000, and other similar standards.
- The instrument comes from the manufacturer already calibrated; however, some method of certification by independent lab, and some method of field verification is necessary.

Operating Parameters

Each model's manufacturer's data sheet contains the specification for that particular model. The measuring range varies between manufacturers and models, so the range can be from 0-500 ppm (0-500 µg cm²) in increments of 1 ppm (1 µg cm²).

Always question readings whenever they are outside known values. Check the procedure, be sure equipment is not contaminated, then redo the test.

Some common errors using the colorimeter include inaccurate readings due to:

- Contamination of the test sample causing inaccurate readings. As previously stated, never touch any part of the equipment that comes in contact with the water, with your bare hands.
- Be sure that all testing materials are kept clean and free of contaminants.

11.4.1.4 Soluble Salts Meter

Figure 11.7 Elcometer 130 SCM400 Salt Contamination Meter

Proper Use

The Elcometer†[1] 130's design fosters repeatability and accuracy. (Figure 11.7) **Reminder: in order to achieve consistently accurate results with all salt test equipment, take care to avoid contamination by touch.**

Use gloves and plastic tweezers to remove one of the sample paper discs. Fill one of the syringes with distilled water then carefully apply the water to the sample paper to until it absorbs the correct amount of water (as described in the operating instructions). Place the water-filled sample paper on the substrate and use the tweezers to gently push the paper into the metal profile. Press the green button on the Elcometer 130 and wait

1. Trade name

for the alarm to indicate testing time is complete. With the tweezers, pick up and place the sample paper onto the central section of the Elcometer 130, close the lid and press the green button again. Read the salt value on the display.

All manufacturer's instruments should meet all coating thickness standards for quality and use in accordance with ANSI/NCSL Z540-6 (National Calibration Standard). This test method can also be used in accordance with SSPC-Guide 15.

Calibration

Contact the gauge's manufacturer or supplier for checks and certification. Make regular calibration checks over the life of the instrument; this is a requirement of quality management procedures, i.e., ISO 9000 and other similar standards. The salt meter comes from the manufacturer already calibrated and cannot be calibrated by the user; however, it is possible to check that the instrument is measuring correctly. To do this, take a sample with standard sample paper, but use precisely 1.5 mil of a solution of 31.6 mg (±0.1) analar sodium chloride, dissolved in 100 ml of high purity water. The reading should be in the range of 5 µg cm^{-2} (10%) at 77°F (25°C). For readings **below** 77°F (25°C), apply a correction factor of -1.7%/°C.

For readings **above** 77°F (25°C), apply a correction factor of +1.7%/°C.

Operating Parameters

Operating parameters vary between different manufacturers and models. Each model's manufacturer's data sheet contains the specific details for that model. For example, the following is information about the Elcometer 130: *the measuring range is 0.1–20 µg cm^{-2} with an accuracy of ± 10%. The instrument resolution is 0.1 µg cm^{-2} and has an operating temperature range of 41° to 104°F (5° to 40°C) <80% RH.*

The paper disks used for testing can be retained after testing. Remoistening the disks allow them to be placed in the meter to evaluate the test results.

Question readings whenever they are outside known parameters. Check the procedure, be sure equipment is not contaminated, then redo the test.

Common error during use may result in inconsistent and inaccurate readings that could be attributed to one of the following:

- Low battery
- Contamination of test samples
- Temperatures outside equipment's range

11.4.1.5 Conductivity Test

This is a method to measure the conductivity of a solution that contains chloride.

Electrical conductivity measurements indicate the total soluble-salt content, but cannot indicate what specific salts that are present. Measure test samples with a **conductivity meter. (**Figure 11.8) It is then common to make calculations based on the results to find the chloride concentration of the test solution.

Figure 11.8 Conductivity Meter

Proper Use

Refer to the manufacturer's instructions for proper use of equipment. Information for the Horiba B-173 is included with the Elcometer 138 salt kits.

Before taking a measurement, calibrate the gauge as follows.

1. Remove the sensor's protection cap.
2. Press the POWER button to switch the meter on. **Note:** Ensure there is no liquid in the sensor before turning the meter on.
3. Set measurement mode (either conductivity or salinity):
   - Conductivity: press CAL/MODE button until Range/mode indicator shows either µS/cm or mS/cm. **Note:** The range switches automatically between mS/cm and µS/cm according to the concentration of the sample.
4. Salinity: press CAL/MODE button until Range/mode indicator shows %.Take measurement. There are two methods of measuring, depending on the quantity of sample available:
   - Method 1: Immerse sensor in sample taking care not to immerse past the maximum immersion level line marked on the body of the sensor.
   - Method 2: Drip sample into sensor cell using syringe or pipette. Ensure the sample fills the sensor cell and there are no bubbles in the sample.
5. Read displayed figure when stabilization indicator appears. The "Hold" function retains the reading on the display. It holds the reading at the end of measurement so the results record.
   - MANUAL HOLD: Press the HOLD button to retain measurement figure on display. The Hold Indicator appears and the displayed figure remains until another button is pressed.
   - AUTOMATIC HOLD: Switch off meter. Press and hold down the HOLD button while pressing the POWER button to switch the meter on. The meter enters automatic hold mode and the Hold Indicator flashes. In this mode, the meter automatically holds the displayed figure when the stabilization indicator appears.

Calibration

Regular calibration checks over the life of the instrument are a requirement of quality management procedures, i.e., ISO 9000 and other similar standards. Calibrate the meter before taking a measurement and at least once a day. To calibrate:

1. Remove the sensor protection cap.
2. Press the POWER button to switch the meter on.
3. Fill the sensor cell with standard solution.
4. Press CAL/MODE button. The display shows Calibration Indicator and 1.41 mS/cm.
   - When Calibration Indicator disappears, calibration is complete.
5. Wash sensor cell with tap water and wipe away any residual water with a clean tissue.

Calibration values store in the memory of the meter when it is switched off.

Operating Parameters

Refer to the manufacturer's operating instructions relevant to the specific model of electronic hygrometer in use.

Measurement mode: Conductivity/sodium chloride (NaCl) salinity conversion

Conductivity Range: 0 µS/cm to 19.9 µS/cm

Repeatability: ± 1%

Common errors can include:

- Inconsistent readings due to low battery power
- Temperatures may be outside the equipment's range. Inaccurate readings due to damaged probe tip

11.5 Inspection Considerations

Part of an inspector's responsibility is to understand and verify the specification. There are a few vital things inspectors need to know when testing for soluble salts, including:

- Test method to use
- Frequency of tests
- Soluble salt limits to be accepted
- Specific salts to be limited in use

In the event soluble salts are above the acceptable limit, ensure that there is an agreed-upon-plan in place for remediation.

11.6 Inspector's Checklist

When necessary information to conduct soluble salts tests are in place, ensure the appropriate equipment and materials are also available and ready for use. Some of the things to have on the checklist include:

- Are manufacturer's equipment instruction manuals available for needed tests?
- Distilled water available to test or clean test instruments? Are batteries (if needed) in good working condition? Are spares readily available?
- Are instruments calibrated (if required)?
- Do instruments/titrators measure within required ranges?
- Does the contractor know remediation procedures for soluble salts? Are he and his crew prepared if needed?

11.7 Anchor Profile

In addition to achieving cleanliness, abrasive blasting alters the substrate from a more or less smooth surface, to a uniformly textured surface. This textured surface results from the sharp abrasive particles striking the steel at high speed, leaving small impact craters or irregularities. As noted in the previous chapter, this texture is called surface profile or anchor pattern.

A well-written coating specification requires a range of surface profile depths, expressed either in mils or micrometers (µm). For example, the specification may require a surface profile of 1.5 to 3.5 mils (37 to 87 µm). Surface profile is important because it increases the surface area and roughness (anchor tooth) enabling the coating to adhere more tightly.

A too shallow surface profile may cause premature coating failure due to lack of adhesion, which can result in peeling, blistering, or delamination.

A too high surface profile may inadequately cover peaks, resulting in rust rashing or rust spots. This is more likely to occur when newly-applied primers without topcoats suffer exposure for some period of time. Good practice suggests, to ensure adequate coverage of surface profile, applying at least two

coats of a coating system over blast-cleaned surfaces.

In general, the greater the surface profile, the better the coating adhesion. An exception to this rule appears to be inorganic zinc silicate primers, which tend to split (lose cohesion) when the anchor profile exceeds about 2.5 mils (67 µm). This may result in part from attempts to increase coating thickness to cover the profile peaks. Inorganic zinc silicate primers are well known to be sensitive to excess thickness. Follow the guidelines provided by the coating manufacturer on the technical data sheets.

11.7.1 Test Methods

There are several methods to evaluate depth of surface profile including:

- ISO comparators
- Replica tape
- Digital profile gauge

11.8 ISO Comparators

Comparators are visual tools for evaluating anchor profile. (Figure 11.9) The inspector places the comparator on the surface and compares the blasted surface to the comparators. The inspector will make a decision based on the comparator segment that most closely resembles the blasted surface.

These comparators are electroformed of high purity nickel from a mild steel master coupon whose segments meet the requirements of ISO 8503, Part 1 when measured by the methods described in ISO 8503 part 3 (Microscope Method) and ISO 8503 Part 4 (Stylus Method). According to ISO 8503, there are two types — Type G for grit abrasives and Type S for shot.

Figure 11.9 Surface Profile Comparators

11.8.1 Proper Use

Remove all loose dust and debris from the test surface. Select the appropriate surface profile comparator type (G or S) and place it against an area on the test surface. Place the comparator on the surface and with the assistance of a 5X (do not exceed 7X) lighted magnifier, assess which profile on the comparator is the nearest match to the profile of the blasted surface and determine the grade.

The comparators come with cards that, among other information, state the parameters of ISO 8503 Part 1 and Part 2. Report the **grade** (one of five), **not** the comparator number. It is a good idea to review all of the information on the cards.

Use the surface comparators in accordance with ASTM D 4417 Method A, ISO 8503-1, and ISO 8503-2.

11.8.2 Calibration

Ensure calibration of the comparators every 6 months (see ISO 8503/1). Comparators require careful handling, if there is any sur

Table 1: Comparator Grades

Finer-than-Fine	Any profile assessed as being lower than the limit for fine
Fine	Profiles equal to segment 1 and up to, but excluding, segment 2
Medium	Profiles equal to segment 2 and up to, but excluding, segment 3
Coarse	Profiles equal to segment 3 and up to, but excluding, segment 4
Coarser-than-Course	Any profile assessed as being greater than the upper limit for coarse

face wear, recalibrate the comparators before further use. Comparators in daily use may require re-calibration every three months. Whenever there is a dispute, recalibrate before re-assessing the test surface.

11.8.3 Operating Parameters

There are five reportable grades:

1. Finer-than-fine
2. Fine
3. Medium
4. Coarse
5. Coarser-than-Coarse

11.9 Replica Tape

Using replica tape is one way to measure surface profile. (Figure 11.10) Replica tape has a small square of compressible foam plastic attached to a non-compressible plastic (Mylar) film. Two types are commonly used: **coarse** for 0.8 to 2.0 mil (20 to 50 µm) surface profiles, and **extra coarse** for 1.5 to 4.5 mil (37 to 112 µm) surface profiles.

11.9.1 Proper Use

Remove all loose dust and debris from the test surface. Select the appropriate replica tape (coarse or extra coarse) and apply to the blast-cleaned surface, dull side down. Use a hard, rounded object (burnishing tool), such as a swizzle stick, to crush the foam to the blast-cleaned surface., This causes the foam to form an exact reverse impression (replica) of the actual surface profile. Apply sufficient pressure to produce a replica with a uniform pebble grain appearance. You should just feel the roughness as you burnish.

Figure 11.10 Replica Tape and Anvil Micrometer

Remove the tape from the surface and use an anvil micrometer to measure the thickness of the compressed foam and the plastic. Subtract the thickness of the Mylar film, 2 mils (50 µm) from the micrometer reading; the result is the depth of the surface profile. Always identify the grade of tape used in any record of profile (Figure 11.11).

Two standards are used to describe the working method for using replica tape:

NACE Standard RP0287 and ASTM D 4417, Method C.

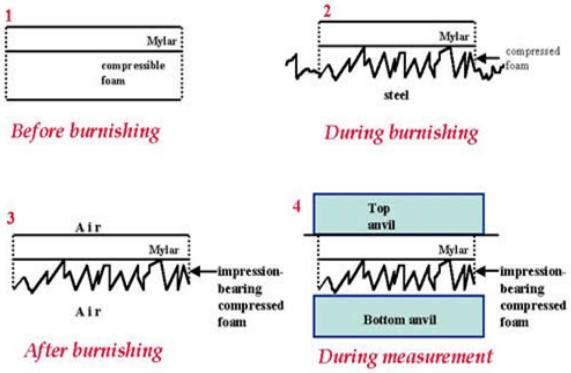

Figure 11.11 How Replica Tape Works

11.9.2 Calibration

Manufacturer's instruments should meet all coating thickness standards for quality and use, and be in accordance with ANSI/NCSL Z540-6 (National Calibration Standard).

Replica tape does not require calibration. Choose the appropriate grade of tape for the desired profile.

Consult manufacturer of the anvil micrometer for checks and certifications. Regular calibration checks over the life of the gauge are a requirement of quality management procedures, i.e., ISO 9000 and other similar standards.

11.9.3 Operating Parameters

As mentioned earlier, two types of tape are commonly used: **coarse** for 0.8 to 2.0 mil (20 to 50 µm) surface profiles, and **extra coarse** for 1.5 to 4.5 mil (37 to 112 µm) surface profiles.

Accuracy: NACE Standard RP0287-95 addresses the issue of accuracy of measurement. It reports the results of round-robin tests in which 14 blasted panels were measured by seven laboratories. All labs agreed that replica tape and focusing microscope measurements were within their 95% confidence limits in 11 of 14 cases. The average difference between the two types of measurement was 0.2 mils (5 microns).

Reproducibility: ASTM standard 4417-93 cites levels of reproducibility for both "X-Coarse" and "Coarse" grade replica tape.

X-Coarse grade replica tape:

"Two results, each the mean of four replicates, obtained by operators in different laboratories should be considered suspect if they differ by more than 37%."

Coarse grade replica tape cites the equivalent level of reproducibility as 28%.

According to these ASTM criteria, the following errors are the maximum that should be expected: (Table 2)

Table 2: Replica Tape Profile Errors

PROFILE (mils) (microns)	ERROR ("COARSE") (mils) (microns)	ERROR ("X-COARSE") (mils) (microns)
1.0 / 25	0.3 / 8	not applicable
2.0 / 50	not applicable	0.8 / 18
3.0 / 75	not applicable	1.1 / 27
4.0 / 100	not applicable	1.5 / 37

Internal testing by Testex[†1] (manufacturer of replica tape), using casts of machined (as opposed to blasted) surfaces, shows micrometer gauge measurements of Press-O-Film to have an accuracy and reproducibility of 0.3 mil (8 micrometers) across the ranges of Coarse and X-Coarse material.

Replica tape is most accurate near the middle of its specified range. Check readings

1. Trade name

near the ends of this range with the next higher or lower grade. Question readings when they are outside of known parameters.

Common sources of error in determining the profile of a blasted surface using replica tape and a micrometer gauge are:

1. Inherent variation in point-to-point profile over the surface being measured. The Society for Protective Coatings (SSPC) recommends a minimum of three profile measurements per 100 square feet (10 square meters).
2. Dirt particles on either the replica tape or gauge. Take reasonable care to keep the gauge anvils free of dirt or grit. Double check questionable measurements.
3. Gauge accuracy. Good micrometer snap gauges commonly cite an accuracy of ±0.2 mil (5 microns). In addition to gear errors of this magnitude, observers note that they commonly read approximately 0.1 mil higher at room temperature and 0.1 mil lower at freezing.
4. Rubbing technique. Either excessive or inadequate burnishing force.

11.10 Digital Profile Gauge

There are a number of digital surface profile gauges on the market today (Figure 11.12). This gauge measures peak-to-valley distances on the test surface. Depending on the gauge manufacturer and model, there are different capabilities. Some gauges may not have memory, but determine the surface profile quickly and accurately.

Figure 11.12 Elcometer 224 Model T Digital Surface Profile Gauge

To use the Elcometer 224, for example, follow these procedures:

1. Take the 224 out of its protective pouch. Remove the black probe protector from the bottom of the gauge.
2. Check the batteries (2 X AAA-Duracell for Elcometer instruments) in the battery compartment on the back of the gauge. Take the batteries out of the compartment and remove the protective paper used in shipping to prevent the gauge from turning on unintentionally.
3. Replace the batteries and replace the compartment cover.
4. Look at the front of the gauge and press the bottom soft key under the readout screen to turn on the gauge (Figure 11.13).

Figure 11.13 Turn Gauge "on"

5. Remove the glass shim from the slot in the pouch.
6. Press the soft key under the word Zero (Figure 11.14).

Figure 11.14 Press the soft key under the word "Zero"

7. The display directs the user to place the probe on the glass plate. (Figure 11.15) The gauge reads "0.0".
8. The gauge is now ready to take the readings.
9. For each of the 10 readings, place the 224 probe on the surface until the screen shows a reading. (Figure 11.16)
10. Repeat step 9 for additional readings. The gauge saves these readings, calculates the average, then the statistical mean, and records the highest and lowest readings.

Figure 11.15 Place probe onto glass

Figure 11.16 Take readings

11. Press the soft key under the word "Stats;" five information points display on the screen. Use the up and down arrows to see each of the following:
    - n = the number of readings taken
    - x = the average of the anchor profile readings
    - o = the mean (the average of the differences between the 10 readings)
    - Hi = highest reading taken in the set
    - Lo = the lowest reading taken in the set
12. Options: Print out the results and attach to printed report, download to computer to be added to report (224-T), or just write or type in results on a print out of the computer report (224-B). "B" means

basic gauge and "T" means top-of-the-line gauge with blue tooth and printer capability.

13. Report the range, the appropriate average of the determinations, the number of readings measured, and the approximate total area covered. Identify the location of the readings, including the date, job, and inspector's name.
14. Press the soft key below "back" to resume taking readings in the same set OR press the soft key below "clear" to erase all the data from the set just taken. Now the instrument is ready to take a new set of data from another location.

The Elcometer 224 measures the peak-valley height at various locations; the readings will vary somewhat and may not may not have the same final results as Testex Tape.

Other more advanced gauges, like the Elcometer 224 Model T, offer many features such as memory, high and low readings, the ability to store statistics and batch readings. They can also be connected to a computer to download data from the gauge, using such software as ElcoMaster Data Management Software to track trends, as well as generate complex reports (Figure 11.17).

11.10.1 Proper Use

Always refer to manufacturer's data sheet for the model-specific detailed instruction. Before taking measurements, always zero the gauge on a hard flat surface using the glass plate supplied with the gauge or a similar flat surface such as window glass. Press ZERO. When the display directs, place the probe on the glass plate. When the display shows "0" (zero) the gauge is ready to use immediately.

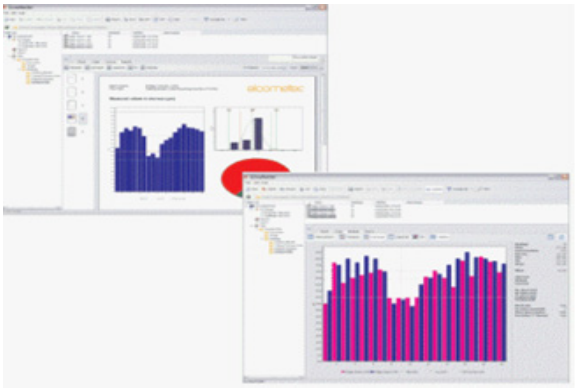

Figure 11.17 Screen-shot of Elcometer ElcoMaster™ Data Management Software

If a glass plate is not available, use the factory zero (refer to operator's manual).

The gauge is very easy to use. Switch it on then press the tip of the gauge firmly into the bottom of the profile valley. The display shows the profile depth and the measurement units (µm, mil or thou). Use this gauge in accordance with ASTM D 4417 B, NSTM 0009-32, and SANS 5772.

The reading may be inaccurate if the probe is not held flat against the surface.

11.10.2 Calibration

The gauge comes from the factory already calibrated. It should not have to be returned to the manufacturer for re-calibration during its lifetime. Set the gauge to zero before taking any measurements *(see operators manual)*. In the unlikely event of a fault, return the gauge either to the local supplier or

directly to the manufacturer. The gauge does not contain any user-serviceable components, except for the probe tip which can be replaced by the user.

11.10.3 Operating Parameters

Refer to the manufacturer's data sheet for the operating parameters specific to that model. The following are the operating parameters for the Elcometer 224 digital surface profile gauge:

- Measuring range: 0 mils to 20 mils (0 µm to 500 µm)
- Accuracy: ±5% or ±0.2 mil (±5 µm)

11.10.4 Operating Parameters

Refer to the manufacturer's data sheet for the operating parameters specific to that model. The following are the operating parameters for the Elcometer 224 Digital surface profile gauge:

- Measuring range: 0 mils to 20 mils (0 µm to 500 µm)
- Accuracy: ±5% or ±0.2 mil (±5 µm)
- Resolution: 0.1 mils (1 µm)

The repeatability of the instrument's results depends on the individual manufacturers, so always consult their specific instructions.

Always question readings outside known parameters. In the unlikely event of a fault, return the gauge either to the local supplier or directly to the manufacturer.

Common errors include:

- Inconsistent readings due to low battery power
- Temperatures outside equipment's range
- Inaccurate readings due to damaged probe tip

Key Terms Definitions

Chlorides: Chlorides are the salts of hydrochloric acid HCl. The chloride ion forms when the element chlorine picks up one electron to form the anion Cl^- (a negatively-charged ion).

Nitrates: Nitrates are salts of nitric acid with an ion composed of one nitrogen and three oxygen atoms (NO^-3).

Soluble Salts: These are non-visible and require testing to determine their presence. Although they are termed "soluble" they really are not very soluble at all.

Sulfates: Sulfates are the salts of sulfuric acid; the IUPAC-recommended spelling is *sulfate*; the British English spelling is *sulphate*.

Study Guide

1. Types of soluble salt contamination include:

_____
_____
_____

2. If inspection is to be effective with regards to soluble salts, the specification should very clearly state:

_____
_____
_____
_____

3. Tests for soluble salts include:

_____
_____
_____

4. Depth of surface profile can be evaluated by several methods:

_____
_____
_____

5. The ISO comparator grades may be recorded:

_____
_____
_____

6. The two (2) types of replica tape that are commonly used:

_____
_____

7. List the standards for using the replica tape:

_____
_____

8. When using replica tape common errors include:

_____
_____
_____

Chapter 12: Surface Preparation Instrumentation – Practice Lab

Surface Preparation Instrumentation Practice Lab

This lab builds on the previous chapter by giving students the opportunity to use the instruments described. The instructor will show each instrument along with the necessary materials required to do each test. Each student will then have hands-on experience with the instruments.

The following lists the task and equipment at each workstation.

Station 1: Bresle Patch[†1]

Measure the surface density of salt on the test panel using Method 1 (immerse sensor in sample) and Method 2 (drop sample into sensor cell using syringe or pipette).

Equipment:

- Elcometer 135[†2] Bresle Patches
- Pure water
- Syringes, 5 ml with blunt needle
- Beaker, plastic, 30 ml
- Conductivity meter model B-173 and sensor
- Batteries, CR2032 lithium
- Standard solution 1.41 mS/cm
- Moistening solution
- Purified water (deionised water)
- Operating instructions
- Steel test panel

Station 2: Sleeve Test

Perform sleeve test for soluble salts using the test panel provided. Document results in parts per million (ppm) and micrograms per square centimeter (µg/cm2).

Equipment:

- Latex sleeve
- Pre-measured bottle of Chlor*Rid ™ Extract solution
- Titration tube
- Titration tube snapper
- Operating instructions
- Steel test panel

Station 3: ISO Comparators

Use ISO comparators (grit or shot) to check profile of the test panels provided.

Equipment:

- ISO comparators for grit and shot
- 5X magnifier
- Operating instructions
- Test panel blasted with steel grit
- Test panel blasted with steel shot

1. Trade name
2. Trade name

Station 4: Replica Tape

Measure anchor profile on both sides of the test panel using the appropriate tape (coarse or X-coarse) and micrometer.

Equipment:

- Testex[†1] (replica) tape — coarse and X-coarse
- Anvil micrometer
- Operating instructions
- Test panel (sandblasted on both sides with different grit sizes)

Station 5: Digital Profile Gauge

Measure anchor profile of the test panel provided using the digital profile gauge.

Equipment:

- Digital surface profile gauge
- Glass plate (to zero the gauge)
- Test panel

1. Trade name

CIP Level 1 — Instrument Practice Worksheet

Name:_____

Date: _____

Station 1: Bresle Patch

Equipment: **Bresle Patch Salt Kit**

- Elcometer 135 Bresle Patches
- Pure water
- Syringes, 5 ml w/blunt needle
- Beaker, plastic, 30 ml
- Conductivity meter model B-173 and sensor
- Batteries, CR2032 lithium
- Standard solution 1.41 mS/cm
- Moistening solution
- Purified water (deionised water)
- Operating instructions
- Steel test panel

Assignment: Measure the surface density of salt on the test panel using Method 1 (immerse sensor in sample) and Method 2 (drop sample into sensor cell using syringe or pipette)

Calibrate conductivity meter before performing test.

	Conductivity	Conversion Factor	Salt Density
Method 1		If the reading is in µS/cm, multiply it by 1.2 If the reading is in mS/cm, multiply it by 1200 The result is in milligrams per square meter (mg/m²)	
Method 2			

Station 2: Sleeve Test

Equipment: 6°˘˘ó˘#7˘¹#.Ł

- Latex sleeve
- Pre-measured bottle of extraction solution
- Titration tube
- Titration tube snapper
- Operating instructions
- Steel test panel

Assignment: Perform sleeve test for soluble salts using the test panel provided. Document results in parts per million (ppm) and micrograms per square centimeter (µg/cm2)

Test Result	Miligrams/SQ Meter	µg/cm2

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Station 3: ISO Comparators

Equipment:

- ISO comparators for grit and shot
- 5X magnifier
- Operating instructions
- Test panel blasted with steel grit
- Test panel blasted with steel shot

Assignment: Use ISO comparators (grit or shot) to check profile of the test panels provided. Document results in the table below using the proper grade.

- Finer-than-fine
- Fine
- Medium
- Coarse
- Coarser-than-coarse

	Comparator Used (G or S)	Grade
Panel 1		
Panel 2		

Extra Tables for Practice:

	Comparator Used (G or S)	Grade
Panel 1		
Panel 2		

	Comparator Used (G or S)	Grade
Panel 1		
Panel 2		

Station 4: Replica Tape

Equipment:

- Testex® (replica) tape — coarse and X-coarse
- Anvil micrometer
- Operating instructions
- Test panel (sandblasted on both sides with different grit sizes)

Assignment: Measure anchor profile on both sides of the test panel using the appropriate tape (coarse or X-coarse) and micrometer. Take two readings on each side of the test panel and average. Document results in the table below.

	Tape Type (coarse/x-coarse)	Reading 1	Reading 2	Average
Panel Side 1				
Panel Side 2				

Extra Tables for Practice:

	Tape Type (coarse/x-coarse)	Reading 1	Reading 2	Average
Panel Side 1				
Panel Side 2				

	Tape Type (coarse/x-coarse)	Reading 1	Reading 2	Average
Panel Side 1				
Panel Side 2				

Station 5: Digital Profile Gauge

Equipment:

- Digital surface profile gauge
- Glass plate (to zero the gauge)
- Test panel

Assignment: Measure anchor profile of the test panel provided using the digital profile gauge. Take ten measurements on each side of the panel and average them. Document measurements in the table provided below.

Before taking any measurements, zero the gauge using the glass plate provided.

	Average
Panel Side 1	
Panel Side 2	

Extra Tables for Practice:

	Average
Panel Side 1	
Panel Side 2	

	Average
Panel Side 1	
Panel Side 2	

Chapter 13: Pre-Job Conference

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Goals of a pre-job conference
- Working with the team
- Inspector's role

13.1 Introduction

Always consider holding a pre-job conference/meeting whenever a project/job is about to begin.

The pre job conference is a meeting made up of all interested parties of a project that is about to begin. This is different from a pre-bid or pre-job safety meeting. The pre-bid meeting is held to clarify items presented in a bid prior to proposal submittals whereas a pre-job safety meeting is held to specifically address safety matters before a job. In essence, the pre-job conference/meeting is held after bids have been submitted and a contract awarded.

While owners usually call and chair the pre job conferences, it is not uncommon for someone else to take the lead and initiate such a meeting. General contractors sometimes call such meetings to ensure that the subcontractor(s) are fully aware of and understand the specification's requirements and other contractual documents. The person who calls the meeting usually makes an agenda and circulates it to others prior to the meeting. However, this should not prevent the inspector from introducing items that are important to include.

A competent person designated by the chairperson should record minutes of the pre-job meeting. At no time should the inspector act in such capacity since it is very difficult to do so and still participate fully in the meeting. Pay particular attention to controversial issues and ensure that, in addition to personal notes, the minutes reflect the outcome of any arguments.

13.2 Goals of the Pre-Job Conference

At a minimum, the goals of a pre-job meeting are listed below:

- Discuss health, environment, and safety (HES) requirements, particularly those that are job or site specific
- Address/clarify emergency procedures
- Review and discuss scope of work (SOW)
- Review logistical support
- Discuss line communications between parties
- Review known critical hazards
- Establish list of critical points of contact (POC)
- Discuss and clarify inspector(s) responsibilities and authority
- Clarify the chain of command (reporting system)
- Discuss and clarify areas of concern in the project specification (omissions, clarifications, testing)
- Agree on critical hold points for inspections
- Agree on method of conflict resolution between the inspector and applicator
- Agree on procedures for change orders

Other important issues that should be discussed at a pre-job meeting include:

- *Schedules*. When the job is supposed to start, working days, holidays and the proposed/established completion date
- *Site access*. Who is responsible for allowing the various crews onto the site and what methods of transportation are acceptable?
- *Site accommodation*. Who is responsible for providing office space/facilities and support services for the both the applicator and inspector(s)?
- *Communication*. The appropriate use of landlines, radios, cellular phones, and emails
- *Work access for inspection*. The use of the contractor's access equipment, such as scaffolding and sky climbers, to facilitate inspections

Regardless of the effort to schedule a pre-job conference, there may be times when a project (usually smaller) begins without a pre-job conference. It is the inspector's responsibility to ensure that the contractor has a clear understanding of the specifications and to eliminate any errors or ambiguities. Keep in mind that there is no perfect specification, so compromises may have to be made with the consent of the owner.

13.3 Working with the Team

As stated earlier, the owner usually requests the pre-job conference to bring all concerned parties together. This is very important because it is usually the only opportunity that the team (group) has to meet together in such a way. The setting can be very formal or informal, ranging from the back of a pickup truck to a conference room in the corporate office. As noted earlier, the person requesting the meeting (or delegated representative) acts as the chair of the meeting.

Remember: ***Teamwork*** is an essential factor in the successful outcome of any project.

No inspector alone can accomplish success on any given project. Thus, it may be a good practice for the pre-job meeting requirements to be outlined in the project specification or in the contractual documents. The following people may be required to attend:

- Owner
- Owner's contract manager
- Engineer
- Specifying engineer
- Operations personnel
- Specifier
- Purchasing agents
- Coating manufacturer (preferably technical service representative)
- Coating inspector(s)
- Project safety personnel
- Coatings applicator (supervisory personnel)

13.4 Inspector's Role

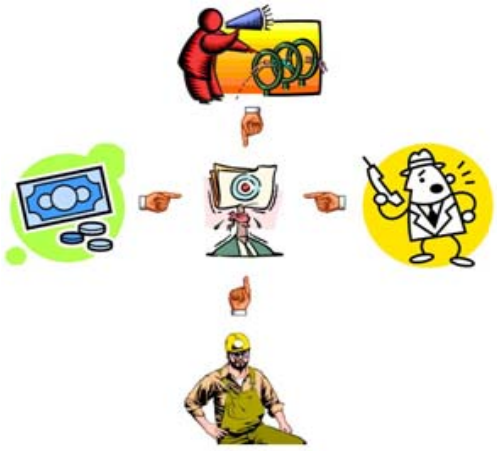


Figure 13.1 Inspector Stuck in the Middle

The role of the inspector in the industry today is ever changing. There are many misconceptions about what role an inspector should play on any given project. The NACE International Coatings Inspection Program (CIP) recognizes this trend but defines an inspector's role as a "**Quality Control Technician**" since the primary function is quality assurance and quality control (QA/QC). However, in today's environment, most inspectors are given additional responsibilities and authority to ensure that specifications are properly verified and that contractors comply. The problem with this trend is that *as the responsibilities increase, the authority decreases*. To avoid such situations, the inspector must focus on the following:

Before the first conference or meeting:

- Whenever possible, get a copy of, read, and understand the specification
- Get a copy, read and understand any standard/procedure referenced in the project specification
- Get a copy, read, understand the manufacturers' product data sheets
- Get a copy, read and understand the safety requirements of the MSDS
- Compare the requirements of the specification with the manufacturers' requirements
- Visit the site and make necessary observations
- Highlight any ambiguities, incorrect statements and/or inconsistencies found in the reviewed documents
- Come prepared to take notes

During the conference/meeting:

- Do not volunteer to be secretary. If asked, politely refuse and if needed, explain why Acting as secretary limits one's concentration on the proceedings and affects the quality of personal notes
- Ask for clarification of the inspector's authority and responsibilities. This will dispel any suspicions or unrealistic expectations from other team members
- Clarify lines of communication (chain of command)
- Clarify reporting requirements and processes
- Ask for clarification of non-conformance reporting and correction processes
- Ask for clarification of all ambiguous items found in review of the specification and other documents
- Get emergency contact information (email, cell, etc.) for all key team members
- Ensure that personal notes are legible enough for follow-up
- Recognize that the inspector is only **one** member of the team, so refrain from dominating the meeting

After the conference/meeting:

- Review personal notes and be familiar with changes made
- Follow-up with team members if something becomes unclear
- Get a copy of the minutes in a timely manner
- Review the minutes to ensure they accurately reflect all items covered in the pre-job meeting
- Inform the secretary of any problems found and request a corrected version of the minutes
- Sign and return to the person responsible

Any changes made to contractual documents (specification) during the pre-job meeting must be reflected in the minutes. After all

signatures are received, the minutes become an addendum the contract documents. It is important the inspector acquire and keep a copy of the approved minutes in the project files for future reference.

Keep in mind that while the pre-job meeting focuses on the technical aspects (specification requirements) of project, take nothing for granted and ask all questions. Inspectors must understand that as soon as the project begins they may be the owner's sole representative onsite and must be prepared to assist application personnel understand specification requirements.

In summary, a well organized pre-job conference or meeting is a decisive step towards the successful outcome of any given project. It is important that no stones are left unturned. Fair and accurate interpretation and understanding of the project requirements during the pre-job meeting prevent or alleviate many problems during the project.

Study Guide

1. Goals of a pre-job conference include:

2. People who may be required to attend a pre-job conference include:

3. Before the start of the pre-job conference the inspector should obtain a copy of, read, and understand the:

Chapter 14: Inspection Project Documentation

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Good record-keeping
- Reporting formats
- Inspection documentation
- Basic reporting principles

Prerequisites

Prior to class, be sure to:

- Review attached reports
- Review attached case study

14.1 Introduction

Like everything done today in the protective coatings industry, *good record keeping is an essential part of what quality control technicians (inspectors) do* (Figure 14.1).

Figure 14.1 Inspector Completing Documentation

A contractor provides a quantifiable deliverable to the client in return for compensation but the inspector on the other hand, provides a valuable service ensuring that the deliverable meets the specification through proper documentation of the process followed and the results attained.

This is done by submitting ***all*** reports as agreed upon in the project documents or as requested by the client on an as-needed basis. The inspector must understand that ***all*** reporting must be legible, honest, objective, and provide a truthful account of what transpires throughout the project.

Even if the specification does not specifically require documentation, good practice dictates keeping accurate, detailed records for future reference. Either the specification or the discussion in the pre-job conference should describe exactly the kind of reporting needed from the inspector. As previously mentioned, the pre-job conference must ensure all parties have a common understanding of specification. Documentation may include:

- Detailed written daily reports
- Inspection logs
- Routine reports
- Reports for weekly progress meetings
- Daily entries in a project log book
- A daily inspection report using standardized forms
- A weekly progress meeting report with sign in sheet
- Monthly or quarterly reports

At a minimum, inspection records should show all environmental conditions and the work process from pretreatment through repairs and final coat application. Good

inspection documentation provides tremendously valuable information on the durability of coatings and the protection they afford. Additionally, good record keeping provides a database for future projects similar in nature, thus saving a great deal of time and money during the planning phase.

Sometimes, the records are of little value when trying to determine the protection a coating affords and the cost of protection per year. A company with a well-developed coatings program, including ongoing maintenance, benefits greatly from detailed inspection reports on past coating projects. Inspection records show:

- Environmental conditions
- Pretreatment details
- Cleaning details
- Materials information
- Coating applications
- Results of work and all tests

For example, a chemical plant producing a variety of chemicals may use several generic coating types throughout the facility based on known or expected performance in similar corrosive environments. This shows a good process of evaluation and good documentation of the entire application process including how inspection can/will allow management to:

- Detect and tag design and fabrication defects for review by the engineering division for future work
- Evaluate coating performance in a realistic environment
- Determine annual cost data on each coating system
- Develop and implement a sound ongoing coatings maintenance program

The protective coatings industry is a very worker-mobile industry. Therefore, the movement of personnel from job to job can easily compromise the ability to keep track of people over the years. This makes it even more important to document the activities accurately and keep in a secure location for future reference. Some inspection documents are kept for a number of years because of legal requirements. Good records also provide maintenance departments with detailed information on what was coated, with what materials, and when, how, by whom, and at what overall cost.

Another important part of the inspector's job is maintaining regular communication with the team members, particularly the owner's representative and the contractor.

In addition to frequent, relatively informal conversations on the job, that communication can take the form of regular reports and meetings.

14.2 Good Record-Keeping

Good records allow management to:

- Detect and tag design defects for future work
- Evaluate coating performance
- Determine annual cost data on each coating system
- Develop ongoing maintenance program

Objective and professional records are important, because they may be used for reference at a later date, and may even be examined in court if disputes arise. Inspectors must make accurate statements of the facts that are complete, clear, and concise.

The following section covers various documents/reports that may be part of a coatings project:

Inspector's Logbook(s) or Daily Report

Some inspectors record field measurements and observations in a small bound book called a daily logbook (Figure 14.2).

The pages are usually numbered and the information is written in ink. Corrections are made by crossing through the error, and writing in the correction along with the inspector's initials. The inspector should initial each page while recording information.

Some inspectors use the logbook in the field and then transfer that information onto a daily report form. Some of the information contained in the logbook is eventually put into the daily inspection report, which becomes part of the documentation an inspector submits to the owner. However, because the inspector's logbook is a personal chronicle of what happens on a daily basis, it is not an item for submittal to anyone for review. It is a valuable reference tool for inspectors when communicating with others about project activities, especially if there are disputes about times and dates.

Please note, this logbook can be subpoenaed by anyone at any time through the legal system should there be a problem. Therefore, it is highly recommended that inspectors refrain from writing anything in a logbook that is unprofessional or potentially embarrassing for others to read.

Many inspectors view keeping both a logbook and a daily report form as duplicate work and choose to use only a daily report. This is not good practice because most inspection forms have room only for QA/QC related items. Further, information can be recorded in a logbook that may not be appropriate for daily "inspection" reports and associated tasks.

Figure 14.2 Inspector's Logbook for CIP Course Work

Some inspectors keep a personal logbook (usually a small, bound book with ink entries), detailing all of their own actions and those of the contractor and their employees. The inspector then transfers the data to a daily report form.

Many inspectors use only a daily report form to save time and make a single accurate record.

As an alternative, the inspector may choose to use a battery-operated, portable tape recorder to save field notes, in lieu of a logbook. They can then transfer these notes later onto the daily report form. However, keep in mind, most tape recorders are not intrinsically safe and using them may require permission, as well as a hot-work permit. If recording field notes, it would also be wise to inform security personnel in the facility to avoid any unpleasant confrontations.

Like daily reports, no single logging procedure is best, though, it can be argued that the written document is the most valuable. Report forms are organized into a logical time sequence inspectors can compile information in sequence (from first specification analysis to completion and acceptance/rejection).

The following material helps prepare students for the upcoming lab day exercise. Below is an example of a logbook (please understand that logbooks differ considerably in style, but the contents are generally consistent). The following information also details what is required from students in preparation for, and during the lab day exercise.

1. **Specification Review**

It is essential for coating inspectors to read and understand the specification. Notes made while reading the document help identify significant points, particularly those issues that may require clarification (Figure 14.3).

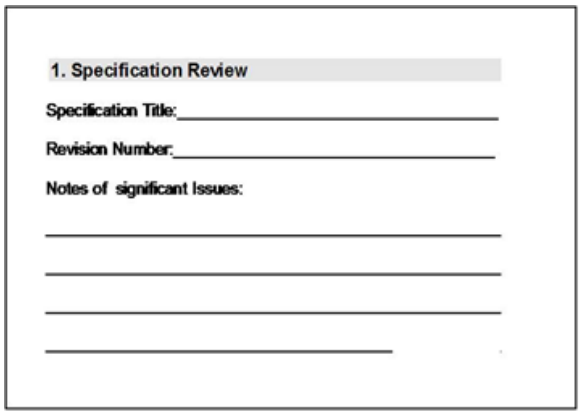


Figure 14.3 Specification Review

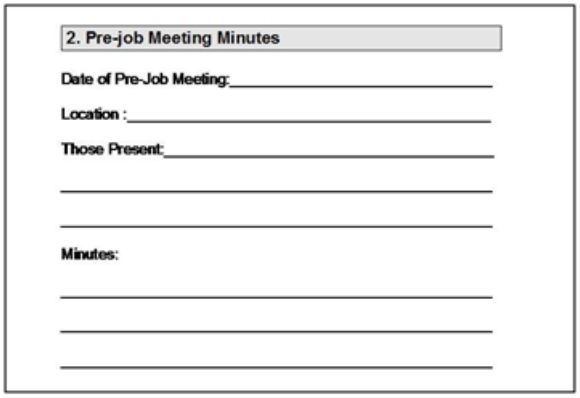
In preparation for lab day:

- Read the specification prior to the pre-job conference conducted in class (before everyone departs for the lab exercise)
- Read and review the product data sheet to compare it with the requirements in the assigned practice piece specification
- Identify inconsistencies, deficiencies, ambiguities, etc. to bring up for discussion during the pre job conference
- Document all safety issues addressed during the conference in the section provided

2. Pre-Job Meeting Minutes

While inspectors are not encouraged to act as a recording secretary (or minute taker) at pre-job meetings, some notes are essential to ensure that the minutes can be checked for accuracy. Written notes are always better than human memory. Inspectors should take care that the notes they make during the pre-job conference are detailed enough to make sense when read after weeks have passed and their memory has faded.

During the pre-job conference for the lab day exercise, individual notes should include items such as: owners' contact information, manufacturers' contact information, attendees, location and chairperson. Record all items added (not changes made) to the scope of work that were not part of the original specification (Figure 14.4).


2. Pre-job Meeting Minutes

Date of Pre-Job Meeting:_____

Location :_____

Those Present:_____

_____

_____

Minutes:

_____

_____

_____

Figure 14.4 Pre-job Meeting Minutes

3. **Safety**

Safety is most often the responsibility of a safety professional who provides written instructions and/or verbal safety briefings to workers. Record general and specific guidelines for safe work.

During the lab day briefing, information provided by the safety professional who conducts the meeting is vital; record this in the space provided in the trainee logbook.

4. **Specification Changes**

Document in the appropriate area any changes made to the specification during the meeting. Keep in mind that while many changes are made during the pre-job meeting, it is possible that additional changes may be made in the field. This is because a coating project is dynamic and challenges will surface at the most inappropriate times.

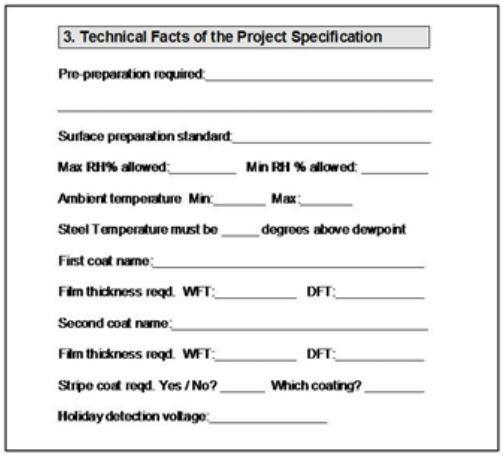
Document any changes made to the specifications by the instructors acting in various roles.

5. Instrument Information

All instruments on a coatings project should have an up-to-date calibration certificate or running log of calibration history accompanying it. A critical component in this area is the name, type (series), and serial number of the testing equipment.

6. Technical Facts of the Project Specification (after changes made at the pre-job meeting)

Following various pre-job discussions, and perhaps correspondence, some of the critical data that applies to a project may have been officially changed. A summary of the facts afterwards would then differ from the original specification documentation. During the lab day exercise, it is quite possible that a number of changes will be made to the specification during the pre-job conference. The working specification will reflect these changes unless additional changes are made upon arrival on site. (Figure 14.5).


3. Technical Facts of the Project Specification

Pre-preparation required:_____

_____

Surface preparation standard:_____

Max RH% allowed:_____ Min RH % allowed: _____

Ambient temperature Min:_____ Max:_____

Steel Temperature must be _____ degrees above dewpoint

First coat name:_____

Film thickness reqd. WFT:_____ DFT:_____

Second coat name:_____

Film thickness reqd. WFT:_____ DFT:_____

Stripe coat reqd. Yes / No? _____ Which coating? _____

Holiday detection voltage:_____

Figure 14.5 Technical Facts of the Project Specification

7. **Field Changes**

Document any changes made in the field and who authorized them. Theses changes are a critical part of the records. Likewise, record any observed deviations.

8. **Scope of Work**

This section is a summary of the work required, based on information contained in the specification. Specifications range from simple to very complex. As part of the lab day exercise, students will be required to draw up a simple scope of work from the

information gathered to that point and record it in the space provided in the logbook. (Figure 14.6)

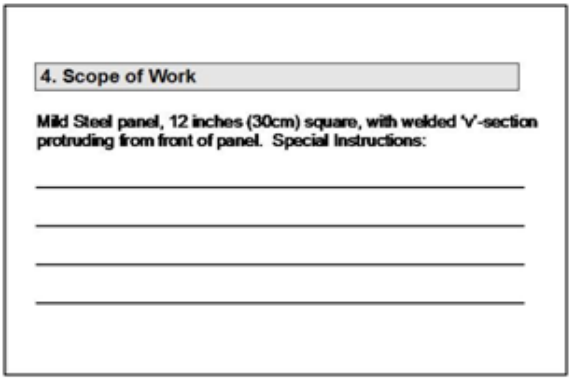


Figure 14.6 Scope of Work

9. **Safety Data**

Record general safety observations (violations, incidents, accidents, etc.) for future reference (Figure 14.7).

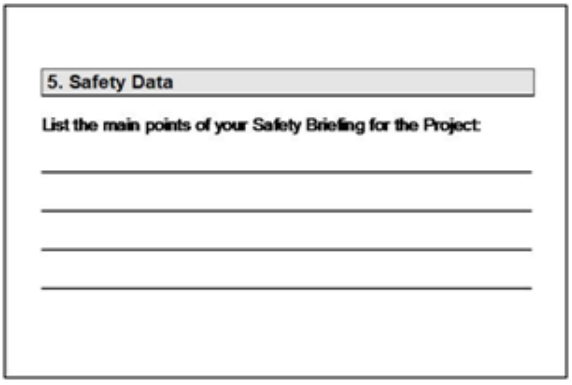


Figure 14.7 Safety Data

10. **Coating Inspector's Checklist**

Good coatings inspectors recognize that a checklist goes a long way in keeping them focused and on top of their game. (Figure 14.8)

If the inspector is able to confirm that each listed aspect is taken care of or has been considered (by checking the box), then the job is most likely on track for success. Always report any deviations or omissions.

The checklist provided in the trainee's logbook is a memory jog to help each trainee stay focused. Review the list and complete accordingly.

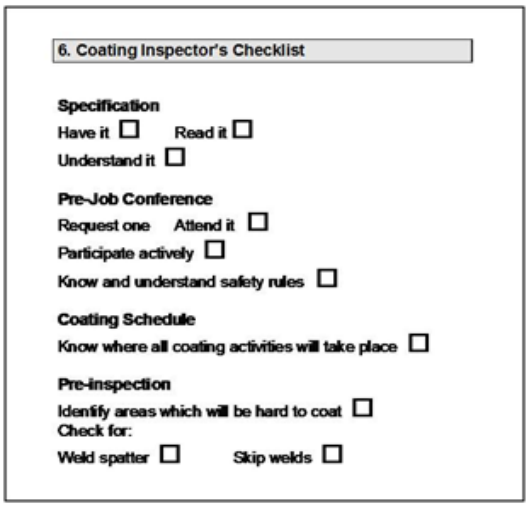


Figure 14.8 Coating Inspector's Checklist

11. **Inspection Details**

This section contains the various QA/QC steps taken throughout the day, including:

- Ambient conditions
- Pre-cleaning
- Initial preparation
- Surface preparation
- Measurement of anchor profile
- Coating application
- Dry-film thickness measurements
- Holiday detection
- Final inspection

12. **Non-Conformance Report**

Upon final inspection, inspectors should be able to determine whether the relevant items meet the agreed-upon specification after all authorized changes were made. If an item does not meet the specification, the inspector must indicate the reason(s) why and recommend corrective actions.

14.3 Reporting Formats

There are at least as many inspection record-keeping formats as there are clients. In particular, documentation for work performed under IMO/PSPC must conform to their requirements. Most forms require such information as:

- Location (general and detailed)
- Contractor's name and phone number
- Information about inspection company and or individual inspector
- Job number
- Environmental conditions
- Quantity of area prepared and painted
- Coating application dates
- Equipment used and operating conditions
- Personnel
- Quantities of abrasive and paint used

In other words, the QA/QC reports contain most of the items described in Section 11 of the trainee combined logbook. It is the coating inspector's responsibility to clearly understand what records and reports are required, the delivery timetable and who receives what. These are items that should be discussed and agreed on in the pre-job conference.

The daily reports and routine reports are customized for each project (Figure 14.9). Due to the criticality of the information required on inspection reports, the inspector must understand the need to take individualized readings and submit individual reports rather than depend on contractor personnel to do so.

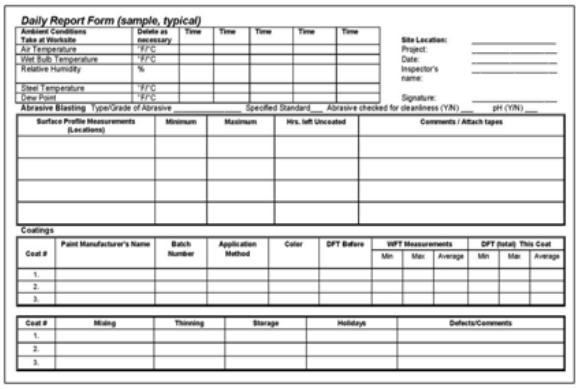


Figure 14.9 Typical Daily Report Form

14.4 Inspection Documentation

Documentation provides:

- Inspection (QC) records
- Management information
- Verification of work performed by the contractor
- Details of non-conforming work

14.4.1 Daily Reports

Daily reports are the most common and most important form of inspection reports and they are important for a number of reasons. In some cases, several inspectors may come and go during the course of the job. An example is offshore work, where inspectors change as often as every 14 days. Complete daily reports provide continuity and enable the inspection process to proceed more easily.

Daily reports are important because:

- Inspectors may change
- The information is valuable for failure analysis
- The information may be an aid in arbitration
- The information aids communication with supervisors

The daily reports also help in cases of a coating failure. The reports can help determine why the coating failed and what can be done to ensure that the repair will be successful.

Daily reports can also assist in arbitration between the contractor and the client. If a dispute arises, daily reports provide a reliable record of the coating process to date and help pinpoint where a misunderstanding may have occurred.

Daily reports also provide a way to communicate with supervisors and are indications that inspection work is being done. The daily reports also verify the amount of days the inspector was present and working. This can be very helpful for invoicing.

As noted previously, forms (including daily reports) vary from company to company. Daily reports are usually quite detailed and cover all aspects of the job, including:

- Environmental conditions (such as dew point, humidity, air/substrate temperatures, wind direction and speed)
- Surface preparation details (such as pre-surface preparation condition and the types/grades of abrasive)
- Description of equipment and personnel
- Details of coating application
- Locations of work inspected that day
- Deviations or non-conformances
- Explanation of any work stoppages
- Estimate of the percentage of work completed
- Results of inspection and the standards and specifications applied

As mentioned before, details increase the importance of daily reports. Diagrams and photographs clarify written documentation of locations and work progress. When possible, attach actual test results, such as a piece of replica tape used to measure an anchor pattern. As always, record all measurements.

14.4.2 Materials Inventory Reports

These periodic (as opposed to regularly scheduled) reports track the inventory of materials on site, such as coatings, thinners, abrasives, etc. It is good practice for the contractor to use coatings in a structured and methodical manner, so inspectors should ensure that:

- Coatings with the same batch number are kept together
- The first-in first-out (FIFO) rotation of materials is continuing
- Instrument calibration history reports are up-to-date

Calibration reports normally contain information on how frequently each instrument should be calibrated. Each instrument should carry a label showing its own serial number or special identifying label, and the last calibration date. The inspector may be required to record the serial numbers on the daily report.

14.4.3 Weekly Reports

In addition to daily reports, a weekly report may be required. The weekly report tends to be less detailed and written in layman's terms (i.e., in narrative form, rather than technical terminology). Often, it is written in the office rather than in the field. To ensure everyone is well informed about progress, copies of both daily and weekly reports go to the:

- Client
- Company doing the inspection
- Engineer on site

The contractor does not generally receive a copy of weekly reports.

14.4.4 Non-Conformance Reports

Non-conformance reports (NCRs) are increasingly common. Initially, they were developed as informational tools for quality assurance to report defect occurrence and subsequent actions to resolve the problems.

Most NCRs provide space to report a problem, propose a solution, and record the remedial action. Participants sign the form at each step to indicate that authoritative decisions were found and implemented. Inspectors and operators are sometimes leery of NCRs because they seem to be critical or damaging. They were originally intended to gather information for management to help identify and resolve problem work areas or routines. In this context, they are helpful and positive documents, not unhelpful and negative documents.

Problems are encountered on most jobs. NCRs record the problems and their resolution and should lead to improvements that reduce problems in the future. However, inspectors must understand that issuing NCRs without proper follow-up to ensure that corrective measures are taken, defeats their very purpose.

14.4.5 Other Reports

As noted in Section 14.4.2, other routine reports may include:

- Materials inventory
- Instrument calibration history

The inspector may elect (or be required) to report on the materials inventory and the instrument calibration history.

14.5 Basic Reporting Principles

The basic reporting principles for inspectors noted here are vital knowledge.

Write all reports in ink so that alteration is difficult. It is perfectly okay to make changes, but it should be very clear that they **are** changes and the person making the change should prominently initial the change. Other basic principles of report writing include:

- Do not leave fill-in spaces on forms blank. The recipient of the report cannot tell whether the space is blank because there is no information or because the question was overlooked. Complete all spaces with either:
  - — the required information
  - — a cross-out line
  - — N/A (not applicable)
- Sign and date all reports.
- It is best to complete reports at the appropriate time. For example, complete daily reports each day while the information is fresh. The report is more likely to be complete, with information un-modified by subsequent experiences.
- Complete all sections of a table which collects data. Delete any spaces not required.

With current technology, inspection reports are mostly digital, since ensuring their validity/legality is paramount. Therefore, as a basic guideline, print out and sign copies of original documents, and ensure that all electronic versions:

- Are in PDF format
- Cells in tables/spreadsheets are protected
- Photos are time stamped and dated

Study Guide

1. Documentation may include:

2. Inspection records show:

3. Good records allow management to:

4. Project inspection documentation provides:

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Chapter 15: Coating Application

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Weather conditions
- Mixing
- Applying the coating

15.1 Introduction

Once the surface preparation is complete and proven to be in conformance with the specification, it is time to apply the coatings. This chapter examines the most common methods of applying industrial coatings and some of the factors affecting application.

15.2 Weather Conditions

Many industrial coating projects are done outside in ambient conditions. The vulnerability to weather presents many challenges for both owners and contractors. Some of the challenges include:

- Job delays
- Surface preparation ruined
- Lost production time from redoing surface preparation
- Seasons when work cannot be done

Environmental controls are available, but add cost to the project. Owners weigh the added cost against the cost of extending the project due to poor weather conditions. In the past, it was very difficult and very costly to enclose a structure. Now, advances in enclosure technology make the process simpler.

15.2.1 Environmental Enclosures

It is not uncommon to enclose a bridge, a high-rise tank, or even the deck of an aircraft carrier to complete a coating project in near perfect environmental conditions. This can be done effectively despite the outside conditions.

While this seems to be the optimum answer to bad weather conditions, there are some **drawbacks** for inspectors. *First,* enclosures may be so tight against the structure that it is difficult to see more than a very small area at one time. *Second,* the inspector may need to work in hazardous enclosed spaces, and needs to be prepared for that. *Third,* some enclosures may not have the proper lighting either for work or inspection. SSPC Technology Guide No. 12 states surface preparation and coating application require a *minimum* of 20-foot candles, and recommends 50-foot candles. Foot Candles are a measure of the amount of light falling on a surface. The same guide states inspection work requires a minimum of 50-foot candles and recommends 200-foot candles.

There are **benefits** from using environmental enclosures. The primary benefit is control of the temperature and humidity, and the ability to keep them in a narrow range. Inspectors need to be familiar with the equipment, and observe and record the environmental readings just like work done outdoors. Even in enclosure pockets of hot or cold air, different surface temperatures can occur. Only use the type of heating and DH equipment appropriate for coating work. **Note:** some types of heating units add

humidity or introduce oil-contaminated air to the enclosure.

There are two industry guides for the design and use of enclosures for coating work:

- SSPC Technology Update No. 6, Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations
- SSPC Technology Update No. 16

15.2.2 Temperatures

The majority of industrial coatings undergo a chemical reaction to convert from a liquid to a solid. By the nature of chemical reactions, low temperatures slow down chemical reactions and high temperatures speed them up. The temperature at which the chemical reaction stops depends on the individual product and its compounds. A successful coating cure is based on a delicate balance of correct mixing, and a predictable solvent evaporation rate that occurs in a predictable time frame and at a temperature that allows the coating to react in a consistent manner. With some exceptions, most coatings are formulated to work best in a temperature range between 60°F and 100°F (16°C and 38°C), with maximum humidity of 85%. There are, of course, exceptions to this — some products are applied underwater or to wet surfaces at 100% RH.

15.2.2.1 Low temperatures

Exceptions to general temperature parameters include low-temperature-cure coatings like inorganic zinc silicate, which cures at temperatures as low as 32°F (0°C) but requires a humidity of 50% or higher. Moisture-cured polyurethanes also require a minimum humidity level. Some coating manufacturers supply a special cure for their epoxy coatings that speed up cure at temperatures below 50°F (10°C). Other manufacturers make special epoxy coatings that cure at temperatures below the freezing point of water. The low temperature of the material increases viscosity, so additional thinner is needed to increase ease of application. Adding thinner is **not a good solution** in low temperature coating application; **heating the coating** to the recommended application temperature i**s the correct solution**. Low temperatures also slow the curing time of chemically cured coatings; this adds to production time and could lead to other possible problems.

Polyurethane coatings normally cure at a minimum temperature somewhat less than epoxies. Most solvent-evaporation-cured coatings are not as sensitive to low temperatures as chemically-cured coatings.

15.2.2.2 High temperatures

Surface or air temperatures that are too high negatively affect coating application and cure. When surface temperatures are too high, the solvent in solvent-borne coatings evaporates too quickly and the pot life decreases, as does the viscosity of many two-component materials. A very high air temperature reduces productivity because craft workers tire more quickly in such conditions.

15.2.3 Humidity

High or low humidity may also negatively affect coating cure. High humidity slows solvent evaporation and under certain conditions, it may also leave moisture on the coating surface. Moisture on coatings during curing can cause problems — precisely what occurs depends on the coating formulation.

Some curing agents used with epoxy and polyurethane coatings are moisture sensitive; instead of reacting with the resin as intended, they instead react with the moisture on their surfaces. This results in blushing. The minimum effect of water on a curing coating is some loss of gloss or color. At worst, the moisture causes amine blush, which must be removed before top coating.

15.2.4 Inspection Steps

1. Record temperature and humidity of the storage area for at least 24 hours before use of the material
2. At a minimum, record the ambient temperature, material temperature, surface temperature, humidity, and dew point at the beginning and end of each shift. As a **best** practice, check all environmental readings at least every 4 hours, and even more often if the weather is changing.
3. If the readings do not conform with the project specification, immediately report this to the project supervisor for his resolution.
4. If at all possible, continue to record environmental readings during the curing phase. This could take as long as 7 days after coating application.
5. Using an electronic data logger eliminates the need to take so many manual readings for such a long period. Electronic data loggers now take readings at whatever interval is needed (i.e., every 5 minutes), then automatically save the information directly to a computer program.

15.3 Mixing the Coating

Mixing industrial coatings requires precision and care to achieve the expected service life. (Figure 15.1) Unfortunately, from the earliest applications of industrial coatings, mixing has been relegated to untrained helpers. Many contractors have learned a hard lesson when their coatings fail immediately. Because of this, some are focusing more on training mixers. However, untrained mixers are still common in the field. Pay close attention to coating preparation.

Figure 15.1 Mixing the paint

The basic inspection steps for mixing coatings include:

1. Review the manufacturers mixing instructions
2. Ensure that the correct materials are used (i.e., correct components in the correct ratio) and the correct color. Also, record the batch numbers.
3. Just prior to mixing, confirm the units and colors are correct for the area to be coated
4. Measure the temperature of each liquid component with an immersion thermometer after each unit is mixed. Just measuring the outside of the bucket or the top of the liquid with an infrared thermometer will not give the true temperature.

5. During mixing, ensure:
    - Can tops are clean prior to opening
    - A power mixer designed to lift coatings from can bottom is used
    - Inorganic zinc powder is sifted before it is added to mix
    - Each component is mixed separately then combined and mixed again
    - The addition of any thinner is documented. Confirm it is the approved thinner for the material; confirm that the quantity added is correct and that it does not exceed the allowable amount.
    - Mixing is done at a slow speed to avoid forming a deep vortex; a deep vortex pulls air into the mixture
    - The length of time spent mixing is documented
    - The time mixing ends is recorded for each unit; (**Tip**: write the time on each can lid after mixing and replace lid)
    - The mixer waited for the required induction time before adding the mixture to the pump reservoir. Document findings.
    - That the coating is used within its pot life or if not, disposed of properly. Document the findings.

15.4 Coating Application

Liquid coatings are commonly applied using brush, roller, spray, flow, and dip methods. Each of these methods can be done with a wide variety of equipment that produce differing results. Most projects use more than one tool. The most common are brushes, rollers, and spray. Application methods are used as needed to conform to the project specification.

Good applicators who use brush or spray methods must know and use the correct techniques, as well as thoroughly understand what results are required. All coating applicators need training in proper techniques and material handling. The NACE/SSPC joint standard “SSPC ACS-1/NACE 13 Regarding Coating Applicator Certification” details training and certification requirements. NACE and SSPC, as well as other organizations, offer applicator training and certification.

Coating inspectors need to confirm that applicators on a project are certified if required in the specification. This includes temporary workers and day laborers.

All coating application methods are both a science and an art form. Productive and accurate applicators are the result of both classroom and on-the-job training. Applicators must be able to apply coatings to a very precise film thickness while working under very adverse conditions. Coating inspectors do not need to be “expert” applicators; however they must know what to look for during the application phase of a project. Inspectors must be able to recognize when an applicator does not meet specification requirements, then report that deficiency to a supervisor.

15.4.1 Brush Application

There are many types of brushes. Applicators should use brushes whose size, shape and type of bristle are appropriate for both the specified coating, and the shape of the structure. Disposable hog bristle brushes are the most common type used for industrial coating projects. Disposable brushes are used because once they are used with a chemically-cured coating they cannot be adequately cleaned.

Industrial coating jobs use brushes to stripe coat welds, edges, and inside corners, as well as areas where spray guns cannot reach. Inspectors recognize that a brush-applied coating will not look like a sprayed coating, nor will it leave a uniformly even coating on the surface. Brush application needs two coats to equal one spray-applied coat.

Brushes are the best choice when applying a primer on uneven surfaces with rough welds or on pitted steel. Applicators can use the brush to work the coating into the small voids that roller or spray application would bridge over. Brushes are ideal to apply extra coating to edges, since the force of spray application can blow the coating off the edges.

15.4.2 Roller Application

Rollers are also available in a wide variety of materials and sizes. One type of roller, used to apply non-skid coatings, has no covering. Rollers are typically used to apply industrial coatings on small areas not easily reached by spray, for strip coating edges and corners, or when spraying is not allowed for environmental or job-specific reasons.

A roller-applied coating does not look like either brush- or spray-applied coatings. As noted previously, inspectors should recognize that different surface application methods produce visually different results. Most manufacturers of coatings designed for brush or roller application supply slowly-evaporating thinners with their coatings. Again, as noted before, brush application needs two coats to equal one spray-applied coat. Inspectors should look for even application at the specified DFT.

15.4.3 Spray Application

The basic principle of spray application is to transform a stream of liquid coating into very small droplets, then deposit them on a surface. Airless spray does this by using very high pressure to force the liquid coating through a very small hole (orifice). The conventional spray method sprays the material though a hole (larger than the airless orifice) at much lower pressure, then breaks it up into tiny particles using a stream of air (atomizing). Several other types of spray equipment do the same thing, but use lower pressure. Examples are high volume low pressure (HVLP) units and air assisted airless equipment, which is a combination of airless and conventional equipment.

15.4.3.1 Airless Spray Application

Airless spray is the most commonly used application method for residential, commercial or industrial jobs (Figure 15.2). The only difference between spray units purchased at a local hardware store and those used on the largest offshore rigs is the **physical size** and **pressure output** of the equipment.

A piston pump pulls material from a container and forces it though a high-pressure line at up to 9000 psi, which pushes it though an orifice on the end of a gun breaking it into very small droplets. The spray gun has no controls on it except a simple on/off trigger. Pulling the trigger releases the full force and volume of the paint.

Figure 15.2 Airless Spray Equipment

Airless Spray Safety

Whenever working around an airless spray pump, be aware of the very high pressure involved and the hazard of injection injury. The coating comes out of the gun tip at about 3,500 psi (241 bar) or higher. Even a leak around a fitting can inject paint into a person's skin. If that happens, get immediate medical attention, even if the injury does not seem serious at first. Also, be wary of any pump, hose, and gun set up that does not look well maintained. Ensure the pressure ratings of all downstream fittings exceed the maximum pressure capacity of the pump. Sometimes, pump owners attempt to fix leaking fittings by substituting a low pressure, more easily obtainable fitting. If that is the case, the fitting can explode and injure those nearby.

Airless Spray Equipment

Most industrial airless spray equipment operates by pressurized air. This powers the air motor that drives the piston pump. The piston pump moves the material, under high pressure, through the hoses to the gun.

The pressure of the material at the gun tip results from the relationship between the pressure of air coming into the air motor and the size of the two pistons. The larger piston is on the air side and the smaller is on the liquid side. The difference in the size of the two pistons is commonly how pumps are referred to (i.e., a 30:1 pump). A 30:1 pump with 100 psi (6.9 bar) of incoming air increases the pressure of the liquid coating by 30, or 3,000 psi (206 bar).

Coating inspectors see pumps from 30:1 all the way up to 90:1 or more. The overall size of both pistons determines the volume of coating that passes through the pump with each stroke. When some pumps are unrestricted and operate continuously, they can spray as much as 5 gallons (20 L) per minute at high pressure. However, the more common rate is about **one to three liters** per minute, since that is about as much pressure an applicator can reasonably control. The greatest benefit of a high-pressure high-volume pump is to enable several applicators to work from it at once. Even with the volume and pressure divided between two to four applicators, each has sufficient volume and pressure to work productively.

Coating inspectors need to understand the quality of the coating finish depends on, in part, whether the pump provides enough pressure to atomize the coating for all of the guns attached to it. If the coating is not atomized at each gun, the DFT will be uneven and coating defects like overspray, runs, and sags can occur.

The only control applicators have with airless spray rigs is **changing gun tips**. This requires a good deal of training since tips have significant influence on the quality of

the coating. Tips come in a variety of sizes with the orifices cut at numerous angles.

Tip selection is based on various factors including:

- Volume and pressure of coating provided by the pump
- Tip size, which controls coating atomization
- Tip angle, which controls width of spray pattern
- Use a size appropriate for coating (recommended sizes shown on product data sheets)

Clearly, tip selection is critical to the quality of finish, since it so directly affects coating atomization and spray pattern width. An improperly atomized coating does not flow out well on the surface, resulting in poor wetting, which causes poor adhesion. Improperly atomized coating also compromises the DFT due to uneven spray pattern, and can cause over spray and dry spray.

Tips are typically named with a number that signifies the tip angle and diameter of the orifice, for example, a 417 tip. The **first number indicates the angle**. This first number also helps calculate the pattern width it creates if the gun is held 12 in (30 cm) from the surface. To calculate, simply double the number (4 x 2 = 8). This means 8 in (20 cm) is the pattern width. The last two numbers, 17, state the diameter of the orifice in thousands of an inch, which in this example is 17 mils (432 microns).

Tips wear out and applicators should inspect them at least daily.

During application, watch the spray pattern to ensure it is even, does not have fingering, and is not misshapen (Figure 15.3). Fingering describes a poorly atomized spray pattern from an airless spray system, resulting in uneven application of the coating.

Figure 15.3 Airless Spray Fingering

At the start of a shift, each applicator should use a comb gauge to take wet film readings (WFT), then use this reading to determine how much coating to apply. Well-trained applicators check WFT each time they change locations or the configuration of the area changes. To calculate WFT, divide the specified DFT by the percentage of solids volume of the coating in use.

Coating inspectors do not measure WFT unless required by the specification for a special reason (i.e., if it is not possible to measure DFT) (Figure 15.4). If this is the case, take the measurement as soon as the material is applied. Work closely with the applicator and ensure both he and his supervisor know what is being done and when.

Trained applicators follow a logical pattern when applying coatings. A perfect technique keeps the gun 12 in (30 cm) from the surface and at a 90° angle to the surface. Since it is not possible for anyone to achieve that perfection, acceptable parameters for airless spraying are: a 10-14 in (25- 25 cm) distance between the tip sand the surface, with the

angle as close to 90° as possible. Anything less than a 10 in (25 cm) distance may lead to an alligator-skin finish and result in too much coating on the surface. A tip distance over 14 in (35 cm) may result in over spray and a thin coating. On nearly every job, it is occasionally necessary to exceed the maximum recommend distance. Hold these occasions to a minimum with proper staging or special equipment (i.e., a gun extension pole) which limits the distance an applicator has to reach.

Figure 15.4 Wet Film Thickness Measurement

It is important for inspectors to pay careful attention to DFT measurements in areas where the applicator had difficulty maintaining angle or distance. The DFT standard, SSPC PA 2, requires a minimum number of readings and allows inspectors to take more readings if they suspect, or find, out-of-conformance areas.

Plural Airless Spray Equipment

Plural airless spray equipment is more widely used now.

Plural airless spray rigs differ from single component airless spray equipment in that there are two pumps (piston pumps) synchronized to operate together at a controlled rate (either variable- or fixed-rate). The two pumps ensure both coating components are delivered at the right pressure and rate. In addition to the two pumps, the equipment generally includes:

- Air compressor
- Air motor
- Two containers for coating components
- Container of solvent
- Supply lines (coating and solvent)
- Filters (low and high pressure)
- Hoses
- Unit to heat the coating
- Pressure gauges (air and coating)
- Control panel with display screen
- Spray gun (configured to mix components)

Plural airless systems have one of two types of pump configurations, either:

- Fixed ratio
- Variable ratio

Since properly operated pumps are so critical to the quality of coatings applied with plural airless spray, pump manufacturers offer classes to teach how to operate their pumps. Operators then receive certification for successfully completing the training. Inspectors need to ensure that operators using this equipment have the necessary training and experience. An incorrectly set up pump that delivers coating at the wrong ratio is a major problem. Unfortunately, an error of that magnitude is not easy to spot until it is too late. The only solution at that point is to remove and re-apply the coating. For applicators, there are only a few differences between using conventional airless equipment (single pump) and plural airless equipment. There is no difference in gun

operation or in how the pressurized coating comes out of it.

There are a couple of drawbacks. One drawback is that the spray gun is quite hot to hold because of the heated coating. Another drawback is that a pause of more than a second or two in triggering the gun negatively affects coating atomization, which causes fingering. Experienced applicators plan their moves carefully to avoid pauses (i.e., stops and starts) in triggering.

Inspectors should following the manufacturer's equipment guidelines, and observe and document:

- Ratio checks at start and end of shifts, and after operating stoppages for breaks or reservoir reloading
- Error messages on equipment screens
- Temperature of each component as it is heated

Conventional Spray Equipment

Conventional spray equipment is commonly used when a fine finish is required. It is also used to apply inorganic zinc coatings because high pressure airless spray equipment can cause the zinc powder to separate out of the liquid. The zinc powder deposits clog and stop up the hoses (Figure 15.5).

This equipment is appropriate for painting a yacht or an automobile. However, large industrial projects need equipment with far greater productivity rates than conventional spray rigs can supply. A drawback is how conventional spray atomizes the coating. It can cause the spray to drift during application, resulting in greater overspray even on flat surfaces.

Figure 15.5 Conventional Pot and Conventional Spray Gun

Conventional spray rig equipment includes:

- A pressure pot for the coating
- A compressed air source
- Two hoses carrying coating to spray gun
- A spray gun with several controls

The pressures that conventional sprays use varies according to the material and its viscosity. Applicators often measure the coating's viscosity before they begin conventional spraying.

Conventional spray pressure pots have two sets of air pressure gauges and controls: one regulates pot pressure and the other regulates the air pressure moving the coating to the gun's tip. The pressure pot uses low pressure, 25 to 50 psi (2 to 3.5 bar) to move the coating to the gun and to the tip. The pressurized air feeds through the air cap and atomizes the coating as the stream leaves the tip. Different tip and air cap sizes are available. The product data sheets list tip and air cap sizes appropriate for the particular coating.

Applicators using conventional spray rigs have several options to control both the size and shape of the spray pattern, and the volume of material coming out of the gun. Two turn knobs on the back of the gun adjust size and shape. The trigger also serves as volume control. To shoot only air, the applicator pulls the trigger only half way and holds it there. The volume of coating being sprayed increases the further back the applicator pulls the trigger. This extra control and the much lower speed and volume of the material coming out of the gun allows a more finely-controlled spray application. Please note: applicators **must** have prior training and experience to use this equipment professionally.

Conventional spray equipment has a couple of drawbacks. Several heavy-duty coatings cannot be applied with conventional spray equipment. High-build, high-viscosity coatings cannot be pushed or atomized with low air pressure. Also, coatings with very short pot lives cannot be spray-applied effectively.

Inspectors should watch for overspray and dry spray when the applicator is using conventional spray.

Other Spray Equipment

Air assisted airless spray equipment consists of an airless spray pump rig, paired with a special gun that uses air pressure at the tip to help atomize the coating. The production rate is between conventional, 25 to 50 psi (2 to 3.5 bar), and airless, 100 psi (6.9 bar) to 3,000 psi (206 bar) and higher, and the pressure at the tip is normally lower than standard airless.

This equipment can be found in shops coating small parts which require more control to reduce wasted material.

High volume, low pressure (HVLP) rigs are most frequently used in shops, or for touch-ups since these rigs can be very portable. This equipment is generally not used for large industrial projects unless local regulations require very low VOC emissions.

HVLP reduces the loss of material and therefore reduces overall VOC emissions. HVLP rigs use a large volume of heated air to push coating through an orifice that is atomized by a very low pressure shot of air. Because of the low pressures, the coating strikes the surface with very low energy and does not bounce back into the air, which is what causes overspray.

Dipping, pouring, and flood coating are other methods to apply coatings to small, complicated equipment and parts. This type of work is usually done in shops.

15.5 Case Study: Theory or Practice?

There is a long-term, on-going debate in the coatings industry. Some regard inspectors as part of the **application team** and think inspectors should be able to tell applicators how to set up and operate equipment.

Others regard inspectors as independent **quality controllers**, and think inspectors should be completely separate from applicators and their problems. This means they think inspectors need to know when work complies with specifications, but do not need to understand the fine details of coating application.

Should inspectors be able to operate blast cleaning or spray application equipment? What does your group think?

Answer **Yes** or **No** and give at least three reasons for your decision. Please write your answers on a flip chart.

Discussion time allowed = 20 minutes

Study Guide

1. One guide to enclosures for coatings projects is:
_____

2. Low temperature concerns during coatings application include:
_____
_____
_____
_____

3. High temperature concerns during coatings application include:
_____
_____
_____
_____

4. High humidity during coating application may:
_____
_____
_____
_____

5. Coatings may be applied by the following methods:
_____
_____
_____
_____
_____

Chapter 16: Dry Film Thickness Measurement Instrumentation

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- WFT Instruments
- Type 1 DFT Instruments
- Type 2 DFT Instruments

Key Trade Terms

- Wet Film Comb
- DFT Gauge (Type 1)
- DFT Gauge (Type 2)

16.1 WFT Instruments

The wet-film thickness gauge is an essential companion to any instrument used to measure DFT. (Figure 16.1) Using the volume-solids content of the coating, applicators can calculate the required WFT to produce the desired DFT.

16.1.1 Wet Film Thickness Comb

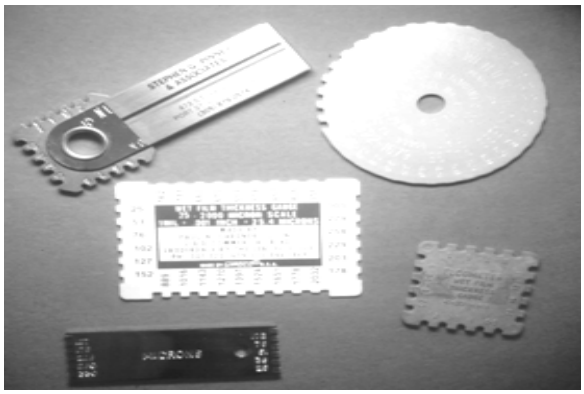


Figure 16.1 Wet Film Thickness Comb

16.1.1.1 Proper Use

Push the gauge firmly into the wet paint film so that the outermost teeth touch the substrate or previously coated surface. It is essential to hold the gauge at a right angle to the surface. Remove and examine the teeth. See what teeth have paint on them and what teeth are clean. The true WFT lies between the last tooth with coating on it and the next higher tooth that is clean. The WFT to report is the last wet, or coated, tooth on the gauge (Figure 16.2).

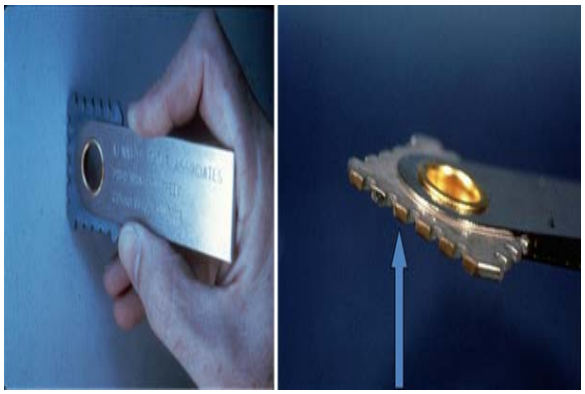


Figure 16.2 Proper Use of WFT Gauge

Use the wet film gauge according to one of the following national and international standards:

- AS/NZS 1580.107.3
- ASTM D 4414-A
- ISO 2808-1A
- ASTM D 1212-A
- ISO 2808-1B
- NF T30-125

- US Navy NSI 009-32
- US Navy PPI 63101-000

16.1.1.2 Calibration

WFT gauges need regular calibration checks over their usable life. This is a requirement of quality management procedures, e.g., ISO 9000, and other standards. There are no field calibration checks. Contact the manufacturer or local supplier to request a WFT calibration check and certification. WFT gauges are fairly inexpensive, so if there is a question about the accuracy of the gauge, it is best to replace it.

16.1.1.3 Operating Parameters

WFT combs are available that can measure anywhere from 0.2 in to 4¾ in (0.5 mils to 120 mils). They generally have an accuracy of about ± 5%. The operator's skill and technique determine whether the measurement results are repeatable. Question readings if they are outside the expected range. Check for damage or paint build-up on the gauge's teeth. If the accuracy of the gauge is questionable, replace it.

Common **errors** that can produce inaccurate readings include:

- Using a damaged gauge
- *Dragging* a gauge through wet coating (this causes a false high reading)
- Placing the gauge *along the circumference* of a pipe or curved surface, *rather than along the longitudinal axis*, when measuring WFT on pipes or curved surfaces.

16.2 Type 1 DFT Instruments

Magnetic pull-off DFT gauges are described as Type 1 gauges in both SSPC PA 2 and ASTM D7091. They work by means of a permanent magnet, a calibrated spring, and a graduated scale. The attraction between the magnet and the magnetic steel substrate pulls the two together. As the coating thickness increases, it becomes easier to pull the magnet away from the substrate. The gauge determines the coating thickness by measuring the pull-off force. Thinner coatings have stronger magnetic attraction while thicker films have comparatively less magnetic attraction.

Figure 16.3 Dial-Type Mechanical Magnetic Pull-Off DFT gauge

16.2.1 Dial-Type Magnetic Pull-Off DFT Gauge

This is commonly referred to as a "Banana Gauge" (Figure 16.3). Magnetic pull-off gauges are rugged, simple, inexpensive, portable, and usually do not require any calibration. They are a good, low-cost alternatives when specifications require only a few readings during inspection. These work well in areas where electronic gauges may cause problems (i.e., potentially flammable atmospheres). Some models may even be used underwater.

16.2.1.1 Proper Use

Place the gauge on a clean, dry, and cured coated surface. Do not use on soft or tacky films. Rotate the dial *beyond* the expected thickness. Move the probe down to the surface. Slowly rotate the dial back (increasing

spring tension) at a constant speed until the magnet pops up from the coated ferrous substrate. Where possible, the gauge should be mechanically stabilized by pressure from the operator's hand (Figure 16.4).

Keep the magnetic tip free of magnetic particles and other residues. Do not use the gauge within 1 in (2.5 cm) of an edge, on or near vibrating equipment, or on metal being welded (the steel may become magnetized). Position the gauge along the longitudinal axis of a pipe.

Figure 16.4 Dial-Type Mechanical Magnetic Pull-Off DFT gauge

16.2.1.2 Calibration

Ensure DFT instruments are calibrated only by the equipment manufacturer, an authorized agent, or an authorized calibration laboratory with trained staff working in a controlled environment using a documented process. The calibrator should be able to issue a certificate of calibration showing its standards are traceable to a national metrology institute, such as the National Institute of Standards and Technology (NIST) in the US.

16.2.1.3 Verification of Accuracy

Before using the gauge, verify the calibration accuracy by using it to measure coated thickness standards. (Figure 16.5) Examine the probe for cleanliness before verifying accuracy and before taking coating thickness measurements using the standards.

If gauge readings taken during verification are outside the combined accuracy of the coated thickness standard and the manufacturer's stated gauge accuracy, return the gauge to the manufacturer or authorized agency for repair and/or re-calibration.

Do not use either plastic or non-magnetic shims to verify the accuracy of Type 1 gauges. Such shims are usually fairly rigid and curved; they do not lie perfectly flat, even on smooth steel test surfaces. Shims frequently spring back from the steel surface when Type 1 gauges near the pull-off point. This raises the magnet too soon and causes erroneous readings (Figure 16.6).

Figure 16.5 Coating Thickness Standards

16.2.1.4 Mathematical Adjustment

Type 1 gauges have nonlinear (logarithmic) scales and adjusting features are linear in nature. Therefore, any mathematical adjustment of readings from these gauges limits the DFT range for which the gauge will provide accurate readings.

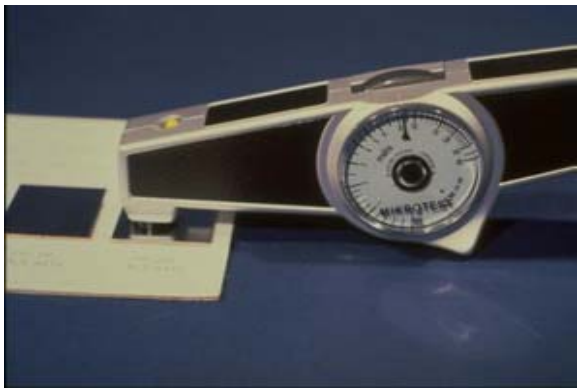


Figure 16.6 Verifying the Accuracy of Type 1 DFT Gauge Using Coated Thickness Standards

Magnetic gauges measure the distance from their probe tips to what is termed the **effective magnetic surface** of the steel. When the steel surface is smooth and even, *its surface plane **is** the effective magnetic surface*. If the steel is roughened (from blast cleaning, etc.), the *"apparent" or effective magnetic surface* is an imaginary plane located somewhere between the highest peaks and the lowest valleys of the surface profile.

To determine 'apparent' effective magnetic surface (i.e., adjust for surface roughness), measure the roughened steel at a number of spots, calculate the average of the measurements, and record this value. This average value is the **base metal reading** (BMR).

Once the DFT measurement is made, deduct the BMR from the DFT. The BMR is typically a small factor, usually 0.3 to 0.8 mil (8 to 20 µm), but can be outside this range.

Experiments show that gauges calibrated on a smooth surface, then used on a grit-blasted surface with a 2 mil (50 µm) profile, have an inaccuracy of around 1 mil (25 µm) on a coating thickness of 10 mils (250 µm).

16.2.1.5 Operating Parameters

Models are available with different measuring ranges. Because scales are logarithmic, these instruments are most accurate at the bottom of their measuring range with atypical tolerance of ±5%.

Instruments generally deliver the consistent results if all things are equal, but the user's technique is also a factor. For example, moving the dial too quickly can affect measurements.

Question any readings that are unusually high or low. As with other gauges, check measurements that are outside the normal range. It is not unusual for an occasional measurement to be quite different from others very close to the same location. If a measurement *cannot* be repeated, then discard it as invalid and make an alternative measurement.

Common errors that may produce inaccurate readings when using a Dial-Type Magnetic Pull-Off DFT Gauge include:

- Failure to determine the BMR
- Rotating the dial too fast when taking measurements
- Taking measurements too close to the edge or on vibrating surfaces
- Measuring dirty, tacky, or soft films

16.2.2 Pencil-Type Magnetic Pull-Off DFT Gauge

The Pencil Pull-off Gauge, Type 1, is another type of magnetic pull-off gauge. (Figure 16.7) The instrument is a hollow tube, similar in size to a large pencil, with an internal magnet and spring.

Figure 16.7 Pencil-Type Magnetic Pull-Off DFT Gauge

16.2.2.1 Proper Use

Most pencil-type pull-off gauges have large magnets and are designed to work in only one position (vertical or horizontal) to avoid the effects of gravity. Some versions have scales designed to compensate for the effects of gravity regardless of their orientation.

Hold the pencil gauge perpendicular to the surface, and place the magnet in contact with the surface. As the gauge body pulls away from the coated surface, the magnet remains magnetically attached to the surface. Keep a close watch on the indicator. Note the reading when the spring tension overcomes the force of attraction and pulls the probe from the surface.

16.2.2.2 Calibration, Verification, and Adjustment

See the relevant sections in the previous discussion of dial-type instruments.

16.2.2.3 Operating Parameters

Pencil gauges generally measure up to around 25 mils (600 µm) with a tolerance of between +10% to ±15%, therefore they are used less frequently than other types of magnetic instruments. Check with the manufacturer regarding the use and limitations of this instrument.

Again, repeatability of results depends significantly on the operator and technique. Because pencil gauges are less accurate than others, that drawback is also a factor in the repeatability of results.

Question any unusually high or low readings. If the gauge proves to be inaccurate, replace it.

Advantages of pencil gauges include:

- No battery or power source required, therefore intrinsically safe
- Can use on small parts (bolts), hot parts (some models), and in hard-to-reach areas
- Fits in a shirt pocket for quick spot checking

16.3 Type 2 DFT Instruments

Electronic gauges are called Type 2 gauges in both SSPC PA 2 and ASTM D7091 (Figure 16.8). They use a measuring probe and the magnetic induction, hall-effect, and/or eddy current measurement principles in conjunction with electronic microprocessors to produce a coating thickness measurement. It is essential to place the probe directly (in a perpendicular position) on the coated surface to obtain a measurement.

16.3.1 Proper Use

Although electronic DFT gauges come from different manufacturers, the basic procedure for taking measurements is the same. Place the probe against the coated surface and hold it there while the measurement is taken. Lift the probe to relocate and take another measurement. Some gauges have fixed integrated probes, some have separate probes, and yet others have interchangeable integral

and separate probes. The procedure remains the same. The gauge's screen displays the coating thickness.

Figure 16.8 Fischer, Elcometer and Defelsko Dry Film Thickness Gauges

Numerous Type 2 gauge models can store up to 40,000 readings in a number of batches or groups. This capability allows users to take readings in multiple areas and keep them stored separately in distinct batch files for future use. Users can transfer the data to computers and, increasingly, to other digital devices.

Some advanced features are presented later in this section. As always, refer to the manufacturer's model-specific operating instructions for detailed instruction and for features new to the user.

There are numerous standards that govern DFT measurement (Figure 16.9). The most commonly used standards are:

- SSPC-PA 2
- ASTM D 7091
- ISO 19840
- IMO Resolution MSC.216 (82), Annex 3

Check the specification for applicable standards, then consult the manufacturers' data sheet to ensure the gauge complies with the standard. Some gauges have features to automatically determine if the DFT over a large area conforms to certain standards such as SSPC-PA2 or IMO MSC.215 (82) and MSC.216(82) PSPC (performance standard for protective coatings in ballast tanks).

16.3.2 Calibration

Ensure instruments are calibrated only by the equipment manufacturer, an authorized agent, or an authorized calibration laboratory with trained staff working in a controlled environment using a documented process. A certificate of calibration showing traceability to the National Institute of Standards Technology (NIST) can be issued.

16.3.3 Verification of Accuracy

Before using the gauge, verify the calibration accuracy by using it to measure coated thickness standards. Examine the probe for

cleanliness before verifying accuracy and before taking coating thickness measurements using the standards.

If gauge readings taken during verification are outside the combined accuracy of the coating thickness standard and the manufacturer's stated gauge accuracy, return the gauge to the manufacturer or authorized agency for repair and/or re-calibration.

Measure the thickness of a series of reference standards (shims or coated metal plates) that cover the expected range of coating thickness. To guard against measuring with an inaccurate gauge, check the gauge with one or more of the reference standards at least at the beginning and end of each work shift. If the gauge is dropped or suspected of giving erroneous readings during the work shift, recheck its accuracy.

Figure 16.9 Two common types of DFT Reference Standards

16.3.4 Adjustment

'Adjustment' and 'calibration adjustment' refer to the adjustment of a gauge's thickness measurements to match that of a known sample. This is done to improve the effectiveness of the gauge on a specific surface or in a specific portion of its measurement range.

Sometimes gauge readings are influenced by changes in substrate shape, composition, surface roughness, or by changes in measurement location on a part. This is why manufacturers make calibration adjustments possible for Type 2 gauges. If critical DFT measurements are not in the expected range, 1- or 2-point calibration adjustments can be done.

Type 2 electronic gauges have manufacturer-specific methods to make field adjustments. Some gauges have built-in self-adjustment routines or can revert to a standard factory calibration. Newer gauges also have a variety of calibration adjustment methods, each of which can lead to measurement variations. Always adjust gauges according to the manufacturer's instructions and/or in accordance with an agreed-upon procedure.

16.3.4.1 Adjustment Using Nonmagnetic Shims

Adjust Type 2 gauges to account for the profile of the substrate; this allows the gauge to read the coating thickness directly. Use a portion of the substrate, after blast cleaning but prior to coating, to adjust the gauge.

Another method is to use an uncoated test panel (blasted at the time the structure was blast cleaned) with a profile representative of the structure, to adjust the gauge. Note:

ensure the test panel is of material with magnetic and geometric properties similar to the substrate to be measured. If this is not available, apply a correction value to a smooth-surface adjustment, such as that described below.

It is customary to adjust Type 2 gauges for substrate roughness by using plastic shims. Verify shim thickness with a micrometer. Please note: gauge measurements are less accurate when shims are used.

The following are four adjustment examples (some gauges have limited adjustment options):

1. **Single Point Adjustment**

Use a single shim value which is at or close to the upper thickness to be measured. Making an adjustment affects the range of thickness in which accurate measurement is possible. This range varies with gauge design.

If the coating thickness to be measured is 4.0 mil (100 µm), then use a shim of approximately 4.0 to 5.0 mil (100 to 125 µm) to adjust the gauge. Place the shim on an area of the substrate that has been blast cleaned to the required standard, or on a blasted test coupon with a similar shape and surface profile.

Take at least 10 measurements on the shim, then average the results. This is a sufficient number of measurements to allow for statistical variation in the blast profile. Avoid excessive pressure that could bend, indent, or crush the peaks of the shim.

This method ensures that the gauge reads the thickness of the coating over the peaks of the profile.

2. **Two Point Adjustment**

This example uses two shim values: one above and one below the expected film thickness range to be measured.

If the coating thickness to be measured is 4.0 mil (100 µm), then shims of 10.0 mil (250 µm) and 2.0 mil (50 µm) are appropriate to use to set the upper and lower values on the gauge scale. Because protective coatings are normally applied to blast cleaned metal surfaces, a statistical approach must be used to obtain a typical value for the adjustment. Ten measurements on each shim are sufficient to establish a reliable average value for the roughened surface. Follow the manufacturer's instructions for adjusting the gauge to match each shim's thickness value.

This method ensures that the gauge reads the thickness of the coating over the peaks of the profile.

3. **Smooth Surface Adjustment**

Sometimes the bare blasted substrate is not available for measurement. Place the shims on a bare steel plate that has at least 3 x 3 x 0.125 in (7.6 x 7.6 x 0.32 cm) free of mill scale and rust. If the surface of the plate does not have a profile and the coated surface does, estimate an offset value to allow for the profile. This is typically about 0.5 to 0.8 mils (12 to 20 µm) to subtract from the measurements made (as noted in ISO 19840).

4. **Reference Sample**

Another procedure sometimes used is to create a reference sample. Use a small steel sample approximately 6 x 4 in (15 x 10 cm), then blast clean it according to the specification at the start of a project. This panel can then act as the reference panel to check surface profile and DFT gauge measurements. Ensure the panel is made of similar material

(i.e., steel alloy) with a similar shape and thickness to the structure being coated.

16.3.5 Operating Parameters

Various models are available with different measurement ranges. Typical tolerances are between ±1% and ±3% with a resolution of 0.1 mil (2 µm).

As with any DFT gauge, question any readings that are unusually high or low. Check measurements that are outside the normal range. It is not unusual for an occasional measurement to be quite different from others very close to the same location. If a measurement *cannot* be repeated, then discard it as invalid and make an alternative measurement.

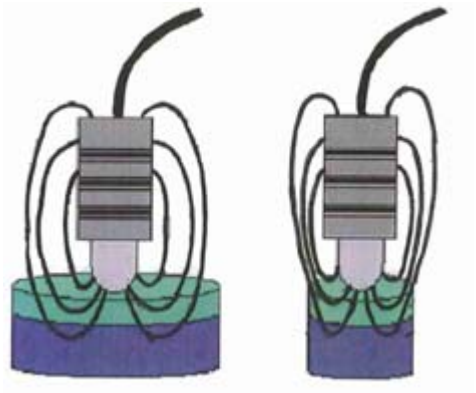


Figure 16.10 Proximity of the Probe to the Edge Can Have an Effect on the Fields Created by the Gauge.

Common errors that may produce inaccurate readings when using this gauge can include:

- Probe **not** placed perpendicular to the surface. Not doing so causes elevated readings (Figure 16.10).
- Failure to make appropriate adjustments for the substrate surface being measured.
- Disregarding the edge effect as defined by ASTM B244; the gauge is sensitive to abrupt changes in surface contour.

16.3.6 Equipment Connectivity

Depending on the manufacturer and model of Type 2 DFT gauges, there are numerous ways to transfer stored data:

- **RS-232 Serial** – Many DFT instruments can connect to computers via high speed data transfer cables. Stored measurements can downloaded directly to the computer for future reference or, sometimes, can connect directly to printers.
- **USB** – Most personal computers and other devices have replaced the serial ports with USBs which provide faster, simpler connections.
- **IR** - Some DFT models can transmit stored measurement data wirelessly for short distances to portable infrared printers.
- **Bluetooth** – Some DFT gauges feature Bluetooth Wireless Technology to transfer data to a PC or other compatible Bluetooth devices such as PDAs.

16.3.7 Software Systems

Some manufacturers have software available to help users quickly and easily transfer measurement data to computers or other digital devices (Figure 16.11, Figure 16.12). The software makes viewing and using the data easy.

The software may allow users to:

- Create a wide range of reports including: individual measurement listings, statistics, histograms, individual line or bar charts, pie charts and more
- Fully customize reports with entry of notes and annotations
- Export reports to spreadsheets, text files, or save as PDF or JPEG files
- Copy and paste reports into other documents

- Combine reports to compare different batches
- Link batches together from different gauges into one comprehensive inspection file
- E-mail reports directly from software
- Assign batch identification tags
- Include company graphics and logos on reports

As always, refer to the manufacturer's operating instructions for a full list of features and operation procedures.

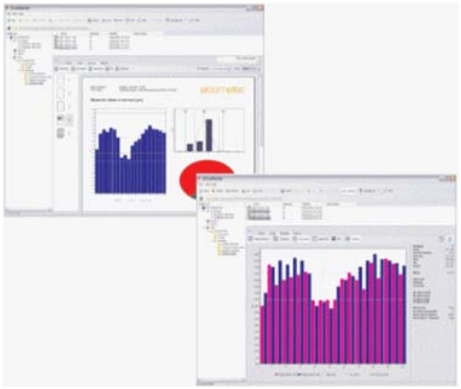


Figure 16.11 Screen Snap-shot of Elcometer ElcoMaster™ Data Management Software

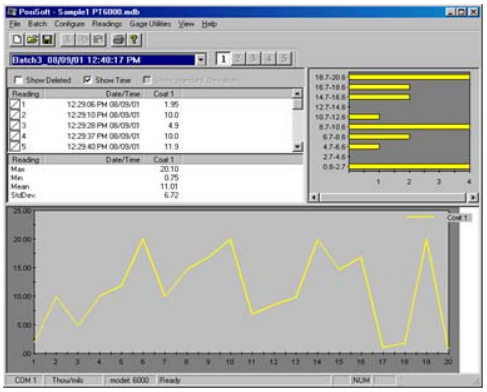


Figure 16.12 Screen Snap-shot of Defelsko PosiSoft Software

16.3.8 Inspection Considerations

Before making measurements with a Type 2 gauge, consider the many factors that influence which gauge to choose and which procedure to use. Factors to consider may include:

- Type of Substrate (Ferrous/Non-Ferrous): Some gauges automatically recognize the substrate and select the correct principle of operation (magnetic or eddy current).
- Anticipated coating thickness range: Gauges have different measurement ranges. Choose the gauge whose measurement range is not only closest to the thickness range needed, but also has optimum accuracy and resolution.
- Specification requirements: Some specifications require special adjustment and measurement procedures, or even state which gauge to use.
- Standards to follow: Depending on some of the factors listed above, reference and follow the specific standards that govern proper calibration, verification, adjustment and measurement procedures.

16.3.9 Inspector's Checklist

Before taking measurements, check the following:

- Is the proper gauge/probe for the substrate easily available?
- Is the gauge/probe appropriate for the anticipated DFT range?
- Are the batteries in satisfactory working condition?
- Has gauge accuracy been checked? Is the calibration adjustment procedure known and understood?
- Has the operations manual for the gauge been reviewed?
- Have the specification and standards that govern how the measurements are taken been reviewed?

16.4 Standards Referenced

16.4.1 SSPC-PA 2 — DFT Measurement with Magnetic Gauges

Various standards define methods of measuring DFT. SSPC-PA 2 and ASTM D 7091 both define similar methods to calibrate, verify, and adjust magnetic-type DFT gauges and to take DFT measurements of nonmagnetic coatings over ferrous magnetic metal surfaces. SSPC-PA 2 is the standard this course examines.

A project specification may, however, require other standards. Inspectors must be careful to use the specified standard. If the specification does not state a required standard, then it is good practice to choose a standard, such as **SSPC-PA 2**, whose guidelines are broadly accepted in the coatings industry (Figure 16.13).

Another option is for the inspector to suggest a standard to follow at the pre-job conference; this way all parties can have a say in the decision.

SSPC-PA 2 requires five spot measurements (a minimum of three **readings** per spot are needed to account for surface irregularities within the 1.5 in [4 cm] circle of the spot; these readings are averaged to arrive at a single measurement) for each 100 ft^2 (10 m^2) measured. Note that individual readings are not subjected to rules but are included in the average for a spot measurement.

The average of the five spot measurements (i.e., at least 15 individual readings) can be **no more** than the specified **maximum** thickness and **no less** than the specified **minimum** thickness.

No single spot measurement can be less than 80% of the specified minimum thickness and no more than 120% of the specified maximum thickness.

Spots->	1	2	3	4	5
Reading 1	7.5	9.2	8.6	8.1	9.6
Reading 2	8.1	9.1	8.7	8.2	9.5
Reading 3	7.7	9.0	8.8	8.3	9.4
Average	**7.8**	**9.1**	**8.7**	**8.2**	**9.5**
				Overall Average =	**8.7**

Figure 16.13 SSPC-PA 2 Measurement Record

Minimum Thickness

The average of the spot measurements for each 100 ft^2 (10m^2) area shall not be less than the specified minimum thickness. No single spot measurement in any 100 ft^2 (10m^2) area shall be less than 80% of the specified minimum thickness (although a single gauge reading may under-run by a greater amount). If the average of the spot measurements for a given 100 ft^2 (10m^2) area meets or exceeds the specified minimum thickness but one or more spot measurements are less than 80% of the specified minimum thickness, the operator may make additional measurements to better define the nonconforming area.

Maximum Thickness

The average of the spot measurements for each 100 ft^2 (10 m^2) area shall not be more than the specified maximum thickness. No single spot measurement in any 100 ft^2 (10 m^2) area shall be more than 120% of the specified maximum thickness (although a single gauge reading may over-run by a greater amount). If the average of the spot

measurements for a given 100 ft^2 (10 m^2) area meets or falls below the specified maximum thickness, but one or more spot measurement is more than 120% of the specified maximum thickness, the operator may make additional measurements to better define the nonconforming area. Consult manufacturers' literature to determine if higher maximum-thickness readings are allowable under specific circumstances.

Area Measured

For areas under 1,000 ft^2 (100 m^2), randomly select and measure three 100 ft^2 (10 m^2) areas. If the DFT in those areas complies with the specified limits, proceed. If not, take more measurements to define the nonconforming area, then begin again.

For areas over 1,000 ft^2 (100 m^2), measure first 1,000 ft^2 (100 m2) described above, and provided DFT is OK for each additional 1,000 ft^2 (100 m^2), randomly select and measure one 100 ft^2 (10 m^2) area.

All of these definitions and procedures may, according to the standard, be varied by agreement. SSPC–PA 2 states:

Other size areas or number of spot measurements may be specified in the procurement documents as appropriate for the size and shape of the structure to be measured.

As with all specified standards, take the time to become thoroughly familiar with this specification (located at the end of this chapter).

SSPC describes two methods of calibration adjustment and defines DFT gauges according to the two methods. Magnetic pull-off DFT gauges are termed "SSPC-PA 2, Type I," while fixed-probe gauges are termed "SSPC-PA 2, Type II."

16.4.2 Other Standards

Another standard, often referenced in specifications, is **ASTM D 7091**, **"Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals."** Like SSPC-PA 2, this standard describes the measurement of the thickness of nonmagnetic coatings applied to ferrous metal substrates as well as nonmagnetic, nonconductive coatings applied to nonferrous metals. Another standard that may be specified is BS 3900, "Methods of Test for Paints, part C5."

Whatever standard method is used, it is imperative to record the correct number of measurements. The inspector may use a figure similar to the following:

7.7 Inspection – DFT Measurements (*Type 1 Gauge*)

Calibration Standard Used: Test Block ☐ Plastic Shims ☐							
Adjustments for BMR and Gauge Deviations							
Spots →	1	2	3	4	5	Test Block Value	Gage Reading on Test Block
BMR							
Average BMR Adjustment							
Adjustment for Gauge Deviation							
Total Adjustment for BMR & Gauge Deviation							

Primer DFT Specified	Min. DFT ____	Max. DFT _____				
Spots →	1	2	3	4	5	Primer DFT Average of Spots ↓
1						
2						
3						
Avg. Before Adjustments						
Avg. After Adjustments						

Total System (Primer + Topcoat) DFT Specified	Min. DFT_____	Max. DFT _____				
Spots →	1	2	3	4	5	Total System DFT Average of Spots ↓
1						
2						
3						
Avg. Before Adjustments						
Avg. After Adjustments						

Evaluation of DFT for Spot Measurements (SM's)			
	Minimum SM	Maximum SM	Average of SM's
Primer	_____mils/µ	_____mils/µ	_____ mils/µ
Total System	_____mils/µ	_____mils/µ	_____mils/µ
Conforms to Specification	Yes / No	Yes / No	Yes / No

Figure 16.14 DFT Data Collection Chart

It is helpful, when nonconforming areas are found, to physically mark areas where the coating is either too thick or too thin. This can be done by applying a contrasting color of the same coating, but never make marks that could damage the coating. Ensure the method to mark coating deficiencies is agreed upon during the pre-job conference.

International Maritime Organization (IMO) Resolution MSC.216(82), Annex 3, Dry Film Thickness Measurements

The new IMO[1] standard details a specific methodology to collect DFT measurements. It requires the following DFT verification measurements to be taken:

Surface measurements:

- One gauge reading per 50 ft^2 (5 m^2) of flat surface area
- One gauge reading at 6.5 to 10 ft (2 to 3m) intervals, and as close as possible to tank boundaries, but not further than 0.6 in (15 mm), from edges of tank boundaries

Longitudinal and transverse stiffener members:

- One set of gauge readings taken at a 6½ to 10 ft (2 to 3m) run and not less than two sets between primary support members, as shown in Figure 16.15
- Three sets of gauge readings for each set of primary support members and two sets of gauge readings for each set of other members, as indicated by the arrows in the diagram
- For primary support members (girders and transverses), one set of gauge readings for a 6.5 to 10 ft (2 to 3m) run but not less than three sets
- Around openings, one gauge reading from each side of the opening
- Five sets of gauge readings per square inch (in^2) (square meter [m^2]) but not less than three gauge readings taken at complex areas (i.e., large brackets of primary support members)

Take additional spot checks to verify coating thickness for any area considered necessary by the coating inspector.

1. International Maritime Organization (IMO), 4 Albert Embankment, London, SE1 7SR, United Kingdom.

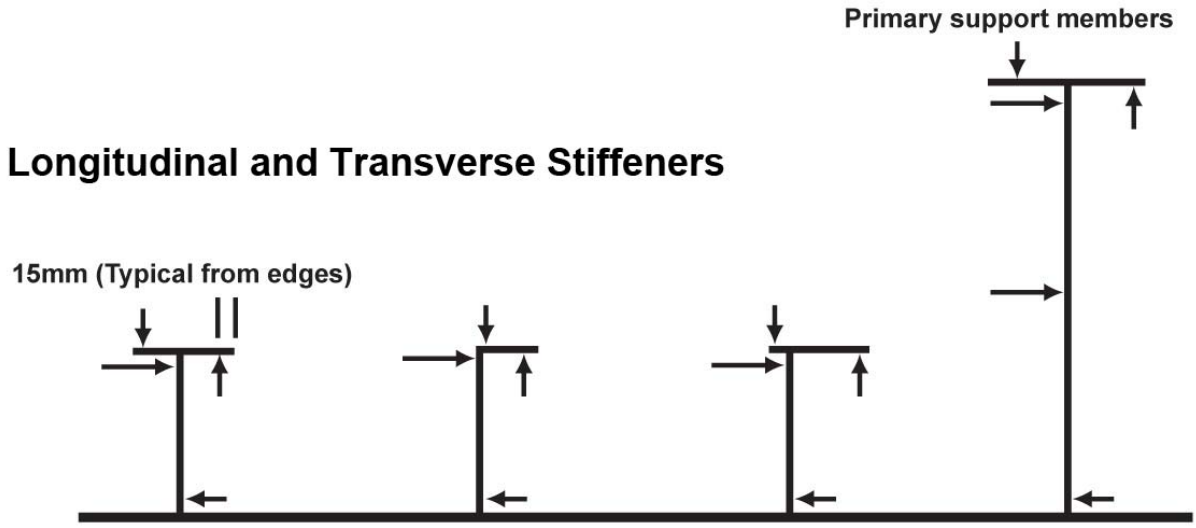


Figure 16.15 Readings at Longitudinal and Transverse Stiffener Members

Key Terms Definitions

BMR (Base Metal Readings): To adjust for surface roughness, measure the blast profile of the steel to be painted at a number of spots to obtain a representative average value. This average value is the base metal reading (BMR).

DFT Gauge (Type 1): Type 1 instruments are described as magnetic pull-off gauges. The force required to pull a magnet from a ferrous surface is used to determine the film thickness.

DFT Gauge (Type 2): Type 2 instruments are electronic gauges. They use electronic circuitry to convert a reference signal into coating thickness.

Wet Film Comb: Instrument used to measure film thickness. The comb is pushed into the film. Upon removal, the thickness measure is shown on the gauge.

Chapter 17: Coating Film Thickness Measurement Instrumentation - Practice Lab

Coating Film Thickness Measurement Instrumentation

This lab builds on the previous chapter as the instructor demonstrates each instrument and provides the necessary material required to perform each test. Each student will have hands-on practice with the instruments.

Note: the practical math self-study exercise is located in the appendix.

Station 1: Coating Thickness

Magnetic Pull-Off Gauge (Type 1)

Equipment:

- Type 1 DFT gauge
- Test panel
- Coating thickness standards (test blocks): range 0 - 40 mils (0 to 1,000 µm)
- Plastic shims
- Anvil micrometer
- Operating instructions
- Copy of SSPC-PA2 Standard

Assignment: Check the gauge (use the method defined in SSPC-PA 2): (1) determine the DFT of the two coated areas of the panel in mils or µm and (2) provide the four answers required.

Adjusted Readings:

	Mils		Microns	
BMR				
PRIMER DFT				
Final (total) DFT				
Circle Calibration standard used?	Test Blocks	Plastic Shims	Test Blocks	Plastic Shims

Work areas for measurements and calculations below:

Adjustments for BMR and Gauge Deviation								
Spots->	**1**	**2**	**3**	**4**	**5**		**Test Block Value**	**Gauge Reading on Test Block**
BMR								
Average BMR Value Adjustment =								
Total Adjustment for Gauge Deviation								
TOTAL ADJUSTMENT for BMR and Gauge Deviation								

For Primer Measurements:

	Spots->	1	2	3	4	5	
PRIMER	1						PRIMER DFT Average of the Spots
	2						
	3						
	Average Before Adjustments						
	Average After Adjustments						

For Final (total) DFT Measurements (includes primer + finish coat):

	Spots->	1	2	3	4	5	
FINAL (Primer + Finish Coat)	1						FINAL (total) DFT Average of the Spots
	2						
	3						
	Average Before Adjustments						
	Average After Adjustments						

Station 2: Coating Thickness: Magnetic DFT (Type 2)

Equipment:

- Electronic DFT gauge
- Test panel
- Coating Thickness standard (test blocks): range 0 to 1,000 µm (0 to 40 mils)
- Plastic calibration shims

Assignment: Check the gauge (use the method defined in SSPC-PA 2):(1) determine the DFT of the two coated areas of the panel in mils or µm and (2) provide the four answers required.

Adjusted Readings:

	Mils		Microns	
BMR				
PRIMER DFT				
Final (total) DFT				
Circle Calibration standard used?	Test Blocks	Plastic Shims	Test Blocks	Plastic Shims

Work area for measurements and calculations below.

Adjustments for BMR and Gauge Deviation								
Spots->	1	2	3	4	5		Test Block Value	Gauge Reading on Test Block
BMR								
Average BMR Value Adjustment =								
Total Adjustment for Gauge Deviation								
Total Adjustment for BMR and Gauge Deviation								

For Primer Measurements:

	Spots->	1	2	3	4	5	
PRIMER	1						PRIMER DFT Average of the Spots
	2						
	3						
	Average Before Adjustments						
	Average After Adjustments						

For Final (total) DFT Measurements (includes primer + finish coat):

	Spots->	1	2	3	4	5	
FINAL (Primer + Finish Coat)	1						FINAL (total) DFT Average of the Spots
	2						
	3						
	Average Before Adjustments						
	Average After Adjustments						

Station 3: Wet Film Thickness Gauges

Equipment:

- WFT Comb (2)

Assignment: Use the instruments provided to: (1) determine the WFT of the material applied, (2) calculate DFT, then (3) fill in the tables below. Volume Solids = 55%

WFT Measurements:

	WFT Gauge #1	WFT Gauge #2
WFT Measurement		

Determine the likely DFT of the applied coating (DFT = WFT x Volume Solids);

	WFT Gauge #1	WFT Gauge #2
Estimated DFT		

Answer only one of the following questions: use either Metric or Imperial units.

Question A (Metric)	Answer
The following technical data is provided for a given coating: Recommended DFT = 125 µm, solids by volume = 55%, thinner added = 10% The applicators must apply the coating to 500 m^2 and anticipate 20% loss. How many liters should they order?	Liters

Question A (Imperial)	Answer
The following technical data is provided for a given coating: Recommended DFT = 5 mils, solids by volume = 55%, thinner added = 10% The applicators must apply the coating to 5,000 ft^2 and anticipate 20% loss. How many US gallons should they order?	Gallons

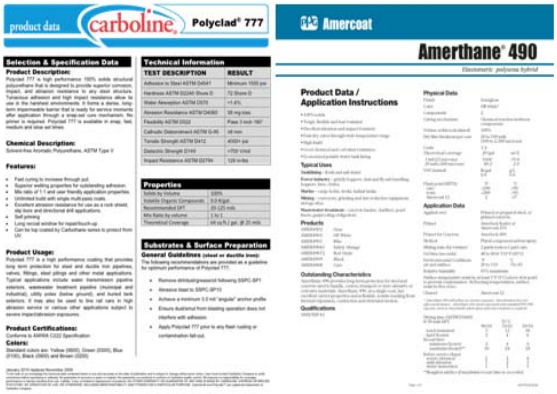
Chapter 18: Product Technical Data Sheets and Material Safety Data Sheets

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Product technical data sheets
- Material safety data sheets
- HazComm
- Inspection considerations

18.1 Product Technical Data Sheets


product data carboline Polyclad® 777

Selection & Specification Data

Product Description:

Chemical Description:

Features:

Product Usage:

Product Certifications:

Colors:

Technical Information

TEST DESCRIPTION	RESULT
Adhesion to Steel ASTM D4541	Minimum 1500 psi
Hardness ASTM D2240 Shore D	72 Shore D
Water Absorption ASTM D570	<1.8%
Abrasion Resistance ASTM D4060	58 mg loss
Flexibility ASTM D522	Pass 3 inch 180°
Cathodic Disbondment ASTM G-95	48 mm
Tensile Strength ASTM D412	4320+ psi
Dielectric Strength D149	>700 V/mil
Impact Resistance ASTM D2794	128 in-lbs

Properties

Solids by Volume	100%
Volatile Organic Compounds	0.0 lb/gal
Recommended DFT	20-125 mils
Mix Ratio by volume	2 to 1
Theoretical Coverage	64 sq ft/ gal. @ 25 mils

Substrates & Surface Preparation

General Guidelines (steel or ductile iron):

Amercoat

Amerthane® 490

Product Data / Application Instructions

Physical Data

Typical Uses

Application Data

Products

Outstanding Characteristics

Qualifications

Figure 18.1 Product Data Sheet from several major Coatings Manufacturers

Coatings Product Data Sheets (a coating's specification commonly called a *Product Data Sheet*) provide users with valuable information about application of the product (Figure 18.1). They provide the technical facts and application properties of the coating. Often, there is also a small section on safe use of the product.

Important physical properties such as flash-point temperature and volume solids content are listed and can help establish safe storage and/or working conditions. This is usually a very brief section; use this section as a substitute for the MSDS, which also is covered in this chapter.

Product data sheets are an important part of the project specification and should not be pushed aside because the specification carries more weight. Though product data sheets are limited in overall scope, in some cases, it *is* the specification.

Many owners and general contractors try to keep things simple and only reference the product data sheet as the ultimate coatings project specification. If this happens, the inspector should understand the limits of product data sheets and bring the topic up for discussion during the pre-job conference.

In the pre-job conference, it is important to discuss differences between the product data sheet and the specification. Keep in mind that it may not be possible to change the process, but at least this gives everyone involved a heads-up on the situation. Inspectors need to have the product technical data sheet and thoroughly review it prior to the pre-job conference.

Like a well-written MSDS, this document is also broken down into various sections but is less technical in its language, making it easier to read. There are as many variations in

product data sheets as there are in MSDS and their content varies from country to country.

A product data sheet written for use in a country in Africa may be quite different than the one written for the same product in the US or Europe. Though not very common, it is possible to see a single page product data sheet that only gives the name of the product with very little additional information. However, product data sheets issued by most major coating manufacturers have significant similarities.

The key point is inspectors need to have a thorough understanding of the product that is being used on a project. This means the inspector may need to communicate directly with the manufacturer on items needing clarification.

Most well written product data sheets will include the following sections:

- Generic type
- Description
- Features
- Color
- Finish
- Dry film thickness
- Solids contents
- Theoretical coverage rate
- VOC values
- Curing schedules
- Performance data
- Approvals and certificates
- Description on how to use the coating, including recommended primers and/or topcoats
- Recommendations for application method and equipment, including brush, roller, conventional spray, and airless spray, as appropriate
- Mixing and thinning
- Cleanup and safety
- Packaging
- Handling and storage
- VOC
- Recommended DFT and WFT
- Theoretical and practical coverage
- Shelf life, pot life and induction time (as the time/temperature are related)

Coatings inspectors *should always consult product technical data sheets* because they are an essential part of the coatings project. In many instances, the inspector may come across discrepancies between the project specification and the product data sheet. When this happens, contact the owner of the specification for clarification. In general, it is not the inspector's job to authorize changes. *Regardless of what the product sheet may say, the specification is the overriding document on any project unless changes are made in writing by an authorized person.*

The inspector and owner should also keep in mind that when a requirement is stated in a product data sheet and it is not adhered to in the specification (for whatever reason), the manufacturer may choose not to warranty product performance. In addition, technical data for quality control is largely stated in the specification. Hence, specification writers should work closely with manufacturers to avoid those situations.

Most contractors want to do a good job. However, due to the competitive nature of the bidding process, undue pressure is put on contractors. Although the information in

product data sheets is generally clearly stated, experience shows that some applicators often appear to overlook fundamental data. Below is a list of the areas that are most commonly overlooked:

- Surface preparation
- Storage
- Mixing and thinning (Figure 18.2)
- Application procedure
- DFT requirements

In summary, the importance of a thorough understanding **cannot be over emphasized**.

Figure 18.2 Mixing

18.2 Material Safety Data Sheets (MSDS)

The MSDS is a document/form containing data regarding the properties of a particular substance. It is intended to provide workers and emergency personnel with critical information on composition, handling, or working with that substance in a safe manner.

The MSDS includes information such as melting point, boiling point, flash point, toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill handling procedures.

The exact format of an MSDS can vary from source to source within a country depending on how specific the national requirement is. In most countries, legislation is in place to protect workers against the unknown risks of using toxic or hazardous materials. Information regarding the safety issues associated with any hazardous (or potentially hazardous) material must, by law, be provided to users, usually by means of the MSDS.

MSDSs are a widely used system to catalog information on chemicals, chemical compounds, and chemical mixtures. As such, MSDSs play a vital role in the protective coatings industry and their importance should never be overlooked. It is important to use a MSDS that is both country-specific and supplier-specific. The same product (e.g., paints sold under identical brand names by the same company) can have very different formulations in different countries. A product using a generic name like Epoxy Mastic can also have a formulation and degree of hazard which varies between different manufacturers in the same country. In some jurisdictions, the MSDS is required to state the chemical's risks, safety, and impact on the environment, while in other jurisdictions it may only address health-related issues.

Any manufacturer of potentially hazardous substances **must** provide information to anyone who might be exposed to the hazard that describes the potential problems, and provides instructions to minimize hazardous exposure. MSDSs also provide instructions for the correct action to take in the event of explosion, fire, or hazardous exposure.

These information sheets are likely to be different in various countries and may be known by different names. Whatever the name, the information is likely to be similar for coating or paint materials. In the United

Kingdom, for example, safety data is provided on a Control of Substances Hazardous to Health (COSHH) sheet.

It is **very important** that inspectors not only ask for but receive MSDSs for all chemicals in use on any given project. If a supplier cannot, or refuses, to provide an MSDS for a given product, the inspectors should *immediately contact their supervisor* for further guidance. MSDSs are now commonly available on the web, but because there may be minor changes to formulations, inspectors need to ensure they have the most recently updated MSDSs.

The United Nations (UN) defines certain details used in MSDSs, such as the UN numbers (in a standard format), that are used to identify some hazardous materials while in international transit. More information about this is located in the upcoming Section 18.4 HazComm.

In the coating industry worldwide, MSDSs generally follow the outline determined by American National Standards Institute (ANSI) in standard ANSI Z400.1.

18.3 Understanding the MSDS

As previously stated, MSDSs are prepared and supplied by material manufacturers to inform users of any potential hazards of that product. They also list the proper action to take in the event of a spill, fire, or hazardous contact.

The ANSI MSDS format, noted above as one of the most commonly used worldwide, is divided into sixteen sections or categories of information. The sections are listed below:

- Identification of the chemical product and company
- Composition (information on ingredients)
- Hazard identification
- First aid measures
- Firefighting measures
- Accidental release measures
- Handling and storage
- Exposure controls and personal protection
- Physical and chemical properties
- Stability and reactivity
- Toxicological information
- Ecological information
- Disposal considerations
- Transport information
- Regulatory information
- Other information

While all workers should read and understand the MSDS for the product they are using, it is still very common to find applicators or coatings inspectors who do not do this. However, most applicators know exactly where they are located on a job site. Knowing the location of the MSDS, however, does not convey knowledge or foster understanding.

Compounding the problem is the fact that the MSDSs use complex chemical names, abbreviations, and acronyms which makes the data very difficult to read, even for experienced and knowledgeable readers. Because of this, most workers feel intimidated to ask for clarification and this poses an even greater risk.

If the MSDSs were written using symbols and clear diagrams, there might be increased interest in reading and understanding the contents. Coatings inspectors should do whatever is needed to understand the MSDS and keep a copy on hand at all times while

on a project. If any section is not easy to understand, seek further advice. Because knowledge and understanding of these documents directly affects the safety of all workers, **always report** unsafe practices when they are found.

MSDS sheets are, of course, produced in various languages and designed to meet local regulations and larger paint companies may produce differing versions of their MSDSs. However, the regulations referenced are likely to be those of the country of origin and not necessarily the location of coating application. Some countries are now requiring MSDSs to be in local language before paint/coatings products can be imported.

18.4 HazComm

When coating materials are being transported, there is a constant risk of spills or exposing others to potentially toxic chemicals. Laws in some countries require that MSDS sheets are carried by transporters whenever industrial quantities of coatings are moved by road, rail, or air. Most people are familiar with the multicolored hazard identification signs on trucks or rail cars, depicting explosion or toxic hazard categories for the product. The same warning signs can sometimes also be seen on paint cans.

The purpose of such hazard communication is to inform emergency services of potential hazards if there is a spill, fire or some other accident. In the US, MSDS are also required to provide a 24-hour emergency telephone number to link first responders to a live source of specific information regarding the particular product.

Chemicals commonly used and judged to be hazardous are listed by various industry organizations or national authorities.

Information on the chemicals is freely available on the web. For example, the National Occupational Health and Safety Commission of Australia (NOHSC) provide a database of hazardous chemicals at *www.nohsc.gov.au*. Another authoritative source is the American Council of Government Industrial Hygienists (ACGIH), which publishes many volumes concerned with hazardous chemicals; their website is *www.acgih.org*.

Regardless of the source of the information, chemical listings use the universally applied Chemical Abstracts Service (CAS) number from which the properties of the chemical can be determined. This enables emergency services to determine the best course of action.

The CAS database (*www.cas.org)* contains more than 22 million chemical substance records. More than 200,000 chemical substances in the CAS lists are identified on national or international chemical inventories and regulatory lists.

An international collaboration resulted in the creation of the International Chemical Safety Cards, published generally by the World Health Organization. They are made available in the US by the National Institute for Occupational Safety and Health (NIOSH) at *www.cdc.gov/niosh*. Many of the chemicals judged to be potentially hazardous, toxic, or harmful to workers are found in the coatings industry. Significant changes to the formulations of coating materials have been made as a result of the grow-

ing lists of chemicals hazardous to health as reported by various medical research bodies.

18.5 Inspection Considerations

Like the project specification, the coating inspectors must make it their responsibility to read and have a good understanding of the MSDS and Product Data Sheets, just as they must with project specifications. All contain valuable information that is critical to a safe and high quality project. **Remember, during pre-job conferences, inspectors should make every effort to ask any questions they may have regarding these documents**.

Study Guide

1. Coatings Product Data Sheets (a coating's spec) provide users with the following:

_____
_____
_____
_____
_____

2. MSDS contains the following:

_____
_____
_____
_____

Chapter 19: Lab Day Specification

Coating Specification ARC-CS2

For Lab Day Panels – NACE International

General Scope

This section describes the work to be done, when, and where it will be done. This specification is intended for use by the owner and appointed contractors who work directly or indirectly for the company (owner).

The contractor shall clean and repaint the exterior surfaces of tanks numbered tank #1642 (10,000 bbl), and tank #1626 (7,500 bbl), and shall furnish, at his or her cost, all labor, supervision, equipment, and materials as necessary to perform the work. Consult the attached shop drawing (plate #32, dated August 21, 2009 prepared by Echo Engineering Co.) for location of the above described tanks and appurtenances.

All instruments, recorders, gauge glasses, and galvanized surfaces associated with the tanks shall be protected throughout the work and protected against damage or over-coating.

The project is scheduled to commence operations within 270 days from the date of this tender proposal. The owner will conduct an inspection of the facilities to be painted and will hold a pre-tender meeting of all prospective tender submitters on site at 14:00, October 26, 2009. Tenders will be due on or before 14:00, November 5, 2009, and the contractor will be required to commence work on or before April 19, 2010. All coating work covered by this specification must be completed on or before June 21, 2010, subject to a penalty of $5,000 for each day completion of the job is delayed beyond June 21, 2010.

The owner has inspected these tanks and believes there is no lead in the existing paint on these tanks.

Echo Engineering Co., Boulder, NC is the designated representative responsible for all aspects of this coating project, entitled job #RP-16378. For additional information on this project, contact Mr. James Glenn, project engineer, Echo Engineering Co., (666) 213-8000.

All work shall be subject to inspection by the owner, but this in no way reduces the responsibility of the contractor to comply with the technical requirements of the specification.

Terms and definitions

The words shall, will, shall not, will not, should, and may are to be found in the body of this document and are used to signify the following:

- The words **shall** and **shall not** are used where a provision is mandatory, and the contractor must comply with that part of the specification as written.
- The word **should** is not obligatory and is used where a provision is preferred and indicates a strong recommendation to the contractor to fulfill that part of the specification.
- The word **may** is used where alternatives are acceptable; the contractor has options and should choose his or her preferred option.

- The words **will** and **will not** are used in connection with an action of the owner rather than of the contractor.

Owner means the registered owner of the facility, or his or her designated representative.

Applicator/contractor means the successful tender submitter responsible for doing the coating work.

Foreman means the applicators' representative on site who is the responsible party for the contractor.

Inspector means the person designated to carry out the inspection procedures according to the specification.

Specifying engineer means the person with the authority to resolve non-conformance or make changes to the specifications.

Specifier means the person who drafted the specifications. He or she may or may not also be the specifying engineer.

Coating manufacturer means the supplier of the coating materials used on the project, or a designated representative.

19.1 Reference Standards

19.1.1 American Society for Testing and Materials (ASTM)

- ASTM D 3925 (1991) *Sampling Liquid Paints and Related Pigmented Coatings*
- ASTM D 4285 (1993) *Indicating Oil or Water in Compressed Ai*r

19.1.2 Code of Federal Regulations (CFR)

- 29 CFR 1910.134 *Respiratory Protection*
- 29 CFR 1910.1000 *Air Contaminants*
- 29 CFR 1910.1200 *Hazard Communication*

19.1.3 Federal Standards (FED-STD)

- FED-STD-595 (Rev. B) C*olors Used in Government Procurement*

19.1.4 NACE International — The Corrosion Society (NACE)

- NACE Standard RP0287 (1995) *Standard Recommended Practice Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using a Replica Tape*

19.1.5 SSPC —The Society for Protective Coatings (SSPC)

- SSPC Guide to VIS 1 (1989) G*uide to Visual Standard for Abrasive Blast Cleaned Steel*
- SSPC-VIS 1 (1989) *Visual Standard for Abrasive Blast Cleaned Steel (Standard Reference Photographs)*
- SSPC-SP COM (1995) *Surface Preparation Commentary*
- SSPC-SP 1 (1982) *Solvent Cleaning*
- SSPC-SP 10 (1991) *Near-White Blast Cleaning*
- SSPC-PA 1 (1991) *Paint Application Specification No. 1, Shop, Field, and Maintenance Painting*
- SSPC-PA 2 (1997) *Measurement of Dry Paint Thickness with Magnetic Gages*

19.1.6 International Organization for Standardization (ISO)

- Sa 2 ½ V*ery Thorough Blast Cleaning*

19.2 Safety

All persons involved in this project shall follow all appropriate safety rules, including those defined at the pre-job meeting. Safety rules shall include, but shall not be limited to:

1. Use of breathing apparatus in accordance with 29 CFR 1910.134 (owner may require respirator fitting for all contract personnel).
2. Air monitoring posts shall be established around the work area, and the air shall be monitored for fugitive emissions, in accordance with 29 CFR 1910.1000 (Air Contaminants).
3. Warning signs shall be posted around the perimeter of the blast area, and information provided in accordance with 29 CFR 1910.1200 (Hazard Communications).
4. Use of protective clothing in contrasting but identifying colors as to class of personnel, such as: refinery personnel (owner's personnel) — blue; paint contractor's personnel — orange; other contract personnel — yellow.
5. Special work permits are required for some plant areas, such as confined spaces; such permits usually are valid only for an 8-hour shift and may require a standby worker outside the confined space at all times. Work permits must be obtained from the safety department prior to commencement of work.
6. Contractor must prepare a written safety plan, with details of all specific safety requirements, including identification of safety equipment and safe havens to be used in the event of emergencies.
7. Contract personnel are required to attend a company-sponsored safety school and successfully pass an examination based on site-specific safety issues prior to working on this site.

19.3 Pre-Job Conference

This specification, together with all relevant job standards for surface preparation, primer, top-coating, and inspection shall be reviewed at a pre-job conference (meeting) of all site-based persons involved in this coating project, prior to any other work being performed.

The pre-job conference shall be held prior to commencement of work, at a time to be mutually agreed. The contractor shall provide no less than 48-hours notice of the pre-job conference meeting to the owner.

A record of the meeting shall be made and submitted to all participants, and to the engineer.

19.4 Coating Materials

Coatings shall be as specified in Table 1.

Materials shall be delivered to the site in the manufacturer's sealed containers bearing the manufacturer's labels identifying the type, color, and batch number.

All materials used on the project shall be from the same manufacturer. For multi-coat systems, each coat shall be of a contrasting color. The color of the penultimate coat shall be chosen to ensure that the last coat achieves adequate hiding power and provides a solid and consistent visual appearance.

Materials shall be stored in a space designated by the owner or engineer; the space shall be kept neat and clean with temperatures of no less than 59°F (15°C) and not more than 90°F (32°C). Any damage to the space or its surroundings caused by the contractor shall be made good by the contractor at his own expense.

19.5 Surface Preparation

The contractor shall place a protective cover over all parts of the project engineer's Rolls-Royce motor car during all phases of the coating project and shall remove this cover

only at the request of the project engineer. The contractor should cover all other cars in the vicinity of the coating project. The contractor may use 8.0 mil (200 μm) plastic sheeting or 20 oz (0.62 gm/cm^2) canvas cloth to cover the project engineer's Rolls-Royce.

Pre-Cleaning. Contaminants such as oil, grease, dirt, etc., shall be removed by solvent cleaning in accordance with SSPC-SP 1 (on surface preparation by solvent cleaning).

All welds shall be cleaned of rust, slag, and adherent mill scale, and all weld spatter shall be removed, in accordance with SSPC-SP 2, "hand tool cleaning," or SSPC-SP 3, "power tool cleaning."

Any fabrication defects that are located after cleaning shall be corrected as necessary with the approval of the engineer.

Prepare the clean, dry surfaces by abrasive blasting using Dupont Starblast #6™ in accordance with surface preparation standard NACE No. 2/SSPC-SP 10, *Near-white metal blast cleaning*.

For work that takes place off site, in any European location, the blast cleaning standard may be changed to the equivalent standard ISO 8501-1, Sa2½, *Very Thorough Blast Cleaning*.

The front face of any panels or sections with angle iron stiffeners or protrusions shall be abrasive blasted to a white metal finish in accordance with NACE No. 1/SSPC-SP 5 or, where appropriate, ISO Sa3.

Only clean dry air shall be used for blast cleaning. The quality of blasting air shall be verified at least once each day in accordance with ASTM D 4285.

Blast cleaning shall achieve a surface profile (also called anchor profile) of 1.5 to 3.0 mil (38 to 75 μm) as determined by NACE Standard RP0287, *Field Measurement Of Surface Profile Of Abrasive Blasted Steel Using Replica Tape.*

After surface preparation of the substrate, grit, dust, or other surface contamination shall be removed and the first coating (primer) applied within four (4) hours of completion of blasting or before any detrimental corrosion or recontamination occurs.

Venturi nozzles shall be discarded when worn such that the internal diameter is 20% or greater than when new or when the nozzle has worn one size from the original diameter size, e.g., if a #6 nozzle in use wears to a #7 it shall be discarded.

Blast cleaning shall not be performed when the surface is wet, when surface temperature is less than 5°F (3°C) above the dew point, or when relative humidity is higher than 85%.

19.6 Coating Application

All traces of abrasive and other debris shall be removed prior to any coating operation.

All welds, corners, and edges (except outer edges on individual steel plates) shall receive a stripe coat of primer applied by brush. Stripe coats work out better when they're color contrasted.

All coating application shall be by conventional air-spray or airless spray in accordance with the manufacturer's current recommendations and consistent with local regulations.

Total system DFT shall be 9.0 to 12 mils (225 to 300 µm).

All other DFT measurements shall comply with the limits stated in Table 1.

Dry-film thickness (DFT) shall be measured in accordance with SSPC-PA 2.

The manufacturer's stated overcoat intervals shall be observed for all coatings, taking into account the ambient temperature during drying and curing.

19.7 Sampling Coatings

A representative sample of each batch of all coatings used shall be collected and retained in accordance with ASTM D 3925. Samples may be partial retains (0.5 pint to 1 quart U.S. or 250 mL to 1 liter metric) or complete and unopened containers (1 or 5 gallon, [5 or 20 liter units]). The contractor shall be responsible for collection, and witnessing of the collection process by the inspector is mandatory. The sampler should use only clean containers when taking partial samples to avoid contaminating the sample.

All samples shall be unmixed. Where multicomponent coatings are used, samples of each component are required.

Sample containers shall be labeled and clearly marked with details of the material, the date of sampling, the batch number, and the identity of the person collecting the sample. Where possible, the date of manufacture shall also be recorded on the sample label.

Samples shall be stored in a cool dry place for at least two years after collection. The owner may request samples for testing at any time during the storage period.

19.8 Workmanship

All work shall be performed in strict accordance with these specifications and the coating manufacturer's current printed instructions and/or Tech Data sheet for materials to be used on this project. Work shall be performed by skilled workmen in a safe and workmanlike manner.

Application shall be in accordance with the principles of good workmanship described in SSPC-SP 1.

Operators working on this project shall be qualified according to ASTM D 4227 or D 4228 or to the NACE International *Guide to Qualification of Industrial Maintenance Painters.*

19.9 Work Schedule

Contractor shall prepare a written work schedule describing the timeline of the project. The scheduled times should include completion of at least these items:

- Pre-cleaning
- Surface preparation
- Coating application
- Inspection intervals and hold points
- Delivery of documentation and reports
- Hold points

19.10 Repair and Remedial Coating Work

Contractor shall identify damage to the coating, including holidays, and shall repair all such areas.

Contractor shall feather-edge the coating around the damaged area for a minimum of three (3) inches (75 mm) from the damaged area in all directions. Contractor shall use 80-grit abrasive-coated paper to expose each

coat of the coating system, including the primer.

Using the same coating materials required by the specification as the repair materials, the contractor shall apply, by brush, the same number of coats as is found in the repair area. Total thickness of the repair shall be no less than 90% of the total thickness of the adjacent undamaged coating.

19.11 Documentation

The Inspector shall keep a complete record of all tests performed using the NACE Coating Inspection Daily Report Form provided with this specification document.

The inspector shall complete a summary report of tests performed using the CIP practice project report book issued at the pre-job conference.

The completed CIP practice project report form shall be reviewed by the engineer and countersigned to indicate that review has been performed. The NACE Coating Inspection Daily Report Form shall be completed and submitted to the engineer on a weekly basis.

19.12 Inspection and Reporting

The inspector shall perform such tests as are required to ensure performance of this specification, and such tests as may be required from time to time by the engineer.

Inspection is an ongoing, continuous process. Safe access to all work locations shall be provided whenever the engineer or his designated representative so requires.

Pre-inspection: All surfaces will be inspected prior to any other operations. All defects in design and fabrication will be located and reported.

Surfaces shall be inspected for the presence of oils and greases using an Underwriters Laboratories (UL)™ approved ultraviolet lamp. Areas contaminated with oil and grease shall be located and recorded. Oil or grease contamination shall be removed by solvent cleaning in accordance with SSPC-SP 1 using a biodegradable detergent.

Specific test instruments and test procedures shall include, but not be limited to, the following. The inspector shall conduct any additional inspection tasks outlined and agreed to by the parties concerned at the pre-job conference:

1. Environmental Conditions
   - Magnetic steel surface thermometer
   - Sling psychrometer and psychrometric charts
2. Surface
   - Surface comparators (ISO and Keane-Tator
   - Textex™ replica tape
3. Coating
   - WFT gauge (comb type)
   - DFT gauge (Positector 6000™, Mikrotest III,™ or approved equivalent)
   - Holiday detectors (low-voltage wet sponge or high-voltage pulsed DC, as appropriate)
4. Equipment and air supply
   - Blotter test
   - Hypodermic needle pressure gauge
5. Abrasive
   - Sieve test
   - Vial test
6. Inspection Procedure
   The contractor shall prepare an inspection procedure for all quality control

testing to be performed. The procedure shall include, as a minimum, the following items:

- When, where, and how many measurements to take
- Pass/fail criteria for all measurements
- What inspection tools to use
- Guidelines for completion and submission of inspector's reports
- A comprehensive statement of the inspectors's reports
- An organizational chart showing the chain of command and the inspector's position

Table 1: Coatings

Item	Generic Description	International Paint	Carboline	Ameron
First Coat (DFT: min/max) [Color]	Water-borne Zinc-rich primer [Gray]	Interzinc 280 (2.5/3.5 mils, 62/87 µm) [Gray/Green]	Carbozinc 11[a] **(2.0/3.0 mils, 50/75 µm)** [gray]	Dimetcote 21-5 (2.5/3.5 mils, 62/87 µm) [Gray]
Second Coat (DFT: min/max) [Color]	Water-borne epoxy high-build [White]	Intergard 401 (3.0/5.0 mils, 75/125 µm) [off-white]	Carboline 890[b] **(4.0/6.0 mils, 100/150 µm)** [white]	Amercoat 385[c] **(4.0/6.0 mils, 100/150 µm)** [white]
Third Coat (DFT: min/max) [Color]	Urethane finish [Blue]	Interthane 870 (2.5/4.0 mils, 62/100 µm) [Blue]	Carbothane 833 **(3.0/5.0 mils, 75/125 µm)** [Blue]	Amercoat 450HS **(2.0/3.0 mils, 50/75 µm)** [Blue]

a. Carbozinc 11™ is not water-borne zinc
b. Carboline 890™ is not water-borne epoxy
c. Amercoat 385™ is not water-borne epoxy

Chapter 20: Coating Defects

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Non-drying film
- Blushing
- Runs, sags, curtains, and wrinkles
- Discontinuities, skips, holidays, missed areas
- Chalking
- Cratering
- Air Voids
- Pinholing
- Discoloration/staining
- Heat-related damage
- Blistering
- Cracking and detachment
- Checking
- Adhesion failures: flaking, delamination, detachment, and peeling
- Failure on welds and edges
- Gouges/chipped spots
- Inspection considerations
- Inspection checklist

20.1 Introduction

While it is not the intent of this course to teach coating failure analysis, it is sometimes necessary for coating inspectors to document a visible failure and to have an understanding of what caused it. This chapter details common industry names for various failures and a short description of each. There are a number of books available that examine coating failure in considerable depth. Students who want to continue their education and wish to learn more about the industrial coating business are urged to seek out and read those books. Inspectors should consult with a manufacturer's technical representative about coating failures whenever possible.

20.2 Non-Drying Film (Failure to Cure)

Non-drying film is a common problem on many projects, frequently caused simply by not adding the cure to the base, adding the wrong cure, or not adding the correct amount of cure during mixing. As mentioned in an earlier chapter, it is vitally important to the success of the project that the inspector observe during mixing.

Other issues that might cause non-drying or curing of a coating film are: (Figure 20.1)

- Problem with the coating material sent from the manufacturer; a check with the manufacturer with the batch number in hand might give a quick answer
- Environmental issues; to cold, too hot, too humid, all of which are covered in other chapters in this course
- Wrong thinner or contaminated thinner; moisture in some generic thinners can react with the cure

Figure 20.1 Non Cured Epoxy Coating

20.3 Blushing (Amine Sweating)

If cured during conditions of cool ambient temperatures, dropping temperatures, or high humidity, amine-cured epoxy resin coatings can develop a surface oiliness or exudate, commonly referred to as "amine-blush" or "sweating" (Figure 20.2). This is caused by the absorption of carbon dioxide and water into the coating film and its reaction with the amine curing agent. Some of the problems can be:

- Surface tackiness or greasiness
- Incomplete cure
- Poor adhesion
- Poor adhesion on over-coating
- Coating discoloration over time
- Poor gloss retention

Figure 20.2 Blushing

The best method to fix this defect is to avoid it by adhering to strict environmental controls. Another, sometimes recommended, solution is to lengthen induction times. However, do not do this without the written approval of both the coating manufacturer and the project owner. If amine blush does occur, the coating inspector should consult with the coating manufacturer and the project owner prior to making any recommendation regarding the attempt to repair or overcoat it.

Note: There are a number of commercial kits on the market that detect amine blush.

20.4 Runs, Sags, Curtains, Wrinkles

Runs, sags, curtains, or wrinkles may be caused or worsened by (Figure 20.3, Figure 20.4):

- Applying the coating too thickly
- Using too much thinner or using the wrong thinner
- Surface too hot to apply the coating
- Applying a coating at the end of its pot life
- Wrong thixotrope used in manufacturing
- Improper spray technique

Figure 20.3 Run

Figure 20.4 Wrinkling

See if the applicator can fix a run or drip right away by lifting or spreading the coating with a brush or roller. However, if the run or drip is already hard, report the problem to the owner. In some cases, the run or sag is acceptable. Otherwise, ensure the crew sands it down and reapplies the new material at the correct thickness, based on the specification and the manufacturers' recommendations for repair.

20.5 Discontinuities, Skips, Holidays, and Missed Areas

These defects are exposed areas of the substrate or previous coating, caused by poor application technique, lack of stripe coating, and/or lack of or poor inspection (Figure 20.5).

Figure 20.5 Discontinuity, Skip, Holiday or Missed Area

Base the repair method on the specification, or if not specified, then on the coating manufacturers' recommendations. Ensure the owner gives approval before making the repair. Quick recognition and repair means the repair is easier and it will blend in better.

20.6 Chalking

Chalking is a powdery, friable layer on the surface of a coating normally caused by exposure to UV light (Figure 20.6). It can also be due to exposure to other forms of radiation including nuclear radiation.

The UV light or radiation break down the bond between molecules in the coating film. It is most common in epoxy coatings but can be seen in almost all coatings left exposed to causative conditions for a long enough period of time.

Figure 20.6 Chalking

To overcoat, remove the powdery layer by sanding or pressure washing to a point acceptable to the project owner.

A test method to use is: ASTM D4214-07, *Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films*.

20.7 Cratering

Cratering is the formation of small bowl-shaped depressions in the coating caused by

air trapped in the coating (Figure 20.7). The air forms a bubble that bursts, leaving the crater. Cratering is common in coatings that are roller- or brush-applied by an inexperienced applicator. Improper mixing procedures can also trap air in the coating, thus causing cratering. See vacuoles and pinholing.

Figure 20.7 Cratering

20.8 Air Voids (Vacuoles)

Initially invisible, these pockets of air trapped inside the coating film generally lead to failure in the near future (Figure 20.8). They are caused by air trapped in the coating during mixing. This typically occurs when the mixer is run too fast. This creates a foam or bubbly surface on the liquid coating.

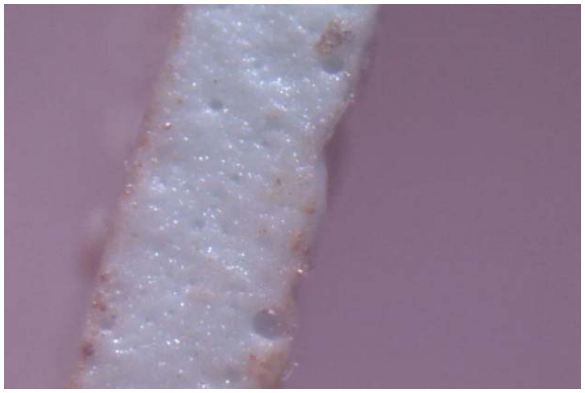


Figure 20.8 Air Void

20.9 Pinholing

Pinholes are very small holes in a coating, typically caused by painting over an inorganic zinc coating (IOZ) or sprayed metal coatings (Figure 20.9). Air or solvent, escaping through a porous film, cause these tiny holes. Zinc coatings set up so quickly that the small holes will not fill back in. This defect is easy to avoid by simply using a mist coat followed by a full coat.

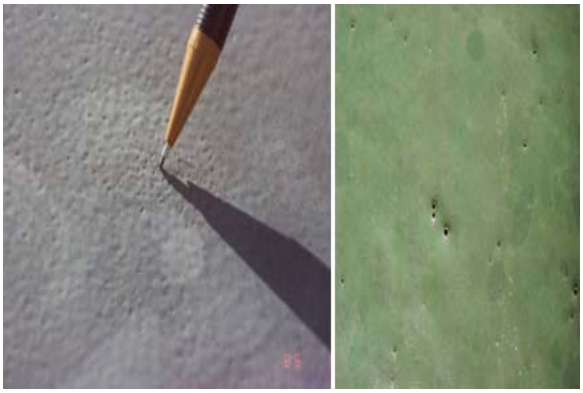


Figure 20.9 Pinholing

Repairs for cratering, vacuoles and pinholing are very difficult since the hole generally just re-forms in any coating applied over them. Sanding down to bare metal is the only sure fix.

20.10 Discoloration/Staining

Rust stains are normally not a problem except as a matter of aesthetics. If necessary, clean by sanding and over-coating. The only way to stop this from occurring is to repair or replace the item that is rusting and bleeding onto the coating. (Figure 20.10)

Figure 20.10 Discoloration/Staining

20.11 Heat-Related Damage

Heat-related damage can occur during any project because it is very common for someone to weld over new paint. The repair should, just like any other repair, follow the specification or the manufacturer's recommendations.

20.12 Blistering

Blistering is dome- or circular-shaped projections of the coating film held away from the substrate (Figure 20.11). Blisters can have irregular shapes, depending on the cause. They may be filled with pure water, solvent, caustic, gas, oxygen, crystals, or rust. The basic cause is a loss of adhesion in localized areas. They can be any size and distribution, which is typically classified by using ASTM D 714, S*tandard Test Method for Evaluating Degree of Blistering of Paints.*

Numerous factors can lead to blistering, but the most common is a contaminant of some kind left on the surface after cleaning. In **atmospheric service,** the blisters may be caused by coating over:

- Oil
- Moisture
- Grease
- Dirt
- Dust
- Soluble pigments
- Retained solvents

In **immersion** or **buried service,** blistering can also be caused by electro-endosmosis due to:

- An overactive cathodic protection system
- Stray currents
- Osmosis caused by trapped soluble salts

Figure 20.11 Blistering

Do not to break blisters unless it is to test them or their contents to determine cause. Remember that blisters may be protecting the surface. The only reasonable repair, if repair is necessary, is to remove the coating system, clean the area, fix whatever caused the blisters, then replace the coating system.

20.13 Cracking and Detachment

These defects are visible cracks in a coating that may either penetrate down to the substrate, or just penetrate through a single coat in a multi-coat system (Figure 20.12).

The main cause is stress related, either due to movement in the substrate or internal stress in the coating as it ages. Chemically cured coatings that are applied too heavily are prone to cracking. Two other causes are

absorption and desorption of moisture. An example is antifouling cracking, which is seen when the ship comes out of the water for inspection or work. Aging also causes cracks in coatings. A good example is sometimes seen in an older alkyd coatings.

Figure 20.12 Cracking and Detachment

Once a coating has cracked, remove and replace it, preferably with a more flexible coating.

20.14 Checking

Checking appears as line cracks in the coating surface (Figure 20.13). Normally, this appears only in the topcoat and the cracks rarely go through to the substrate. Sometimes, magnification is needed to fully see them. The fundamental cause is stress in the coating film. The stress can occur because of incorrect formulation (a manufacturers' issue), or a poorly written specification which requires a coating that is not meant for the service or is incompatible with the underlying coating.

Figure 20.13 Checking

Remove the checked coating and replace with the proper coating material.

20.15 Alligatoring

Alligatoring occurs where a hard, tough coating is applied over a softer extensible coating. Some thickly applied coatings can alligator when exposed to sunlight.

Coatings that cure by oxidization-polymerization may alligator if the coating is heated, i.e., the surface cures rapidly relative to the underlying coating.

Figure 20.14 Alligatoring

20.16 Adhesion Failures: Flaking, Delamination, Detachment, and Peeling

These defects are due to loss of adhesion between coating layers or the substrate, caused by (Figure 20.15):

- Coating applied to a contaminated surface
- Wrong surface preparation specified
- Failure to inspect surface preparation
- Insufficient surface profile
- Exceeding the topcoat window
- Application of incompatible coatings (e.g., alkyd over IOZ)
- Applying a coating to a glossy surface

Figure 20.15 Adhesion Failure

The repair depends on the extent of the failure. For smaller areas, remove, clean, feather edges, and replace. In larger areas, completely remove the coating and replace; this may mean removing the entire coating system down to the substrate before completely re-coating.

20.17 Failure on Welds and Edges

Unless addressed by using a stripe coat, a common source of in-service coating failure is rust that starts at a sharp edge or rough or spattered weld seam (Figure 20.16). The fundamental reason is that coatings pull away from a sharp edge, and industrial application using spray or roller can cause the coating to bridge over small depressions in the substrate.

Grind or round edges to at least a 0.078 in (2 mm) radius. Unfortunately, this is not required in many specifications. When that is the case, the coating inspector cannot require stripe coating. The addition of a stripe coat adds additional material on the edge, with the goal of having a coating system with the same DFT on edges as on the flats surfaces. The International Maritime Organization (IMO) performance standard for protective coatings (PSPC) requires rounding edges to a 0.078 in (2 mm) radius or performing a three-pass grinding. There are special DFT gauges available that measure DFT on edges. Typical gauges will not accurately measure closer to an edge than 1 in (25 mm).

Figure 20.16 Edges

Welders should dress welds and remove weld spatter to the extent called for in the project specification (Figure 20.17). However, *what is acceptable for a weld* ***may not be good for a coating***. Coat rough welds using a brush to work the coating into the roughness. Weld spatter is a separate issue. Remove it by grinding or it will cause coating failure. Coating does not encapsulate

beads of weld spatter, nor does abrasive blasting remove it.

Figure 20.17 Welds

Another issue with welds and cut edges of steel is that the heat from certain types of welding can harden the steel surface for a short distance around the weld. The hardened steel may not receive the same profile as surrounding steel during abrasive blasting. Coating inspectors should always check profile depth near any area that may have been subjected to heat from welding, or cutting prior to abrasive blasting. Flame cut edges need to be ground down *before* abrasive blasting.

20.18 Gouges or Chipped Spots

No matter how careful a contractor is, damage inevitably occurs on coating projects and it must be addressed. Moving equipment around a work site can cause gouges or chipped spots, and unfortunately these gouges normally go through to the substrate. Even a small chip can start an active corrosion cell causing a pit to form.

Sand down damaged areas to the bare substrate and feather the surrounding coating. Ensure the repairs exactly replicate all coats of the original system and precisely follow the specification, curing, and environmental requirements used for the undamaged portions of the coating system.

20.19 Cissing

Cissing (also known as ‘fisheyes’ or ‘crawling’) is the term for surface breaks in the film that reveal the substrate. It is often a result of grease or oil contamination on the substrate.

20.20 Inspection Considerations

The fundamental reason to have a coating inspector on a job site is to avoid all of the above failures. However, since most jobs cannot be inspected 100% of the time over 100% of the surface, application-related coating failures do occur.

However, inspectors who are diligent and who closely observe work at critical times, reduce (if not fully eliminate) premature coating failure.

20.21 Case Study

The following photographs present a potential defect in the applied coatings system. As a team, determine the defect and potential problems that may arise from the situation. Describe the actions required to prevent and/or remedy the situation.

Figure 20.18 Defect 1

Figure 20.19 Defect 2

Figure 20.20 Defect 3

Figure 20.21 Defect 4

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Study Guide

1. Non-drying films (failure to cure) may be caused by:

_____
_____
_____

2. Some of the problems that can be caused by amine blush are:

_____
_____
_____

3. Runs, sags, and wrinkles may be caused by:

_____
_____
_____
_____
_____
_____

4. _____ is a powdery, friable layer on the surface of a coating that is most common with epoxy coatings.

5. Cratering may be caused by:

_____
_____
_____

6. Vacuoles or voids are typically caused by:

_____

7. Pinholes are:

_____
_____

8. A common cause of blistering is:

_____

9. Cracking of a coating is noted:

_____
_____

10. Checking can be described as:

_____

11. Adhesion failures may be caused by:

_____
_____
_____
_____
_____
_____

Chapter 21: High Voltage and Low Voltage Holiday Testing Instrumentation

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Low voltage instruments
- High voltage holiday instruments
- Inspection considerations
- Inspector's checklist

Key Trade Terms

- Low voltage holiday detector
- High voltage pulse-type DC Holiday detector
- High voltage constant current DC holiday detector
- High voltage AC holiday detector

21.1 Introduction

Holiday detectors are used to detect holidays of various kinds in coatings. Not all types of structures or all industries use holiday detectors. General types of holiday detectors include:

- Low-voltage DC
- High-voltage DC
- High-voltage pulsed DC
- High-voltage AC

Holiday testing is performed to find defects or discontinuities in coating film such as:

- Pinholes (Figure 21.1)
- Fisheyes
- Cratering
- Nicks

Correcting coating defects is especially important for tanks intended for immersion service and buried pipelines.

Cissing (also known as 'fisheyes' or 'crawling') is the term for surface breaks in the film that reveal the substrate. It is often a result of grease or oil contamination on the substrate (Figure 21.4).

Cratering is the result of air released from the surface of the coating at the point where the coating is partially cured and the coating does not flow back to cover the void created by the air release (Figure 21.3).

Incorrect coating thickness can be detrimental, whether too thick or too thin. The images below show some examples of these coating defects, and there are many others of a similar nature.

Figure 21.1 Pinholes

Figure 21.2 Sags and Runs

Figure 21.3 Cratering

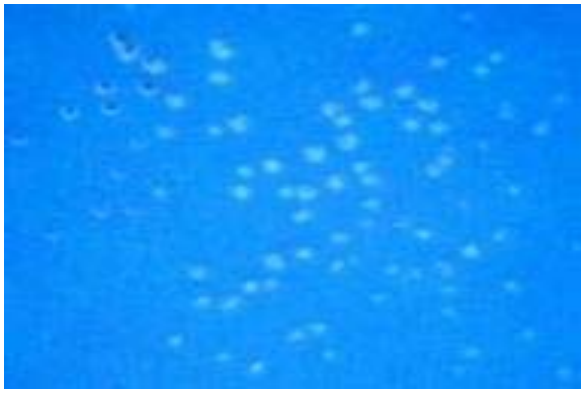

Figure 21.4 Cissing

Low voltage holiday detectors are only able to detect holes in the coating that go all the way through the coating to the metal substrate. High voltage holiday detectors can detect weaknesses in the coating that do not penetrate to the conductive substrate (metal or concrete with moisture present).

Specifications should indicate the points in the job when holiday testing is required. The coating should be reasonably well cured (but not fully cured, for ease of repair) before testing is done.

Note: coatings that are not cured may show false holidays. In fact, solvent remaining in coatings may create weak spots of low electrical resistance that high-voltage detectors may disrupt, creating holidays where none previously existed. Nevertheless, in some cases, such as with baked phenolics or glass-flake epoxies, the user may elect to test the coating before final cure so that any repair material would effectively bond to the underlying coat.

Holidays in coatings *should be repaired*. Correcting coating defects is especially important for tanks intended for immersion service and buried pipelines. Repair defects then test the coating again to ensure that repairs were successful.

21.2 Low Voltage Instruments

The low voltage holiday detectors shown in Figure 21.5 are sensitive, low-voltage, wet-sponge, electronic devices powered by batteries with output voltages ranging from 5–120V DC, depending upon the equipment manufacturer's circuit design. The detectors consist of:

- Portable battery-powered electronic instrument
- Nonconductive handle with clamps (to hold sponge)
- Open-cell sponge (cellulose)
- Ground wire

Some low-voltage holiday detectors are fixed at a specific voltage, while other may have a test voltage selected.

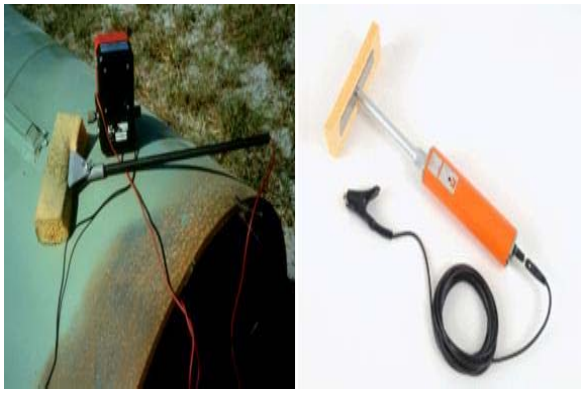

Figure 21.5 Low Voltage Holiday Detectors (Tinker & Rasor; Elcometer 270)

21.2.1 Proper Use of Instrument

The ground cable of this instrument (see Figure 21.5) is attached directly to the conductive substrate for positive electrical contact. With a coated steel substrate, connect directly to the bare metal. With a concrete substrate, connect directly to the reinforcing steel (rebar) in the concrete where possible. If no rebar or other metal object within the concrete is available, make a ground connection to the concrete by placing the bare ground wire on the concrete and anchoring it down with a burlap bag filled with damp sand. Alternatively, if there is no rebar or metal object, drive a metal fastener, stub or nail into the concrete. Wetting the concrete in the immediate area also helps to establish continuity.

Saturate the sponge with a solution of tap water (not distilled) and a low sudsing wetting agent (such as that used in photographic film development). Combine 1 oz (7.4 mL) fluid wetting agent to 1 gal (1 L) water. This breaks down to a ratio of 1 part wetting agent to 128 parts water (1:128). Wet the sponge enough to barely avoid dripping solution while moving it over the coating.

Contact a bare spot on the substrate with the wetted sponge to verify that the instrument is properly grounded. Repeat this procedure periodically during the test. This process is particularly important when testing coatings over concrete.

> Excess moisture can cause erroneous indications by creating a path across the surface of the coating to pinholes previously detected, or directly to the signal return connection. This is often referred to as “telegraphing.”

With the ground wire attached to the substrate, wipe the coated surface with the wetted sponge at a maximum rate of 1 linear foot per second (lfps) (30 cm/s). Avoid using excess water in the sponge because the run-down could complete the circuit across the coating surface to a flaw located several feet away, thus giving false readings. Use a double stroke of the sponge electrode over each area. This ensures better inspection coverage. When a holiday is found, the instrument will emit an audible tone (Figure 21.6, Figure 21.7).

Use only approved or specified wetting agents. Mark all holidays with a non-intrusive marker, such as white-calcium chalk. Clean the area to be repaired to ensure the wetting agent is removed before making coating repairs.

Some users in certain industries, such as railcar companies, choose not to use a wetting agent between coats for fear of contaminating the surface or leaving moisture under the repair coating, which could lead to premature failure. In this case, the low-voltage wet sponge holiday detector is limited for use on coatings under 10 mils (250 µm) thick. By this action, the user has chosen to modify the standard method (e.g., NACE Standard SP0188) to suit individual needs.

Solvents retained in the protective coating film can cause erroneous indications (false holidays) during electrical testing.

Figure 21.6 Low Voltage Holiday Detector in Use

21.2.2 Standards

Relevant standards that may be consulted (depending on specification requirements, coating and substrate type) include:

- ASTM 3894.2
- ASTM D 5162-A
- ASTM G6
- ASTM G62-A
- BS 7793-2
- ISO 8289 A
- ISO 14654
- NACE SP 0188
- NACE TM0384

21.2.3 Calibration and Frequency

Low-voltage holiday detectors are factory-calibrated, so calibration in the field is not generally necessary. Typical factory calibration is set at 700 microamperes (± 10%) of current flow to complete the circuit triggering the audible signal that indicates a coating holiday on metal substrates. For coatings on concrete substrates, the detectors must be adjusted for current flow of 500 microamperes (± 10%). This is generally achieved by removing a resistor from the electronic circuitry.

One typical unit has an internal jeep tester that is continually enabled at start up. The internal jeep tester ensures that the voltage output matches the voltage selected on the display. If the selected voltage cannot be generated, the unit does not allow that voltage to be selected.

Another instrument is equipped with both a red and a black button on the face of the unit. To check for correct calibration on conductive substrates, depress the **black button** (80 K). The detector will signal and the LED will light if the detector is **calibrated**. Depress the **red button** (90 K), and the detector will not signal and the LED will not light if the detector is properly calibrated.

To verify if the same instrument is properly calibrated for use on concrete substrates, verify the unit is properly calibrated for use with coatings over metal substrates. Once calibration is completed, remove the small jumper wire inside the red cover side of the detector and it is now ready to use with coatings applied over concrete.

21.2.4 Operating Parameters

These low-voltage (wet-sponge) holiday detectors may also be used to locate holidays in nonconductive coatings applied to conductive substrates. These instruments are portable and easy to operate. They are reliable on coatings up to 20 mils (500 µm) thick. The instrument *can* locate defects in coatings thicker than 20 mils (500 µm), but requires a slower wipe speed since the moisture has further to travel to the substrate.

The low-voltage method is preferred by some users because it does not easily damage the coating film. However, use is limited to uncovered substrate. The units are generally not intrinsically safe and cannot therefore be used in a hazardous environment.

21.2.5 Accuracy and Precision

Accuracy is generally ± 5–10%, depending on the manufacturer. Common voltages used are 9, 67.5, 90, and 120 V. Because different results are obtained with each voltage, selecting the proper voltage is critically important. These voltages are specified in NACE, ASTM, and ISO low-voltage holiday detection standards. Ideally, the job specification should cite the test method the inspector should follow.

21.2.6 Repeatability

Given equal conditions, repeatability of results is very high for the instruments. Variations in results stem from the operator's technique and the speed at which the test is done.

21.2.7 When to Question Readings

Make occasional checks to see if the detector is operating properly; particularly if no holidays are being found (i.e., question results if a known discontinuity is checked and the instrument does not respond). Once the instrument is functioning properly, retest any areas in question.

21.2.8 Common Errors and Causes

Common **operator-based** errors include:

- Failure to keep the probe in contact with the surface
- Moving the electrode too quickly or slowly across the testing surface
- Loss of connection to the substrate
- Over- or-under saturated sponge

Some **equipment-based** errors include:

- No fault alarm caused by low battery or a bad lead/ground connection causing high electrical resistance
- Excess moisture

Figure 21.7 Low Voltage Holiday Detector in Use

21.3 High-Voltage Holiday Instruments

21.3.1 High-Voltage Pulse-Type DC Holiday Detectors

High-voltage pulse-type DC holiday detectors are designed to locate holidays in non-conductive coatings that are applied over a conductive substrate (Figure 21.8). These instruments are ideal for use:

- In moist conditions
- On wet coating surfaces
- On contaminated coating surfaces
- On carbon-impregnated coatings (i.e., carbonated rubber)
- On "plastic"/fiberglass type coatings likely to become electrostatically charged

High-voltage pulse-type DC detectors consist of:

- High-Voltage DC Unit
- Various probes for different substrates and configurations
- Calibration accessories
- Charging unit
- Ground wires
- General accessories

Figure 21.8 High-Voltage Pulse-Type DC Holiday Detector

21.3.1.1 Proper Use of Instrument

There are a number of manufacturers and models available. Generally, each manufacturer/model has particular differences related to safety or operation that operators need to know.

Tinker & Rasor[†1]'s APS "Stick-Type," for example, is equipped with a release trigger that instantly turns the instrument off. Hold the handle down on the grip to operate the instrument; release the handle and the unit shuts down immediately. This feature increases job-site safety since instruments cannot be left energized while unattended.

Some older high-voltage holiday detector models may not be equipped with the safety or convenience features of newer models. As always, consult the operations manual specific to the particular model for specific, detailed operating instructions.

The operating procedure of most high-voltage pulse-type DC holiday detectors is generally similar to the operating procedure described in the following paragraphs.

When the electrode is passed over the surface, a spark arcs through the air gap or coating to the substrate at any holidays, voids, or discontinuities, which simultaneously causes the detector to emit an audible sound.

The ground wire should be connected directly to the metal structure, where possible. If direct contact is not possible, use the high-voltage holiday detector with a trailing ground wire; provided the structure to be tested is also connected to the ground. If the building is not connected to the ground, establish direct contact or connect a ground

1. Trade name

wire and spike at some point between the ground and the structure.

On concrete structures, attach the ground to rebar in the concrete, or if there is no rebar, lay the bare ground wire on the concrete and anchor it with a burlap (cloth) bag filled with damp sand.

Set the voltage as stated in either the specification or the referenced standard. If no guidelines are provided, the US industry's rule of thumb is to use a voltage setting of:

- 100 V/mil of coating thickness

The European industry's most-frequently-used rule of thumb is slightly different:

- 4 V/µm of coating thickness

Two alternate methods to set the correct voltage is to identify another type of defect, e.g., low DFT, or make a pinhole through the coating to the substrate, then set the voltage at the lowest available setting on the unit. Increase the voltage until it is sufficiently high to create a spark at the holiday. Use that setting to inspect the coating for holidays.

Inspectors should always obtain written authority before:

- Making a pinhole in the coating, since that is a destructive test
- Using this procedure to set voltage, unless already specified

Please note: when the voltage is set too high, the coating may be damaged. The same damage can occur if the coating is tested before it has released all or most of its solvent content. **Once a spark generates through the coating to the substrate, a specific holiday now exists;** even if there was no a pinhole or break in the coating before the test was performed.

When testing, move the electrode at a rate of about 1 ft/s (0.3 m/s) in a single pass (according to NACE SP0188). Moving the probe too quickly may miss a void. Moving too slowly may create damage at thin spots or prove to be more exacting than was intended by the specifier.

21.3.1.2 Standards

Standards that may need to be consulted, depending on the specification's requirements, and coating and substrate types, include:

- AS3894.1-2002
- ASTM G62-07
- ASTM D5162-08
- ASTM D4748-08
- NACE RP0274-04
- NACE SP0490-2007
- NACE SP0188-2006
- ANSI/AWWA C214-07
- ANSI/AWWA C213-07
- ISO 2746:1998

21.3.1.3 Calibration and Frequency

High-voltage pulse-type DC holiday detectors come calibrated from the manufacturer and cannot be calibrated by users. Check the voltage output periodically, following the manufacturer's suggested method. If there is ever a question about the accuracy of results, take the detector out of service and return it to the manufacturer or supplier for service.

21.3.1.4 Operating Parameters

Before using high-voltage pulse-type DC holiday detectors, ensure:

- Coating cure is complete
- Visual inspection is complete

- Acceptance of inspection is complete
- Thickness testing is complete
  - — Coating thickness is above 6 mils (150 µm)
  - — Low-voltage (wet sponge) testing of coatings below 6 mils (150 µm) is complete

The high-voltage pulse-type holiday DC detectors generally have a voltage output range from 800–60,000V. (Figure 21.9) Generally, these devices are used on protective coating films ranging in thickness from 6–240 mils (150–6,000 µm).

When checking the output voltage from the probe, use of a high input impedance voltmeter is required to prevent a flow of current and a subsequent voltage drop from the power supply.

Most high-voltage holiday detectors have a wide range of electrodes available for different uses, including:

- Flat-section rolling springs are used to test pipeline coatings
- Smooth neoprene flaps (impregnated with conductive carbon) are used for thin-film coatings such as fusion-bonded epoxy
- Copper-bronze-bristle brushes are commonly used on glass-reinforced plastic (GRP) coatings

High-voltage pulse-type DC holiday detectors are not intrinsically safe and may lead to an explosion if used in an explosive atmosphere.

21.3.1.5 Accuracy and Precision

Accuracy for the voltage setting is generally ± 5%. Depending on model (voltage range), resolution is 10V or 100V.

Figure 21.9 High Voltage Holiday Detector in Use with Rolling Spring Electrode

21.3.1.6 Repeatability

Given all conditions are equal, repeatability of results is very high. Results are dependent on the operator's technique and speed while the test is performed.

21.3.1.7 Sensitivity

Some high-voltage holiday detectors allow the sensitivity of the alarm to be adjusted so that it does not sound the audible alarm when a steady flow of current from the probe to charge the surface of the coating is present, or when the coating is partially conductive (due to conductive pigments such as carbon black). When the sensitivity is set to a low value, the audible alarm will sound only when a high current spark is present. When the sensitivity is set to a high value, all current flows from the probe will cause the alarm to sound.

21.3.1.8 When To Question Readings

Make occasional checks to see if the detector is operating properly, particularly if no holidays are being found (i.e., question results if a known discontinuity is checked and the instrument does not respond). Once the instrument is functioning properly, retest any areas in question.

21.3.1.9 Common Errors and Causes

Common **operator-based** errors include operator failure to keep the probe in contact with the surface and moving the electrode too quickly or slowly across the testing surface.

Some **equipment-based** errors include:

- *Lack of display:* due to low battery or bad/missing fuse (depends on model).
- *Continuous alarm:* due to damp surface, moving the probe too quickly across the surface, conductive pigments in the coating, or certain types of coatings which hold electrical charge on the surface causing current flow as the probe passes across the surface.
- *No alarm on fault:* on conductive substrates could be due to too-low voltage sensitivity setting, or a bad ground connection. On concrete substrate, no alarm on fault could be due to insufficient conductivity. (The conductivity of the concrete is due to its moisture content; less than 5% can mean insufficient conductivity).
- *No spark at the probe tip:* due to lead or connection failure.

21.3.2 High-Voltage Constant Current DC Holiday Detectors

High-voltage constant current DC holiday detectors are used to detect holidays in dielectric (insulation type) coatings on conductive substrates (Figure 21.10). This detector can be used on many substrates and provides excellent results on concrete.

Figure 21.10 High-Voltage Constant Current DC Holiday Detectors

21.3.2.1 Proper Use of Instrument

There are a number of manufacturers making a variety of models, with manufacturer- and model-specific safety and/or operational differences that operators must know.

The Elcometer 266® model is equipped with a safety release switch that is part of the handle. When the operator releases the handle, the voltage output is cut off immediately. This feature serves to increase jobsite safety since the instrument cannot be left energized while unattended.

The PCWI DC30 is equipped with a "momentary on switch" which allows auto shut-off. This instrument also offers an optional on/off switch in the handle.

Older models of high-voltage holiday detectors may not be equipped with many of the safety or convenience features of newer models.

As with all instruments, refer to the manufacturer's model-specific operating instructions for detailed use instructions.

Use and operating procedures for the constant current DC holiday detectors are the same as those for the pulse-type DC holiday detectors.

Set the voltage according to both the thickness of the coating and the specified standard (see Section 21.3.2.2, immediately following). Once this is done, pass the electrode over the surface. Any holidays, voids, or discontinuities cause a spark to arc through the air gap or coating to the substrate. At the same instant the detector emits an audible sound to alert the operator.

Connect the signal return wire (or ground wire) directly to the metal structure. Provided the structure to be tested is also electrically connected to the ground in some way (establish this connection by fixing a ground wire and spike at some point between the ground and the structure), connect the ground wire to the earth. Use this with caution and electrically test regularly during inspection.

Figure 21.11 High-Voltage DC Holiday Detector in Use

On concrete structures, attach the ground to rebar in the concrete or a metal object that runs through the concrete (e.g. copper pipe), or if there is no rebar or metal object, attach a metal fastener, stub or nail. Another method is to lay the bare ground wire on the concrete and anchor it with a burlap (cloth) bag filled with damp sand.

21.3.2.2 Standards

Standards that may need to be consulted depending on specification requirements, coating and substrate type include:

- ANSI/AWWA C213
- AS 3894.1
- ASTM C 536
- ASTM C 537
- ASTM D 4787
- ASTM G 6
- ASTM D 5162-B
- ASTM G 62-B
- BS1344-11
- DIN 55670
- EN 14430
- ISO 2746
- JIS K 6766
- NACE RP0274
- NACE SP0188
- NACE SP0490
- NACE SP0188

21.3.2.3 Calibration and Frequency

High-voltage DC holiday detectors come from the manufacturer already calibrated and cannot be calibrated by the user. Check the voltage output periodically, following the manufacturer's suggested method. If there is ever a question about the detector's accuracy, take it out of service and return it to the manufacturer or supplier for service.

21.3.2.4 Operating Parameters

When using these detectors, the coating thickness should be above 6 mils (150 µm). Test coatings below this thickness with a low-voltage (wet sponge) unit. High-voltage constant current holiday detectors generally

have a voltage output range from 0–30,000V.

21.3.2.5 Accuracy and Precision

Accuracy is generally ± 5%. Depending on model (voltage range), resolution is 10V or 100V.

21.3.2.6 Repeatability

Given equal conditions, repeatability of results is very high. Results depend on the operator's technique and the speed at which the test is performed.

21.3.2.7 When To Question Readings

Make occasional checks of the detector's operation, particularly if no holidays are being found. Question results if a known discontinuity is checked and the instrument does not respond. Ensure the instrument is functioning properly and retest any areas in question.

21.3.2.8 Common Errors and Causes

Common **operator-based** errors include the operator's failure to keep the probe in contact with the surface and moving the electrode either too quickly or slowly across the testing surface.

Some **equipment-based** errors include:

- *Lack of display:* due to low battery or bad/missing fuse (depending on model).
- *Continuous alarm:* due to a damp surface or moving the probe too quickly across surface.
- *No alarm on fault:* due to a too low voltage/sensitivity setting or bad ground connection.
- *No spark at the tip:* caused by lead or connection.
- *Incorrect voltage generated:* Some gauges, such as the Elcometer 266®, have a built in jeep tester and closed loop system to guarantee the voltage selected is generated at the tip. However, many gauges do not have this function. Ensure that the voltage selected is indeed generated, especially as the battery weakens. Take care when verifying the test voltage at the tip. Make sure that no current is drawn from the power supply thus causing a voltage drop.

21.3.3 High-Voltage AC Holiday Detector

High-voltage AC holiday detectors use a 110v or 220v power supply. They are based on the principle of the Tesla coil and do not use a ground wire. The probe emits a blue corona, which is attracted to any ground. This type of detector is encountered less frequently than pulsed DC holiday detectors.

While these AC units are available, they present a much higher risk of severe shock during use than DC or pulsed DC high-voltage holiday detectors. **Use AC units with extreme care at all times.**

21.3.3.1 Proper Use of Instrument

The high-voltage AC holiday detectors operate on a different electrical principle, but the testing procedure is generally the same as for high-voltage DC holiday detectors.

As with all instruments, refer to the manufacturer's operating instructions for model-specific detailed instructions for use.

21.3.3.2 Standards

Standards that may need to be consulted (depending on specification requirements, coating and substrate type) include:

- AS3894.1-2002
- ASTM G62-07
- NACE RP0274-04

- NACE SP0490-2007
- NACE SP0188-2006
- ANSI/AWWA C214-07
- ANSI/AWWA C213-07
- ISO 2746:1998

21.3.3.3 Calibration and Frequency

The instrument comes calibrated from the manufacturer and cannot be calibrated by the user. Check the voltage output periodically, following manufacturer's suggested method. If there is ever a question about the accuracy of the holiday detector, take it out of service and return to the manufacturer or supplier for service.

21.3.3.4 Operating Parameters

Use AC-type holiday testers to test nonconductive linings on steel substrates (e.g., rubber, glass, or sheet linings). AC testers have a variety of voltages but typical use is for very thick coatings, with test voltages in the range of 25,000–60,000V.

21.4 Inspection Considerations

There are many factors inspectors must consider before performing holiday detection. Some factors affect what instrument and/or procedure are chosen to perform the test. Some of the factors include:

- *Work Environment.* The high-voltage AC holiday detectors are not intrinsically safe and cannot therefore be used in a hazardous environment. Any instrument that can generating a spark when a flaw is detected is not intrinsically safe.
- *Type of Substrate and/or Type of Coating.* Although all the instruments are designed to locate holidays in nonconductive coatings applied over a conductive substrate, a particular type of holiday detector may achieve better results on certain substrates or with certain coating types.
- *Anticipated coating thickness.* As mentioned earlier, use low-voltage (sponge) holiday detectors on coatings up to 20 mils (500 µm) thick and the high-voltage detectors on higher film thicknesses. (This is a general rule and does not always apply)
- *Specification requirements.* Some specifications may require special procedures or recommend a specific type of holiday detector to be used.

  Example: The specification may call for a low-voltage detector on a film thickness over 20 mils (500 µm), which contradicts the general rule.
- *Standards to follow.* Depending on some of the other factors listed above, there ***are*** specific standards that should be referred to in order to ensure proper procedures are followed.

21.5 Inspector's Checklist

Before testing for holidays, check the following items:

- Are non-intrinsically safe instruments allowed in the work environment?
- What are the grounding and safety issues
- Have the specification and standards that govern how to conduct the testing been thoroughly reviewed and understood?
- Is the proper instrument for the anticipated DFT at hand?
- Is the battery charged and in satisfactory working condition?
- Has the operations manual for the holiday detector been thoroughly reviewed and understood?
- Has the voltage output been checked to ensure accurate readings?

- Have the signal return cable and electrode connections been checked to ensure there is no electrical resistance in the circuit?

Key Terms Definitions

High-Voltage AC Holiday Detector: This uses a 110v or 220v power supply. The AC detector is based on the principle of the Tesla coil and does not use a ground wire. The probe emits a blue corona, which is attracted to any ground.

High-Voltage Constant Current DC Holiday Detector: This instrument is used to detect coating holidays in dielectric coatings. Once the voltage is set, pass the electrode over the surface. A spark will arc through the air gap, causing the detector to emit an audible sound.

High-Voltage Pulse-Type DC Holiday Detector: This instrument is ideal for use in moist conditions. Pass the electrode over the surface. A spark will arc through the air gap at any holidays, voids, or discontinuities, causing the detector to emit an audible sound.

Low-Voltage Holiday Detector: This instrument is a sensitive, low-voltage (wet-sponge) electronic device powered by a battery with output voltages ranging from 5–120V DC.

Study Guide

1.General types of holiday detectors include:

_____
_____
_____

2. Low-voltage (wet sponge) holiday detectors are powered by a battery with output voltages ranging:

_____

3. Describe low-voltage (wet sponge) holiday detectors:

_____
_____
_____
_____
_____
_____

4. High-voltage DC holiday detector types include:

_____
_____

5. Describe high-voltage DC holiday detectors:

_____
_____
_____

6. The type of high-voltage holiday detector used for concrete is a:

_____

Chapter 22: High Voltage and Low Voltage Holiday Testing Instrumentation — Practice Lab

22.1 Introduction

This lab builds on the previous chapter by demonstrating some of the holiday detection instruments discussed. The instructor will show each instrument along with the necessary material required to perform each test. Hands-on experience with the instruments then follows.

Safety Precautions

- Operate all hand-held high-voltage test equipment responsibly.
- Ensure the unit is grounded properly before it is powered on. If there is any question, ask the instructor for assistance.
- The detector output can be up to 65,000 volts. Never point the electrode toward another person. Ensure everyone not involved in testing is well clear of the equipment. The operator should wear rubber gloves to prevent receiving a shock or electrical zap if he or she accidentally makes contact with the test electrode.
- No one with a cardiac condition should use this equipment.
- Keep sensitive electronic equipment (mobile phones and computer equipment) out of close proximity to the detector.

Station 1: Wet-Sponge Low-Voltage Holiday Detector

Equipment:

- Wet-sponge detector
- Rubber gloves
- Surfactant
- Water
- Coated panel

Assignment: Fill in all necessary blanks and answer all questions. After use, wipe the panel until clean and dry. Do not mark the panel.

Question	Answer
1. What is the highest recommended DFT for proper use?	
2. Can this holiday detector be used successfully to find holidays on coated concrete? Yes or No?	
3. How much surfactant should be added to the water?	
4. How many holidays did you find?	

Make a sketch in the box above, showing where you found holidays.

Comments or additional information (if any)?

Station 2: High-Voltage DC Holiday Detector

Equipment:

- High-voltage DC holiday detector
- Rubber gloves
- DFT Gauge (Type 1 or 2)
- Coated Panel

Assignment: Use the equipment provided at this test station for holiday detection on the coated panel. Do not mark the panel. Answer the following questions:

Question	Answer
1. What is the total DFT of the coating on the test panel	
2. Based on the rule of thumb formula defined in the CIP course, what maximum voltage could you safely use on this coating?	
3. Name one standard you might use to control your working method?	
4. List four (4) precautions you should take to ensure safe and accurate use of the holiday detector.	
4 a)	
4 b)	
4 c)	
4 d)	
5. How many holidays did you find?	

Make a sketch in the box above showing where you found the holidays.

Comments or additional information, if any?

Chapter 23: Standards

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- NACE International standards

23.1 Introduction

Throughout the course, numerous standards for the coatings industry have been discussed and referenced. This chapter examines them more closely, including what they mean in the industry, who writes them, and how inspectors and others can obtain needed standards. Below is a simple definition of the term.

23.2 Definition

A standard is an established norm or requirement that is written by industry professionals. It is *usually a formal document* that establishes uniform engineering or technical criteria, methods, processes, and practices. Standards are meant to ensure industry personnel have a shared, uniform understanding of principles, methods, processes, criteria and practices to minimize confusion, particularly with reference to how the industry does business. These standards enable different groups to realize mutual gains by making mutually consistent decisions.

Coatings inspectors **must** remember that unless a standard is referenced in contractual documents, or in some amendment to an existing contract, it is non-binding. Therefore, a contractor cannot be expected to comply with an inspector's demand to perform work in accordance with a standard because the inspector has knowledge of such a standard.

There are a number of standards organizations in our industry. Keep in mind that approximately 50% of all NACE International Standards are related to protective coatings. Inspectors are not expected to learn every standard available in the industry today, but should know that there are a number of organizations that write standards for the industry. The most common ones are listed below.

23.3 Surface Cleanliness Standards Review

23.3.1 Surface Preparation Standards for Abrasive Blasting

NACE No. 1/SSPC-SP5, *White Metal Blast Cleaning.* When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter.

NACE No. 2/SSPC-SP 10, *Near-White Metal Blast Cleaning*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter. Random staining shall be limited to no more than 5% of each unit area of surface and may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coatings.

NACE No. 3/SSPC-SP 6, *Commercial Blast Cleaning*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter. Random staining shall be limited to no more than 33% of each unit area of surface and may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coatings.

NACE No. 8/SSPC-SP 14, *Industrial Blast Cleaning*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, and dirt. Traces of light adherent mill scale, rust, and coating residues are permitted to remain on 10% of each unit area of the surface if they are randomly distributed. The traces of mill scale, rust, and coating are considered tightly adherent if they cannot be removed by lifting with a dull putty knife. Shadows, streaks, and discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coatings may be present on the remainder of the surface.

NACE No. 4/SSPC-SP 7, *Brush-Off Blast Cleaning*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, loose mill scale, loose rust, and loose coating. Lightly adherent mill scale, rust, and coating may remain on the surface. Mill scale, rust, and coating are considered tightly adherent if they cannot be removed by lifting a dull putty knife.

23.3.2 ISO 8501-1 Hand and Power Tool Cleaning Grades

Sa 3, *Blast Cleaning to Visually Clean Steel*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, and shall be free from the mill scale, rust, paint coatings, and other foreign matter. It shall have a uniform metallic color.

Sa 2½, *Very Thorough Blast Cleaning*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, and shall be free from the mill scale, rust, paint coatings, and other foreign matter. Any remaining traces of contamination will show only as slight stains in the form of spots or stripes.

Sa 2, *Thorough Blast Cleaning*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, and shall be free from most of the mill scale, rust, paint coatings, and other foreign matter. Any residual contamination shall be firmly adhering.

Sa 1, *Light Blast Cleaning*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, and from poorly adhering mill scale, rust, paint coatings, and foreign matter.

St 2, *Thorough Hand and Power Tool Cleaning*. When viewed without magnification, the surface shall be free from visible oil, grease, dust, dirt, and from poorly adhering mill scale, rust, paint coatings, and foreign matter.

St 3, *Very Thorough Hand and Power Tool Cleaning*. Same as St 2, but the surface shall be treated much more thoroughly to give a

metallic sheen arising from the metallic substrate.

23.3.3 SSPC Surface Preparation Standards for Hand and Power Tool Cleaning

SSPC-SP 2, *Hand Tool Cleaning*. Hand tool cleaning removes all loose mill scale, rust, paint, and other detrimental foreign matter. It is not intended that adherent mill scale, rust, and paint be removed by this process. Mill scale, rust, and paint are considered adherent if they cannot be removed by lifting with a dull putty knife.

SSPC-SP 3, *Power Tool Cleaning*. Power tool cleaning removes all loose mill scale, rust, paint, and other detrimental foreign matter. It is not intended that adherent mill scale, rust, and paint be removed by this process. Mill scale, rust, and paint are considered adherent if they cannot be removed by lifting a with dull putty knife.

SSPC-SP 15, *Commercial Grade Power Tool Cleaning*. A commercial grade power tool cleaned surface when viewed without magnification, shall be free from visible oil, grease, dirt, dust, coating, oxides, mill scale, corrosion products, and other foreign material, except as noted in Section 2.2 of the standard. Random staining shall be limited to no more than 33% of each unit area of surface. Staining may consist of light shadows, slight streaks, or minor discolorations caused by rust, mill scale, or previously applied coatings. Slight residues of rust and paint may also be left in the bottom of the pits if the original surface is pitted.

SSPC-SP 11, *Power Tool Cleaning to Bare Metal*: A steel surface cleaned with power tools to bare metal, when viewed without magnification, shall be free from visible oil, grease, dirt, dust, coating, oxides, mill scale, corrosion products, and other foreign matter. Slight residues of rust and paint may also be left in the bottom of the pits if the original surface is pitted. The surface profile roughness shall be a minimum of 25 micrometers (10 mil) as measured in accordance with Method C of ASTM D4417 or other mutually agreed upon method. The peaks and valleys on the surface shall form a continuous pattern with no smooth, unprofiled spots in between.

23.4 NACE International Standards

NACE standards are prepared by the association's technical committees to serve as voluntary guidelines in the field of prevention and corrosion control. These standards are prepared using consensus procedures. NACE offers its standards to the industrial and scientific communities as voluntary standards to be used by any person, company, or organization. As a ***current*** NACE member, all NACE International standards are available at no cost.

23.4.1 NACE Standards Related to Protective Coatings

- **NACE No. 1/SSPC-SP 5: Joint Surface Preparation Standard,** *White Metal Blast Cleaning*
- **NACE No. 2/SSPC-SP 10: Joint Surface Preparation Standard,** *Near-White Metal Blast Cleaning*
- **NACE No. 3/SSPC-SP 6: Joint Surface Preparation Standard,** *Commercial Blast Cleaning*
- **NACE No. 4/SSPC-SP 7: Joint Surface Preparation Standard,** *Brush-Off Blast Cleaning*

- **NACE No. 5/SSPC-SP 12: Joint Surface Preparation Standard,** *Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating*
- **NACE No. 6/SSPC-SP 13: Joint Surface Preparation Standard,** *Surface Preparation of Concrete*
- **NACE No. 8/SSPC-SP 14: Joint Surface Preparation Standard,** *Industrial Blast Cleaning*
- **NACE No. 10/SSPC-PA 6:** *Fiberglass-Reinforced Plastic (FRP) Linings Applied to Bottoms of Carbon Steel Above Ground Storage Tanks*
- **NACE No. 11/SSPC-PA 8:** *Thin-Film Organic Linings Applied in New Carbon Steel Process Vessels (RP0103-2003)*
- **NACE No. 12/AWS C2.23M/ SSPC-CS 23.00:** *Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and their Alloys and Composites for the Corrosion Protection of Steel*
- **NACE No. 13/SSPC-ACS-1:** *Industrial Coating and Lining Application Specialist Qualification and Certification (SP0307-2007)*
- **RP0105-2005:** *Liquid-Epoxy Coatings for External Repair, Rehabilitation, and Weld Joints on Buried Steel Pipelines*
- **RP0274-2004:** *High-Voltage Electrical Inspection of Pipeline Coatings Prior to Installation*
- **RP0287-2002:** *Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces using a Replica Tape*
- **RP0304-2004:** *Design, Installation, and Operation of Thermoplastic Liners for Oilfield Pipelines*
- **RP0375-2006:** *Wax Coating Systems for Underground Piping System*
- **RP0281-2004:** *Method for Conducting Coating (Paint) Panel Evaluation Testing in Atmospheric Exposures*
- **RP0288-2004:** *Inspection of Linings on Steel and Concrete*
- **RP0297-2004:** *Maintenance Painting of Electrical Substation Apparatus Including Flow Coating of Transformer Radiators*
- **RP0303-2003:** *Field-Applied Heat-Shrinkable Sleeves for Pipelines: Application, Performance, and Quality Control*
- **RP0394-2002:** *Application, Performance, and Quality Control of Plant-Applied, Fusion-Bonded Epoxy External Pipe Coating*
- **RP0399-2004:** *Plant-Applied, External Coal Tar Enamel Pipe Coating Systems: Application, Performance, and Quality Control*
- **RP0402-2002:** *Field-Applied Fusion-Bonded Epoxy (FBE) Pipe Coating Systems for Girth Weld Joints: Application, Performance, and Quality Control*
- **RP0602-2002:** *Field-Applied Coal Tar Enamel Pipe Coating Systems: Application, Performance, and Quality Control*
- **SP0108-2008:** *Corrosion Control of Offshore Structures by Protective Coatings*
- **SP0109-2009:** *Field Application of Bonded Tape Coatings for External*

Repair, Rehabilitation, and Weld Joints on Buried Metal Pipelines

- **SP0178-2007:** *Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service*
- **SP0185-2007:** *Extruded Polyolefin Resin Coating Systems with Soft Adhesives for Underground or Submerged Pipe*
- **SP0188-2007:** *Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates*
- **SP0298-2007:** *Sheet Rubber Linings for Abrasion and Corrosion Service*
- **SP0487-2007:** *Considerations in the Selection and Evaluation of Rust Preventives and Vapor Corrosion Inhibitors for Interim (Temporary) Corrosion Protection*
- **SP0490-2007:** *Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 250 to 760 µm (10 to 30 mils)*
- **SP0892-2007:** *Linings over Concrete for Immersion Service*
- **SSPC-PA2**: *Measurement of Dry Coating Thickness with Magnetic Gauges*
- **TM0102-2002:** *Measurement of Protective Coating Electrical Conductance on Underground Pipelines*
- **TM0104-2004:** *Offshore Platform Ballast Water Tank Coating System Evaluation*
- **TM0174-2002:** *Laboratory Methods for the Evaluation of Protective Coatings and Lining Materials in Immersion Service*
- **TM0204-2004:** *Exterior Protective Coatings for Seawater Immersion Service*
- **TM0304-2004:** *Offshore Platform Atmospheric and Splash Zone Maintenance Coating System Evaluation*
- **TM0404-2004:** *Offshore Platform Atmospheric and Splash Zone New Construction Coating System Evaluation*

23.4.2 ISO Standards Related to Protective Coatings

- **ISO 2409:1992**, *Paints and varnishes — Cross-cut test*
- **ISO 2431:1993**, *Paints and varnishes — Determination of flow time by use of flow cups (Corr.2:1999)*
- **ISO 2808:2007**, *Paints and varnishes — Determination of film thickness*
- **ISO 3668:1998,** *Paints and varnishes — Visual comparison of the color of paints*
- **ISO 4617:2000**, *Paints and varnishes — List of equivalent terms (withdrawn)*
- **ISO 4618:2006**, *Paints and varnishes — Terms and definitions*
- **ISO 4624:2002**, *Paints and varnishes — Pull-off test for adhesion*
- **ISO 4628,** *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance*
  - **ISO 4628-1:2003,** *Part 1: General introduction and designation system*
  - **ISO 4628-2:2003**, *Part 2: Assessment of degree of blistering*
  - **ISO 4628-3:2003,** *Part 3:*

Assessment of degree of rusting

- **ISO 4628-4:2003,** *Part 4: Assessment of degree of cracking*
- **ISO 4628-5:2003**, *Part 5: Assessment of degree of flaking*
- **ISO 4628-6:2007**, *Part 6: Rating of degree of chalking by tape method*
- **ISO 4628-7:2003**, *Part 7: Assessment of degree of chalking by velvet method*
- **ISO 4628-8:2005**, *Part 8: Assessment of degree of delamination and corrosion around a scribe*
- **ISO 4628-10:2003,** *Part 10: Assessment of degree of filiform corrosion*

- **ISO 8501,** *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness*
  - **ISO 8501-1:2007,** *Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*
  - **ISO 8501-2:1994,** *Part 2: Representative photographic examples of the change of appearance imparted to steel when blast-cleaned with different abrasives*
  - **ISO 8501-3:2006,** *Part 3: Preparation grades of welds, cut edges and other areas with surface imperfections*
  - **ISO 8501-4:2006,** *Part 4: Initial surface conditions, preparation grades and flash rust grades in connection with high-pressure water jetting*

- **ISO 8502,** *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness*
  - **ISO/TR 8502-1:1991,** *(Withdrawn Standard) Part 1: Field test for soluble iron corrosion products*
  - **ISO 8502-2:2005,** *Part 2: Laboratory determination of chloride on cleaned surfaces*
  - **ISO 8502-3:1992,** *Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)*
  - **ISO 8502-4:1993,** *Part 4: Guidance on the estimation of the probability of condensation prior to paint application*
  - **ISO 8502-5:1998,** *Part 5: Measurement of chloride on steel surfaces prepared for painting (ion detection tube method)*
  - **ISO 8502-6:2006,** *Part 6: Extraction of soluble contaminants for analysis — The Bresle method*
  - **ISO 8502-8:2001,** *Part 8: Field method for the refractometric determination of moisture*
  - **ISO 8502-9:1998,** *Part 9: Field method for the conductometric determination of water-soluble salts*
  - **ISO 8502-10:1999,** *Part 10: Field method for the titrimetric determination of water-soluble chloride*
  - **ISO 8502-11:2006,** *Part 11: Field method for the turbidimetric determination of water-soluble sulfate*
  - **ISO 8502-12:2003,** *Part 12: Field method for the titrimetric*

determination of water-soluble ferrous ions

- **ISO 8503,** *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates*
  - **ISO 8503-1:1988,** *Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces*
  - **ISO 8503-2:1988**, *Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel — Comparator procedure*
  - **ISO 8503-3:1988,** *Part 3: Method for the calibration of ISO surface profile comparators and for the determination of surface profile — Focusing microscope procedure*
  - **ISO 8503-4:1988,** *Part 4: Method for the calibration of ISO surface profile comparators and for the determination of surface profile — Stylus instrument procedure*
  - **ISO 8503-5:2003,** *Part 5: Replica tape method for the determination of the surface profile*
- **ISO 8504,** *Preparation of steel substrates before application of paints and related products — Surface preparation methods*
  - **ISO 8504-1:2000**, *Part 1: General principles*
  - **ISO 8504-2:2000,** *Part 2: Abrasive blast-cleaning*
  - **ISO 8504-3:1993,** *Part 3: Hand- and power-tool cleaning*
- **ISO 11124,** *Preparation of steel substrates before application of paints and related products — Specifications for metallic blast-cleaning abrasives*
  - **ISO 11124-1:1993,** *Part 1: General introduction and classification*
  - **ISO 11124-2:1993**, *Part 2: Chilled-iron grit*
  - **ISO 11124-3:1993**, *Part 3: High-carbon cast-steel shot and grit*
  - **ISO 11124-4:1993,** *Part 4: Low-carbon cast-steel shot*
- **ISO 11125,** P*reparation of steel substrates before application of paints and related products — Test methods for metallic blast-cleaning abrasives*
  - **ISO 11125-1:1993**, *Part 1: Sampling*
  - **ISO 11125-2:1993,** *Part 2: Determination of particle size distribution*
  - **ISO 11125-3:1993,** *Part 3: Determination of hardness*
  - **ISO 11125-4:1993,** *Part 4: Determination of apparent density*
  - **ISO 11125-5:1993,** *Part 5: Determination of percentage defective particles and of microstructure*
  - **ISO 11125-6:1993,** *Part 6: Determination of foreign matter*
  - **ISO 11125-7:1993,** *Part 7: Determination of moisture*
- **ISO 11126,** *Preparation of steel substrates before application of paints and related products — Specifications for non-metallic blast-cleaning abrasives*
  - **ISO 11126-1:1993,** *Part 1: General introduction and classification (Corr. 2: 1997)*
  - **ISO 11126-3:1993,** *Part 3: Copper refinery slag*
  - **ISO 11126-4:1993,** *Part 4: Coal furnace slag*
  - **ISO 11126-5:1993,** *Part 5:*

Nickel refinery slag
  - **ISO 11126-6:1993,** *Part 6: Iron furnace slag*
  - **ISO 11126-7:1995,** *Part 7: Fused aluminum oxide (Corr.1:1999)*
  - **ISO 11126-8:1993,** *Part 8: Olivine sand*
  - **ISO 11126-9:1999,** *Part 9: Staurolite*
  - **ISO 11126-10:2000,** *Part 10: Almandite garnet*
- **ISO 11127,** *Preparation of steel substrates before application of paints and related products — Test methods for non-metallic blast-cleaning abrasives*
  - **ISO 1127-1:1993**, *Part 1: Sampling*
  - **ISO 11127-2:1993**, *Part 2: Determination of particle size distribution*
  - **ISO 11127-3:1993**, *Part 3: Determination of apparent density*
  - **ISO 11127-4:1993**, *Part 4: Assessment of hardness by a glass slide test*
  - **ISO 11127-5:1993**, *Part 5: Determination of moisture*
  - **ISO 11127-6:1993**, *Part 6: Determination of water-soluble contaminants by conductivity measurement*
  - **ISO 11127-7:1993**, *Part 7: Determination of water-soluble chlorides*
- **ISO 12944,** *Paints and varnishes — Corrosion protection of steel structures by protective paint systems*
  - **ISO 12944-1:1998,** *Part 1: General introduction*
  - **ISO 12944-2:1998,** *Part 2: Classification of environments*
  - **ISO 12944-3:1998,** *Part 3: Design considerations*
  - **ISO 12944-4:1998,** *Part 4: Types of surface and surface preparation*
  - **ISO 12944-5:2007**, *Part 5: Protective paint systems*
  - **ISO 12944-6:1998,** *Part 6: Laboratory performance test methods*
  - **ISO 12944-7:1998,** *Part 7: Execution and supervision of paint work*
  - **ISO 12944-8:1998**, *Part 8: Development of specifications for new work and maintenance*
- **ISO/TR 15235:2001,** *Preparation of steel substrates before application of paints and related products — Collected information on the effect of levels of water-soluble salt contamination*
- **ISO 15741:2001,** *Paints and varnishes -- Friction-reduction coatings for the interior of on- and offshore steel pipelines for non-corrosive gases*
- **ISO 16276**, *Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating*
  - **ISO 16276-1:2007,** *Part 1: Pull-off testing*
  - **ISO 16276-2:2007**, *Part 2: Cross-cut testing and X-cut testing*
- **ISO 19840:2004,** *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces*
- **ISO 20340:2009,** *Paints and varnishes — Performance requirements for protective paint systems for offshore and related structures*

- **ISO 14877:2002,** *Protective clothing for abrasive blasting operations using granular abrasives*

23.4.3 Australia/New Zealand Standards

Standards prepared by the Joint Australia/ New Zealand Standards (AS/NZS) Committee, *CH/3 on Paints and Related Materials* are listed below. These are issued under the terms of the Active Cooperation Agreement between Australia and New Zealand for new projects commenced after July 1992.

In the following table are joint standards (except for Part 10) which form part of a series of product standards for industrial paints referred to in AS/NZS 2312:

Table 1: Joint Standards

AS/NZS 3750 Paints for steel structures		Supersedes	PRN
3750.0:2008	Part 0: Introduction and list of Standard	3750.0:1995	
3750.1:2008	Part 1: Epoxy mastic (two-pack) for rusted steel	AS3750.1-1994	C32
3750.2:2008	Part 2: Ultra high-build paint	AS3750.2-1994	C34
3750.3:2008	Part 3: Heat resisting, Exterior	3750.3:1994	C27, C28, C31, C35
3750.4:1994	Part 4: Bitumen paint		C22
3750.5:2008	Part 5: Acrylic full gloss (two pack)	3750.5 1994	C33
3750.6:2009	Part 6: Full gloss polyurethane (two pack)	AS 2692-1983	C26, C28
3750.7:2009	Part 7: Aluminum paint		
3750.8:1994	Part 8: Vinyl paints – Primer, high build and gloss	AS 3886-1991	C16
3750.9:2009	Part 9: Organic zinc-rich primer	AS 2204-1978	C2
AS 3750.10:2008	Part 10: Full gloss epoxy (two pack)	3750.10:1994	C24
3750.11:2009	Part 11: Chlorinated rubber, high build and gloss	AS 2672-1983	C14, C25
3750.12:1996	Part 12: Alkyd/micaceous iron oxide	AS 2673-1983	C17

Table 1: Joint Standards

3750.13:1997	Part 13: Epoxy primer (two pack)	AS 2674-1983	C6
3750.14:1997	Part 14: High build epoxy (two pack)	AS 2364-1990	C13
3750.15:1998	Part 15: Inorganic zinc silicate paint	AS 2105-1992	C1
3750.16:1998	Part 16: Waterborne primer and paint for galvanized, zinc/aluminum alloy coated and zinc primed steel	AS 3885-1991	C11
3750.17:1998	Part 17: Etch primers (single pack and two pack)	AS 3884-1991	C10
AS 3750.18:2002	Part 18: Moisture cure urethane (single-pack) systems		
3750.19:2008	Part 19: Metal primer – General purpose	AS 4089-1993	C4 & C5
3750.20:2008	Part 20: Anticorrosive metal primer – Solvent borne – Lead and chromate free	AS 4025.4-1994	
3750.21:2008	Part 21: Undercoat – Solvent borne	AS 4025.2-1993	
3750.22:2008	Part 22: Full gloss enamel – Solvent borne	AS 4025.1-1993	C20
3750.23:2008	Part 23: Semi-gloss enamel – Solvent borne	AS 4025.3-1993	

(**Note**: Paint Reference Number (PRN) used is AS/NZS 2312)

The following standards have been developed for use by coatings inspectors and may be referenced in technical specifications for protective coating contracts.

- AS 3894, Site testing of protective coatings
  - — 3894.0-2002, Introduction and list of test methods
  - — 3894.1-2002, Method 1: Non-conductive coatings – Continuity testing – High voltage (brush method)
  - — 3894.2-2002, Method 2: Non-conductive coatings – Continuity testing – Wet sponge method
  - — 3894.3-2002, Method 3: Determination of dry film thickness
  - — 3894.4-2002, Method 4: Assessment of degree of cure
  - — 3894.5-2002, Method 5: Determination of surface profile
  - — 3894.6-2002, Method 6: Determination of residual contaminants:
    - Method A: Chlorides
    - Method B: Oil or water droplets
    - Method C: Surface dust
    - Method D: Soluble salts of

iron
- Method E: Mill scale

— 3894.7-2002, Method 7: Determination of surface temperature
— 3894.8-2002, Method 8: Visual determination of gloss
— 3894.9:2003, Method 9: Determination of adhesion
— 3894.10-2002, Method 10: Inspection report – Daily surface and ambient conditions
— 3894.11-2002, Method 11: Equipment report
— 3894.12-2002, Method 12: Inspection report – Coating
— 3894.13-2002, Method 13: Inspection report – Daily (blast and paint)
— 3894.14-2002, Method 14: Inspection report – Daily painting

Other coating related Standards include:

- AS 1627 Metal finishing-Preparation and pretreatment of surfaces (under review):
  — 1627.0-1997 Method selection guide
  — 1627.1-2003 Cleaning using liquid solvents and alkaline solutions
  — 1627.2-2002 Power tool cleaning
  — 1627.3-1988 Flame descaling (withdrawn in 2002)
  — 1627.4-2005 Abrasive blast cleaning
  — 1627.5-2003 Pickling, descaling and oxide removal
  — 1627.6-2003 Chemical conversion treatment of metals
  — 1627.9-2002 Pictorial surface preparation standards for painting steel surfaces (ISO 8501-1)
- DR 00083-2001 The storage and handling of flammable paints and paint related material (terminated in 2000. Instead refer to:
- AS 1940-2004 (Amdt.2 2006) The storage and handling of flammable and combustible liquids)
- AS/NZS 2310:2002 Glossary of paint and painting terms (Under revision as DR07334)
- AS/NZS 2311:2009 Guide to the painting of buildings
- AS/NZS 2312:2002 (Amdt.1-2004)Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
- AS 700-1996 Colour standards for general purposes
- AS/NZS 4114:2003 Spray painting booths:
  — Part 1: Design, construction and testing
  — Part 2: Installation and maintenance
- AS/NZS 4233:1999 High pressure water (hydro) jetting systems:
  — Part 1: Guidelines for safe operation and maintenance
  — Part 2: Construction and performance
- AS 4361 Guide to lead paint management:
  — Part.1: 1995 Industrial applications
  — Part.2: 1998 Residential and commercial buildings

Other common standards for coatings inspection work may also come from **ASTM, ANSI, SSPC** and other prominent organizations. These standards can be obtained by or all of the following ways:

- Purchase via website
- Purchase by phone
- Purchase by mail

Regardless of the specified standard, the job of the coatings inspector remains the same;

obtain, read, understand and verify per the specification.

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Study Guide

1. What is a standard?

_____
_____
_____
_____

2. What percentage of NACE standards relate to coatings?

_____

Supplement to Systems and Specifications,
SSPC Painting Manual Volume 2, Eighth Edition

SSPC-PA 2

Measurement of Dry Coating Thickness With Magnetic Gages

SSPC Publication No. 04-08

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SSPC: The Society for Protective Coatings

SSPC-PA 2

Measurement of Dry Coating Thickness With Magnetic Gages

1. Scope

1.1 GENERAL: This standard describes the procedures to measure the thickness of a dry film of a nonmagnetic coating applied on a magnetic substrate using commercially available magnetic gages. These procedures are intended to supplement manufacturers' operating instructions for the manual operation of the gages and are not intended to replace them.

1.2 The procedures for adjustment and measurement are described for two types of gages: pull-off gages (Type 1) and electronic gages (Type 2).

1.3 The standard defines a procedure to determine if the film thickness over an extended area conforms to the minimum and the maximum levels specified. This procedure may be modified when measuring dry film thickness on overcoated surfaces (see Note 7.1).

2. Description and Use

2.1 DEFINITIONS

2.1.1 Gage Reading: A single reading at one point.

2.1.2 Spot Measurement: The average of at least three gage readings made within a 4 cm (1.5 inch) diameter circle.

2.1.3 Calibration: The controlled and documented process of measuring traceable calibration standards and verifying that the results are within the stated accuracy of the gage. Calibrations are typically performed by the gage manufacturer or by a qualified laboratory in a controlled environment using a documented process. The standards used in the calibration are such that the combined uncertainties of the resultant measurement are less than the stated accuracy of the gage.

2.1.4 Verification: An accuracy check performed by the user using known reference standards.

2.1.5 Adjustment: The act of aligning the gage's thickness readings to match those of a known sample in order to improve the accuracy of the gage on a specific surface or in a specific portion of its measurement range. Most Type 2 gages can be adjusted on a coated part or on a shim, where the thickness of the coating or of the shim is known.

2.1.6 Coating Thickness Standard (Test Block): A smooth ferromagnetic substrate with a nonmagnetic coating of known thickness that is traceable to national standards.

2.1.7 Shim (Foil): A thin strip of non-magnetic plastic, metal, or other material of known uniform thickness used to verify the accuracy of coating dry film thickness gages.

2.1.8 Dry Film Thickness Reference Standard: A sample of known thickness used to verify the accuracy of the gage, such as coated thickness standards or shims. In some instances with the owner's permission, a sample part (a particular piece of coated steel) is used as a thickness standard for a particular job.

2.1.9 Accuracy: Consistency between a measured value and the true value of the thickness standard.

2.1.10 Structure: A unit composed of one or more connected steel members comprising a bridge, tank, ship, etc. It is possible for a single steel shape (beam, angle, tee, pipe, channel, etc.) to be considered a structure, if it is painted in a shop.

2.2 DESCRIPTION OF GAGES

2.2.1 Gage Types: The gage type is determined by the specific magnetic properties employed in measuring the thickness and is not determined by the mode of data readout, i.e. digital or analog. This standard does not cover gages that measure the effect of eddy currents produced in the substrate (see Note 7.2).

2.2.2 Type 1 – Pull-Off Gages: In pull-off gages, a permanent magnet is brought into direct contact with the coated surface. The force necessary to pull the magnet from the surface is measured and interpreted as the coating thickness value on

a scale or display on the gage. Less force is required to remove the magnet from a thick coating. The scale is nonlinear.

2.2.3 Type 2 – Electronic Gages: An electronic gage uses electronic circuitry to convert a reference signal into coating thickness.

2.3 USE OF PAINT APPLICATION STANDARD NO. 2: This document contains the following:

- Calibration, verification, adjustment, and measurement procedures (Section 3);
- Required number of measurements for conformance to a thickness specification (Section 4);
- Notes on gage principles and various factors affecting thickness measurement (Notes 7.2 to 7.18);
- A numerical example of thickness measurement over an extended area (Appendix 1);
- A numerical example of the calibration adjustment of Type 2 gages using plastic shims (Appendix 2);
- An example protocol for measuring DFT on beams or girders (Appendix 3);
- An example protocol for measuring DFT for a laydown painted in a shop (Appendix 4);
- An example protocol for measuring DFT on test panels (Appendix 5);
- An example protocol for measuring DFT of thin coatings on blast cleaned test panels (Appendix 6).

3. Calibration, Verification, Adjustment, and Measurement Procedures

3.1 GENERAL

3.1.1 ACCESS TO BARE SUBSTRATE: All gages are affected to some degree by substrate conditions such as roughness, shape, thickness, and composition (see Notes 7.3 to 7.8). To correct for this effect, access to the uncoated substrate is recommended. Another option is to use separate uncoated reference panels with similar roughness, shape, thickness, and composition (see Notes 7.3 to 7.8). These would be used as the bare substrate in the procedures of Sections 3.2, 3.3 and 3.4. Reference panels shall be of sufficient size to preclude edge effects (see Note 7.9). Other conditions that could affect measurements are described in Notes 7.10 to 7.14. Measurements on the bare substrate are taken before the coating is applied or by masking off small representative areas during painting. If the coating has already been applied to the entire surface, it is customary to remove small areas of coating for measurement and later patch them. Do not allow the removal process to alter the condition of the substrate. If chemical paint strippers are used, the existing profile will be retained (see Section A2.3).

3.1.2 SPOT MEASUREMENT: Repeated gage readings, even at points close together, often differ due to small surface irregularities of the coating and the substrate. Therefore, a minimum of three (3) gage readings shall be made for each spot measurement of either the substrate or the coating. For each new gage reading, move the probe to a new location within the 4 cm (1.5 inch) diameter circle defining the spot. Discard any unusually high or low gage reading that is not repeated consistently. Take the average of the acceptable gage readings as the spot measurement.

3.1.3 CALIBRATION: Gages must be calibrated by the manufacturer or a qualified lab. A Certificate of Calibration or other documentation showing traceability to a national standard is required. There is no standard time interval for re-calibration, nor is one absolutely required. Calibration intervals are usually established based upon experience and the work environment. A one-year calibration interval is a typical starting point suggested by gage manufacturers.

3.2 VERIFICATION OF ACCURACY

3.2.1 Measure the thickness of a series of reference standards covering the expected range of coating thickness (see Note 7.15). To guard against measuring with an inaccurate gage, the gage shall be checked at least at the beginning and the end of each work shift with one or more of the reference standards. If the gage is dropped or suspected of giving erroneous readings during the work shift, its accuracy shall be rechecked.

3.2.2 Record the serial number of the gage, the reference standard used, the stated thickness of the reference standard as well as the measured thickness value obtained, and the method used to verify gage accuracy. If the same gage, reference standard, and method of verification are used throughout a job, they need to be recorded only once. The stated value of the standard and the measured value must be recorded each time calibration is verified.

3.2.3 If readings do not agree with the reference standard, all measurements made since the last accuracy check are suspect. In the event of physical damage, wear, or high usage, or after an established calibration interval, the gage shall be rechecked for accuracy of measurement. If the gage is not measuring accurately, it shall not be used until it is repaired and/or recalibrated (usually by the manufacturer).

3.2.4 Shims of plastic or of non-magnetic metals which are acceptable for verifying the accuracy of Type 2 (electronic) gages are not used for verifying the accuracy of the Type 1 gages (see Note 7.2.1).

3.3 ADJUSTMENT AND MEASUREMENT - TYPE 1, PULL-OFF GAGES

3.3.1 Type 1 gages have nonlinear scales and any adjusting feature is linear in nature. Any adjustment of these gages will limit the DFT range for which the gage will provide accurate readings, and is not recommended.

3.3.2 Measure the bare substrate at a number of spots to obtain a representative average value. This average value is the base metal reading (BMR). CAUTION: the gage is not to be adjusted to read zero on the bare substrate.

3.3.3 Measure the dry coating at the number of spots specified in Section 4.

3.3.4 Subtract the base metal reading from the gage reading to obtain the thickness of the coating.

3.4 ADJUSTMENT AND MEASUREMENT - TYPE 2, ELECTRONIC GAGES

3.4.1 Different manufacturers of Type 2 (electronic) gages follow different methods of adjustment for measuring dry film thickness over a blast-cleaned surface. Adjust the gage according to the manufacturer's instructions (see Appendix 2).

3.4.2 Measure the dry coating at the number of spots specified in Section 4.

4. Required Number of Measurements for Conformance to a Thickness Specification

4.1 NUMBER OF MEASUREMENTS: Make five (5) separate spot measurements (average of the gage readings, see Section 3.1.2) spaced arbitrarily over each 10 m^2 (100 ft^2) area to be measured. If the contracting parties agree, more than five (5) spot measurements may be taken in a given area (see Section 4.1.5). The five spot measurements shall be made for each 10 m^2 (100 ft^2) of area as follows:

4.1.1 For structures not exceeding 30 m^2 (300 ft^2) in area, each 10 m^2 (100 ft^2) area shall be measured.

4.1.2 For structures not exceeding 100 m^2 (1,000 ft^2) in area, three 10 m^2 (100 ft^2) areas shall be arbitrarily selected by the inspector and measured.

4.1.3 For structures exceeding 100 m^2 (1,000 ft^2) in area, the first 100 m^2 (1,000 ft^2) shall be measured as stated in Section 4.1.2 and for each additional 100 m^2 (1,000 ft^2) of area or increment thereof, one 10 m^2 (100 ft^2) area shall be arbitrarily selected by the inspector and measured.

4.1.4 If the dry film thickness for any 10 m^2 (100 ft^2) area (see Sections 4.1.2 and 4.1.3) is not in compliance with the requirements of Sections 4.3.1 and 4.3.2, then additional measurements must be made to isolate the non-conforming area, and each 10 m^2 (100 ft^2) area painted during that work shift shall be measured.

4.1.5 Other size areas or number of spot measurements may be specified by the owner in the job specifications as appropriate for the size and shape of the structure to be coated (see Appendices 3, 4, 5, and 6).

4.2 SPECIFYING THICKNESS: It is recommended that both a maximum and a minimum DFT thickness be specified for the coating. If a maximum thickness value is not explicitly specified, the specified thickness shall be the minimum and Section 4.3.2 would not apply.

4.3 CONFORMANCE TO SPECIFIED THICKNESS

4.3.1 Minimum Thickness: The average of the spot measurements for each 10 m^2 (100 ft^2) area shall not be less than the specified minimum thickness. Although *no single spot measurement* in any 10 m^2 (100 ft^2) area shall be less than 80% of the specified minimum thickness, it is possible for *any single gage reading* to under-run by a greater amount. If the average of the spot measurements for a given 10 m^2 (100 ft^2) area meets or exceeds the specified minimum thickness, but one or more spot measurements is less than 80% of the specified minimum thickness, additional measurements will more precisely define the non-conforming area and facilitate repair (see Appendix 1 and Notes 7.16 and 7.17).

4.3.2 Maximum Thickness: The average of the spot measurements for each 10 m^2 (100 ft^2) area shall not be more than the specified maximum thickness. Although no *single spot measurement* in any 10 m^2 (100 ft^2) area shall be more than 120% of the specified maximum thickness, it is possible for *any single gage reading* to over-run by a greater amount. If the average of the spot measurements for a given 10 m^2 (100 ft^2) area meets or falls below the specified maximum thickness, but one or more spot measurements is more than 120% of the specified maximum thickness, additional measurements will more precisely define the non-conforming area and facilitate repair (see Appendix 1 and Notes 7.16 and 7.17).

5. Accuracy

5.1 To qualify under this standard, a gage must have an accuracy at least within ± 5% (see Note 7.18). For thicknesses less than 25 μm (1 mil), the gage must have an accuracy at least within ± 2.5 μm (0.1 mil).

6. Disclaimer

6.1 While every precaution is taken to ensure that all information furnished in SSPC standards and specifications is as accurate, complete, and useful as possible, SSPC cannot assume responsibility nor incur any obligation resulting from the use of any materials, coatings or methods specified therein, or of the specification or standard itself.

6.2 This standard does not attempt to address problems concerning safety associated with its use. The user of this standard, as well as the user of all products or practices described herein, is responsible for instituting appropriate health and safety practices and for ensuring compliance with all governmental regulations.

7. Notes

Notes are not requirements of this standard.

7.1 OVERCOATING: Maintenance painting often involves application of a new coating over an existing coating system. It is very difficult to accurately measure the DFT of this newly applied coating using non-destructive methods. First, access to the profile is not available, compromising the accuracy of the BMR or the adjustment of a Type 2 gage. Second, unevenness in the DFT of the existing coating necessitates careful mapping of the "before and after" DFT readings. This unevenness also adds to the statistical variation in trying to establish a base DFT reading to be subtracted from the final DFT.

A paint inspection gage (sometimes called a Tooke or PIG gage) will give accurate DFT measurements, but it cuts through the coating, so each measurement site must be repaired. Ultrasound gages may be used, but their accuracy is much less than a Type 1 or a Type 2 gage. A practical approach to monitoring DFT when overcoating is to compute DFT from wet film thickness readings and the volume solids of the coating being applied.

If the DFT of the existing coating is not too uneven, the average DFT of the existing coating can be measured to establish a base DFT. This base DFT is then subtracted from the total DFT to get the thickness of the overcoat(s).

7.2 PRINCIPLES OF THE MAGNETIC GAGE: Each of these gages can sense and indicate only the distance between the magnetic surface of the steel and the small rounded tip of the magnet or probe that rests on the top surface of the coating. For this measured distance (from the top surface of the coating to the magnetic zero) to equal the coating thickness above the peaks, the gage readings must be corrected for the profile of the steel surface and to a lesser extent the composition and shape of the steel. Such correction is made as described in Section 3.3 for Type 1 gages and Section 3.4 for Type 2 gages.

7.2.1 Type 1 (pull-off) gages measure the force needed to pull a small permanent magnet from the surface of the coated steel. The magnetic force holding the magnet to the surface varies inversely as a non-linear function of the distance between magnet and steel, i.e., the thickness of the dry coating (plus any other films present).

Normally, Type 1 gages are not adjusted or reset for each new series of measurements. Shims of sheet plastic or of non-magnetic metals, which are permissible for adjusting Type 2 (electronic) gages should not be used for adjusting Type 1 gages. Such shims are usually fairly rigid and curved and do not lie perfectly flat, even on a smooth steel test surface. Near the pull-off point of the measurement with any Type 1 gage, the shim frequently springs back from the steel surface, raising the magnet too soon and causing an erroneous reading.

7.2.2 Type 2 (electronic) gages operate on two different magnetic principles. Some Type 2 gages use a permanent magnet. When the magnet is brought near steel, the magnetic flux density at the tip of the magnet is increased. By measuring this change in flux density, which varies inversely to the distance between the magnet and the steel substrate, the coating thickness can be determined. Hall elements and magnet resistance elements positioned at the tip of the magnet are the most common ways that this change in magnetic flux density is measured. Other Type 2 gages operate on the principle of electromagnetic induction. A coil containing a soft iron rod is energized with an AC current thereby producing a changing magnetic field at the tip of the probe. As with a permanent magnet, the magnetic flux density within the rod increases when the probe is brought near the steel substrate. This change is easy to detect by using additional coils. The output of these coils is related to coating thickness.

7.3 REPEATABILITY: Magnetic gages are necessarily sensitive to very small irregularities of the coating surface or of the steel surface directly below the probe center. Repeated gage readings on a rough surface, even at points very close together, frequently differ considerably, particularly for thin films over a rough surface with a high profile.

7.4 ZERO SETTING: Type 1 magnetic gages should not be adjusted or set at the scale zero (0) with the gage applied to either a rough or a smooth uncoated steel surface. Some Type 2 gages can be adjusted to read zero (0) on an uncoated blast cleaned surface. In all cases follow the manufacturer's recommendations.

7.5 ROUGHNESS OF THE STEEL SURFACE: If the steel surface is smooth and even, its surface plane is the effective magnetic surface. If the steel is roughened, as by blast cleaning, the "apparent" or effective magnetic surface that the gage

senses is an imaginary plane located between the peaks and valleys of the surface profile. Gages read thickness above the imaginary magnetic plane. If a Type 1 gage is used, the coating thickness above the peaks is obtained by subtracting the base metal reading (see Section 3.3). With a correctly calibrated and adjusted Type 2 gage, the reading obtained indicates the coating thickness above the peaks (see Section 3.4).

7.6 DIRTY, TACKY, OR SOFT FILMS: The surface of the coating and the probe of the gage must be free from dust, grease, and other foreign matter in order to obtain close contact of the probe with the coating. The accuracy of the measurement will be affected if the coating is tacky or excessively soft. Tacky coating films may cause unwanted adhesion of the magnet of a Type 1 gage. Unusually soft films may be dented by the pressure of the probe of a Type 1 or a Type 2 gage. Soft or tacky films can sometimes be measured satisfactorily with Type 2 gages by putting a shim on the film, measuring total thickness of coating plus shim, and subtracting shim thickness.

7.6.1 Ordinary dirt and grease can be removed from a probe by wiping with a soft cloth. Magnetic particles adhering to the probe can be removed using an adhesive backed tape. Any adhesive residue left on the probe must then be removed.

7.7 ALLOY STEEL SUBSTRATES: Differences among most mild low-carbon steels and high strength low alloy (HSLA) steels will not significantly affect magnetic gage readings. For higher alloy steels, the gage response should be checked. Regardless of the alloy type, the gage should be adjusted to the same steel over which the coating has been applied.

7.8 CURVATURE OF STEEL SURFACE: Magnetic gage readings may be affected by surface curvature. If the curvature is appreciable, valid measurements may still be obtained by adjusting the gage on a similarly curved surface.

7.9 PROXIMITY TO EDGES: Magnetic gages are sensitive to geometrical discontinuities of the steel, such as holes, corners or edges. The sensitivity to edge effects and discontinuities varies from gage to gage. Measurements closer than 2.5 cm (1 inch) from the discontinuity may not be valid unless the gage is adjusted specifically for that location.

7.10 PROXIMITY TO OTHER MASS OF STEEL: The older two-pole gages with permanent magnets are sensitive to the presence of another mass of steel close to the body of the gage. This effect may extend as much as 8 cm (3 inches) from an inside angle.

7.11 TILT OF PROBE: All of the magnets or probes must be held perpendicular to the coated surface to produce valid measurements.

7.12 OTHER MAGNETIC FIELDS: Strong magnetic fields, such as those from welding equipment or nearby power lines, may interfere with operation of the gages. Residual magnetism in the steel substrate may also affect gage readings. With fixed probe two-pole gages in such cases, it is recommended that the readings before and after reversing the pole positions be averaged. Other gages may require demagnetization of the steel.

7.13 EXTREMES OF TEMPERATURE: Most of the magnetic gages operate satisfactorily at 4°C and 49°C (40°F and 120°F). Some gages function well at much higher temperatures. However, if such temperature extremes are met in the field, the gage might well be checked with at least one reference standard after both the standard and the gage are brought to the same ambient temperature. Most electronic gages compensate for temperature differences among the gage, the probe, and the surface.

7.14 VIBRATION: The accuracy of the Type 1 (pull-off) gages is affected by traffic, machinery, concussions, etc. When these gages are set up for verification of calibration or measurement of coating films, there should be no apparent vibration.

7.15 COATING THICKNESS STANDARDS: Coating thickness standards consisting of coated steel plates with assigned thickness values traceable to national standards are available from several sources, including most manufacturers of coating thickness gages. Shims of known thicknesses are also available from most of these same sources.

7.16 VARIATION IN THICKNESS – 80% of MINIMUM/ 120% of MAXIMUM: In any measurement there is a certain level of uncertainty. Two inspectors using the same gage will not necessarily record the exact same number for a given spot measurement using the same 4 cm (1.5 inch) diameter circle. To allow for this natural fluctuation, an individual spot measurement is permitted to be below the specified minimum thickness as long as other spots in the 10 m^2 (100 ft^2) area are high enough to make the average thickness meet or exceed the specified minimum thickness. Similar reasoning applies to maximum thickness. The 80% of specified minimum and 120% of specified maximum allow for the accuracy of the gage and reference standards and for variations in the substrate.

7.17 CORRECTING LOW OR HIGH THICKNESS: The contracting parties should agree upon the method of correcting film thicknesses that are above the maximum or below the minimum specification. This method may be specified in the procurement documents, may follow manufacturer's instructions, or may be a compromise reached after the non-conforming area is discovered.

7.18 TYPE 1 PEN GAGES: Instances may arise where a pen-type pull-off gage is the only practical method for measuring DFT. Although these gages do not normally meet the 5% accuracy requirement, they may be used if the contracting parties agree.

APPENDIX 1 - Numerical Example of Average Thickness Measurement

Appendix 1 does not form a mandatory part of this standard.

The following numerical example is presented as an illustration of Section 4. Metric values are calculated equivalents from U.S. Customary measurements. (Reference *Journal of Protective Coatings and Linings*, Vol. 4, No 5, May 1987.)

Suppose this structure is 30 m^2 (300 ft^2) in area. Mentally divide the surface into three equal parts, each being about 10 m^2 (100 ft^2).

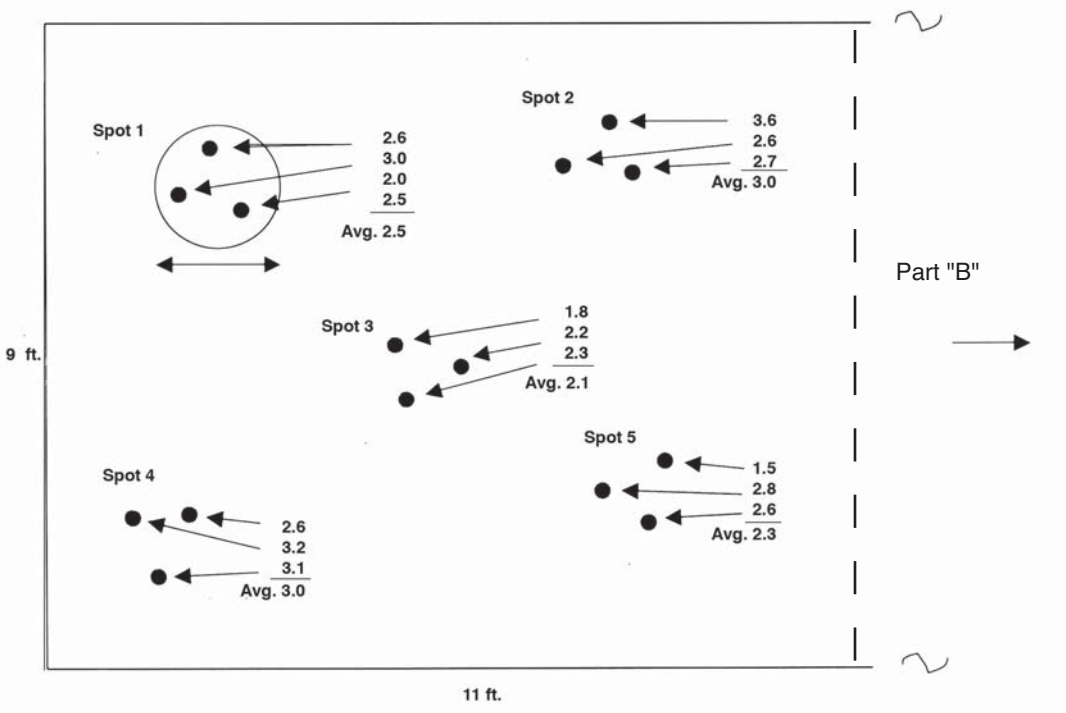
Part A - 10 m^2 (100 ft^2)
Part B - 10 m^2 (100 ft^2)
Part C - 10 m^2 (100 ft^2)

First, measure the coating thickness on Part A. This involves at least 15 readings of the thickness gage (see Figure A1). Assume the specification calls for 64 μm (2.5 mils) minimum thickness. The coating thickness for area A is then the average of the five spot measurements made on area A, namely 66 μm (2.6 mils).

Spot 1	64 μm	2.5 mils
Spot 2	76	3.0
Spot 3	53	2.1
Spot 4	76	3.0
Spot 5	58	2.3
Average	66 μm	2.6 mils

Considering the U.S. Customary Measurements: The average, 2.6 mils, exceeds the specified minimum of 2.5 mils and thus satisfies the specification. Next, determine if the lowest spot measurement, 2.1 mils, is within 80% of the specified minimum thickness. Eighty percent of 2.5 mils is 2.0 mils (0.80 x 2.5 = 2.0). Although 2.1 mils is below the specified minimum, it is still within 80 percent of it, so the specification is satisfied. There are individual gage readings of 1.5 mils at spot 5 and 1.8 mils at spot 3, both of which are clearly less than 2.0 mils. This is allowed because only the average of the three readings (i.e. the spot measurement) must be greater than or equal to 2.0 mils.

Figure A1
Part "A" of Structure (approximately 10 m^2 [100 ft^2])
Gage readings in mils



Considering Equivalent Metric Measurements: The average, 66 μm, exceeds the specified minimum of 64 μm and thus satisfies the specification. Next, determine if the lowest spot measurement, 53 μm, is within 80% of the specified minimum thickness. Eighty percent of 64 μm is 51 μm (0.80 x 64 = 51). Although 53 μm is below the specified minimum, it is still within 80% of it so the specification is satisfied. There are individual gage readings of 38 μm (1.5 mils) at spot 5 and 46 μm (1.8 mils) at spot 3, both of which are clearly less than 51 μm. This is allowed because only the average of the three readings (i.e., the spot measurement) must be greater than or equal to 51 μm.

Since the structure used in this example is about 30 m^2 (300 ft^2), the procedure used to measure the film thickness of part A must be applied to both part B and part C. The measured thickness of part B must exceed the 64 μm (2.5 mils) specified minimum, as must the thickness of part C.

To monitor the thickness of this entire 30 m^2 (300 ft^2) structure, at least 45 individual gage readings must be taken, from which 15 spot measurements are calculated. The five spot measurements from each 10 m^2 (100 ft^2) part of the structure are used to calculate the thickness of that part.

APPENDIX 2 - Examples of the Adjustment of Type 2 Gages Using Shims

Appendix 2 does not form a mandatory part of this standard.

This example describes a method of adjustment to improve the effectiveness of a Type 2 (electronic) gage on a blast cleaned or otherwise roughened surface. Blast cleaning is used throughout this example, but these methods are applicable to other types of surface preparation. A less uniform surface, such as partially rusted hand tool cleaned steel, may require more gage readings to achieve a satisfactory level of statistical significance. Since gage operation differs among manufacturers, follow the manufacturer's instructions for adjustment of a particular gage.

A Type 2 gage needs to be adjusted to account for the profile of the substrate in order to read the coating thickness directly.

A portion of the substrate, after blast cleaning but prior to coating, can be used to adjust the gage. Alternatively, an uncoated test panel, blasted at the time the structure was blast cleaned and having a profile representative of the structure can be used to adjust the gage provided the test panel is of material with similar magnetic properties and geometry as the substrate to be measured. If this is not available then a correction value can be applied to a smooth surface adjustment as described below.

Three adjustment techniques can be used depending on the capability and features of the gage to be used for the inspection. Note that due to the statistical variation produced by a roughened surface, individual readings taken using these three methods may not perfectly agree.

The first two examples describe adjustment and verification to one or more shims. When shims are used, resultant gage measurements are less accurate and must be recalculated. For example, the accuracy of a properly calibrated gage is probably ± 2%. The thickness of a shim might be accurate to within ± 3%. The combined tolerance of the gage and the shim will be ± 4% as given by the sum of squares formula:

$$\sqrt{2^2 + 3^2} = 3.6055 \approx 4$$

For the gage to be in agreement with the shim, the average thickness measured by the gage must be within ±4% of the shim's thickness. If the average thickness measured on a 250 μm (10 mil) shim is between 240 μm (9.6 mils) and 260 μm (10.4 mils), the gage is properly adjusted. The minimum 240 is 250 minus 4% of 250 (9.6 is 10 minus 4% of 10); the maximum of 260 is 250 plus 4% of 250 (10.4 is 10 plus 4% of 10). [4% of 250 is 10; 4% of 10 is 0.4.]

A2.1 SINGLE POINT CALIBRATION ADJUSTMENT: This example uses a single shim value at or close to the thickness to be measured. The thickness range over which this adjustment achieves the required accuracy will vary with gage design.

Assuming that the coating thickness to be measured is 100 μm (4.0 mil), then a shim of approximately 100 μm (4.0 mil) should be used to adjust the gage. The shim is placed on an area of the substrate that has been blast cleaned to the required standards, or on a blasted test coupon with a similar surface profile.

The average of 10 readings on the shim is sufficient to allow for the statistical variation in the blast profile.

A2.2 TWO POINT CALIBRATION ADJUSTMENT: This example uses two shim values, one above and one below the expected film thickness to be measured. It should be noted that not all film thickness gages can be adjusted in this manner.

Assuming that the coating thickness to be measured is 100 μm (4.0 mil), then shims of 250 μm (10.0 mil) and 50 μm (2.0 mil) are appropriate for setting the upper and lower values on the scale of the gage.

As protective coatings are normally applied to blast cleaned metal surfaces, a statistical approach is required to obtain a typical value for the adjustment. Ten readings on a shim are sufficient to establish a reliable average value for that shim on the roughened surface. Following the manufacturer's instructions, the gage is adjusted so that the actual shim thickness is then used to set the gage.

This procedure should be repeated for both the upper and lower shim values.

The average of 10 readings on an intermediate shim, approximately 100 μm (4.0 mil) thick in the case described

above, will confirm that the gage has been adjusted correctly. It is acceptable for the average reading to be within ± 4% of the shim thickness.

This method ensures that the gage reads the thickness of the coating over the peaks of the profile.

A2.3 SMOOTH SURFACE CALIBRATION ADJUSTMENT: If access to the bare blast cleaned substrate is not available because the coating already covers it, a smooth surface can be used to adjust the gage. Adjust the gage on a smooth surface according to the manufacturer's instructions.

Readings taken on the blast-cleaned substrate will be higher than the true value by an amount dependant on the surface profile and the gage probe design. For most applications a correction value of 25 μm (1.0 mil) is generally applicable. Note that this value is not related to the actual surface profile measurement. This correction value must be subtracted from each gage reading to correct for the effect of the profile. The resulting corrected reading represents the thickness of the coating over the peaks.

For fine profiles the correction value may be as low as 10 μm (0.4 mil) but for coarse profiles it could be as high as 40 μm (1.6 mil). Table A2 gives approximate correction values to be used when a blast cleaned surface is not available to adjust the gage.

The use of coated standards to adjust gages means that a correction value must be applied to readings as the coated standards make use of smooth substrate surfaces.

APPENDIX 3 - Methods for Measuring Dry Film Thickness on Steel Beams (Girders)

Appendix 3 is not a mandatory part of this standard, but it provides two sample protocols for measuring DFT on beams and girders.

Table A2
Typical Gage Correction Values Using ISO 8503 Profile Grades (Source: prEN ISO 19840)[1]

ISO 8503 Profile Grade	Correction Value (μm)	Correction Value (mil)
Fine	10	0.4
Medium	25	1.0
Coarse	40	1.6

A3.1 A problem for the painter in coating steel beams or girders is providing the same uniform thickness over high and low vertical surfaces as over horizontal surfaces. On a beam, there are proportionately more edges that tend to have low dry film thickness (DFT) and inside corners that tend to have high DFT compared to the center of the flat surfaces. Each painter usually develops a pattern of work for a specific task. Hence, the DFT on the underside of the top flange, for example, may be consistently on the high side or the low side of the target DFT. This type of error is easy to detect and correct. Random errors pose a more difficult problem. Gross errors where the paint is obviously too thin or too thick must be corrected and are beyond the scope of this standard.

The number of spot measurements in these protocols may far exceed the "5 spot measurement per 10 m^2 (100 ft^2)" required in the standard. The full DFT determination, described in Section A3.2, provides a very thorough inspection of the beam. The sample DFT determination, described in Section A3.4, allows for fewer spot measurements. The user does not have to require a full DFT determination for every beam in the structure. For example, the requirement may be for a full DFT determination on one beam out of ten, or a sample DFT determination on one beam out of five, or a combination of full and sample DFT determinations.

A beam has twelve different surfaces as shown in Figure A3. Any one of these surfaces may have a DFT outside the specified range, and hence, shall be measured. If the thickness of the flange is less than 25 mm (1 inch), the contracting parties may choose not to measure the DFT on the toe,[2] i.e., surfaces 2, 6, 8, and 12 of Figure A3. As an informal initial survey, the inspector may want to check for uniformity of DFT across each surface. Is the DFT of the flange near the fillet the same as near the toe? Is the DFT uniform across the web? The inspector must be sure to use a gage that is not susceptible to edge effects. Follow the gage manufacturer's instructions when measuring the edges.

A3.2 FULL DFT DETERMINATION OF A BEAM: Divide the beam or girder into five equal sections along its length. Identify the 12 surfaces of the beam as shown in Figure A3 for each section. For tall beams where the height of the beam is 91 cm (36 inches) or more, divide the web in half along the length of the beam. For the full DFT determination, each half of the web is considered a separate surface. Take one spot measurement (as defined in Section 3.1.2) on surface 1 in each of the five sections. The location of the surface 1 measurement within a section is arbitrarily chosen by the inspector in each of the five sections. The average of these five spot measurements is the

[1] International Organization for Standardization (ISO), Case Postale 56, Geneva CH-1211, Switzerland. ISO standards may be obtained through the American National Standards Institute (ANSI), 1819 L Street NW, Suite 600 Washington DC 20036. Standards may also be downloaded from http://www.ansi.org. The standard from which this data originates is under development and has not formally been adopted as of June 1, 2004.

[2] On rolled beams, measurement of surfaces 2, 6, 8, and 12 may not be practical.

Figure A.3
The Surfaces of a Steel Beam

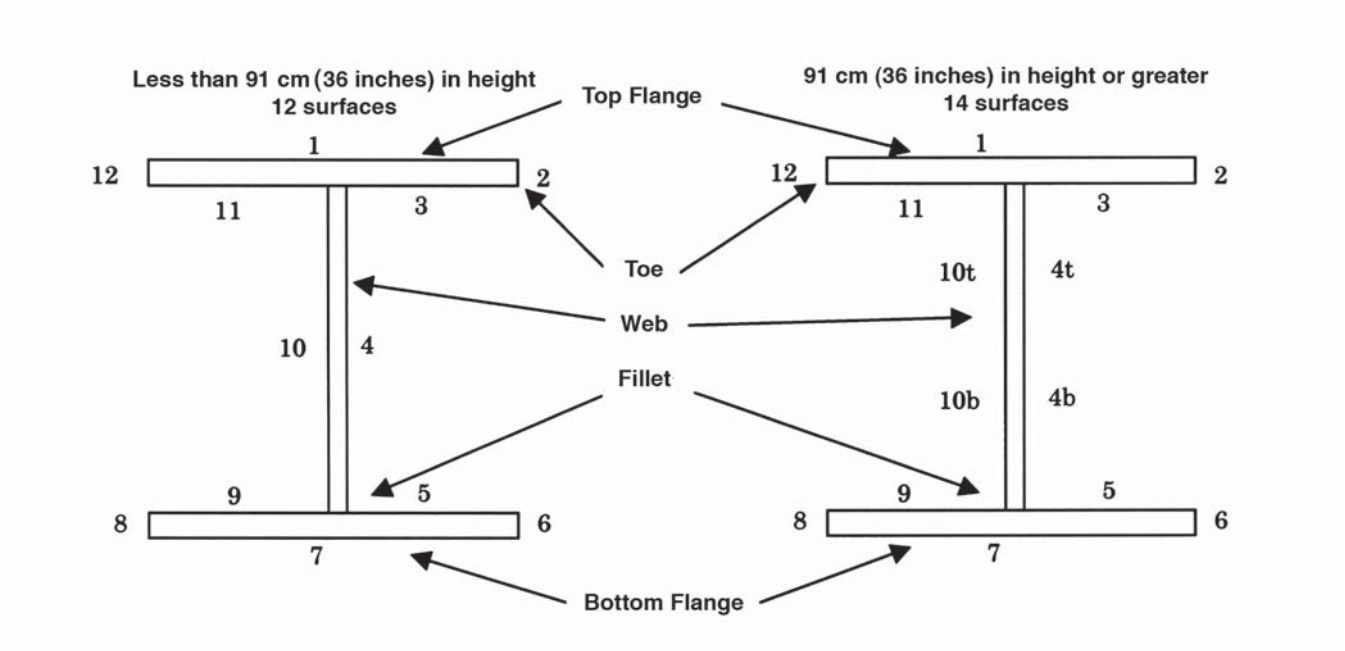


Table A3
Datasheet for Recording Spot Measurements and Average DFT Values for the 12 Surfaces of a Beam or Girder

Surface*	Section 1	Section 2	Section 3	Section 4	Section 5	Average
1						
2						
3						
4t						
4b						
5						
6						
7						
8						
9						
10t						
10b						
11						
12						

* t = top half of web (for tall beams)
b = bottom half of web (for tall beams)

DFT of surface 1. Repeat for the other 11 surfaces (7 surfaces if the toe is not measured; 14 surfaces for tall beams). The data can be reported in a format shown in Table A3.1.

A3.3 No single spot measurement can be less than 80% of the specified minimum DFT. No single spot measurement can be more than 120% of the specified maximum DFT. The average value for each surface must conform to the specified DFT. (There will be only eight average values if the DFT of the toe is not measured; there may be as many as 14 average values for tall beams.)

A3.4 SAMPLE DFT DETERMINATION OF A BEAM: In lieu of a full DFT determination of each beam, the job specification may require only a sample DFT determination for selected beams less than 18 m (60 ft) long. For a sample DFT determination, the web of tall beams is not split.

A3.4.1 Beams less than 6 m (20 ft): For beams less than 6 m (20 ft), take two spot measurements, randomly distributed, on each of the 12 surfaces (8 surfaces if the toe is not measured) of the beam as defined in Figure A3. Each spot measurement must conform to the specified DFT.

A3.4.2 Beams between 6 m (20 ft) and 18 m (60 ft): For beams between 6 m (20 ft) and 18 m (60 ft), take three spot measurements, randomly distributed, on each of the 12 surfaces (8 surfaces if the toe is not measured) of the beam as defined in Figure A3. Each spot measurement must conform to the specified DFT.

A3.5 NON-CONFORMANCE: If any spot measurement falls outside the specified range, additional measurements may be made to define the non-conforming area.

A3.6 RESTRICTED ACCESS: If the beam is situated such that one or more of the surfaces are not accessible, take measurements on each accessible surface in accordance with Section A3.2 or Section A3.4, as specified.

A3.7 ATTACHMENTS: Stiffeners and other attachments to a beam shall be arbitrarily measured at a frequency specified in the job specification.

APPENDIX 4 - Methods for Measuring Dry Film Thickness for a Laydown of Beams, Structural Steel, and Miscellaneous Parts After Shop Coating

Appendix 4 is not a mandatory part of this standard, but it provides two sample protocols for measuring DFT for a laydown.

A4.1 GENERAL: A "laydown" is a group of steel members laid down to be painted in one shift by one painter. For inspection of a laydown, first make a visual survey to detect areas with obvious defects, such as poor coverage, and correct as necessary. As an informal initial survey, the inspector may want to check for uniformity of DFT across each surface.

A4.2 FULL DFT DETERMINATION

A4.2.1 Beam (Girder): Follow the procedure described in Section A3.2.

A4.2.2 Miscellaneous Part: Take one spot measurement (as defined in Section 4.1.2) on each surface of the part. If the part has fewer than five surfaces, take multiple spot measurements on the larger surfaces to bring the total to five. If the total area of the part is over 10 m^2 (100 ft^2), take 5 spot measurements randomly distributed over the part for each 10 m^2 (100 ft^2) or fraction thereof.

A4.3 No single spot measurement can be less than 80% of the specified minimum DFT. No single spot measurement can be more than 120% of the specified maximum DFT. The average value of the spot measurements on each surface must conform to the specified DFT. If there is only a single spot measurement on a surface, it must conform to the specified DFT.

Table A3.1
Number of Spot Measurements Needed on Each Surface of a Beam for a Full or a Sample DFT Determination

	Number of Spot Measurements per Surface	
Length of Beam	**Full DFT Determination***	**Sample DFT Determination**
less than 6 m (20 ft)	5	2
from 6 to 18 m (20 to 60 ft)	5	3
over 18 m (60 ft)	5	NA

***** For tall beams (91 cm [36 inches] or more), the top half and the bottom half of the web are treated as separate surfaces in a full DFT determination.

A4.4 SAMPLE DFT DETERMINATION: In lieu of a full DFT determination of each painted piece as described in Section A4.2, the job specification may require only a sample DFT determination for selected pieces.

A4.4.1 Beams less than 6 m (20 ft): Follow the procedure described in Section A3.4.1.

A4.4.2 Beams between 6 m (20 ft) and 18 m (60 ft): Follow the procedure described in Section A3.4.2.

A4.4.3 Miscellaneous parts: For a miscellaneous part, take three spot measurements, randomly distributed on the part. Each spot measurement must conform to the specified DFT.

A4.5 NON-CONFORMANCE: If any spot measurement falls outside the specified range, additional measurements may be made to define the non-conforming area.

A4.6: RESTRICTED ACCESS: If a beam or miscellaneous part is situated such that one or more of the surfaces are not accessible, take measurements on each accessible surface in accordance with Section A4.2 or Section A4.4, as specified.

A4.7 NUMBER OF BEAMS OR PARTS TO MEASURE: In a laydown, the number of beams or parts to receive a full DFT determination and the number to have a sample DFT determination can be specified. For example, do a full DFT determination on a piece painted near the beginning of the shift, near the middle of the shift, and near the end of the shift in accordance with Section A4.2; and perform a sample DFT determination on every third piece in accordance with Section A4.4.

A4.8 ATTACHMENTS: Stiffeners and other attachments to a beam shall be arbitrarily measured at a frequency specified in the job specification.

APPENDIX 5 - Method for Measuring Dry Film Thickness on Coated Steel Test Panels

Appendix 5 is not a mandatory part of this standard, but it provides a sample protocol for measuring DFT on coated steel test panels.

A5.1 Panel Size: The test panel shall have a minimum area of 116 cm^2 (18 in^2) and a maximum area of 930 cm^2 (144 in^2); e.g., minimum 7.5 x 15 cm (3 x 6 inch) and maximum 30 x 30 cm (12 x 12 inch).

A5.2 Procedure: Use a Type 2 electronic gage. Take two gage readings from the top third, the middle third, and the bottom third of the test panel. Readings shall be taken at least 12 mm (one-half inch) from any edge and 25 mm (one inch) from any other gage reading. Discard any unusually high or low gage reading that cannot be repeated consistently. The DFT of the test panel is the average of the six acceptable gage readings.

A5.3 Minimum Thickness: The average of the acceptable gage readings shall be no less than the specified minimum thickness. No single gage reading shall be less than 80% of the specified minimum.

A5.4 Maximum Thickness: The average of the acceptable gage readings shall be no more than the specified maximum thickness. No single gage reading shall be more than 120% of the specified maximum.

A5.5 Rejection: If a gage reading is less than 80% of the specified minimum DFT or exceeds 120% of the specified maximum DFT, additional measurements may be made to reevaluate the DFT on the area of the test panel near the low or high gage reading. If the additional measurements indicate the DFT in the disputed area of the panel to be below the minimum or above the maximum allowable DFT, the panel shall be rejected.

APPENDIX 6 - Method for Measuring Dry Film Thickness of Thin Coatings on Coated Steel Test Panels that Had Been Abrasive Blast Cleaned

Appendix 6 is not a mandatory part of this standard, but it provides a sample protocol for measuring DFT of thin coatings on coated steel test panels that had been abrasive blast cleaned.

A6.1 A coating is defined as thin if the dry film thickness (DFT) is on the order of 25 micrometers (1 mil) or less. Because the DFT is the same order as the statistical fluctuations of a DFT gage on bare blast cleaned steel, many gage readings must be taken to get a meaningful average.

A6.2 Panel Size: The test panel shall have a minimum area of 116 cm^2 (18 in^2) and a maximum area of 930 cm^2 (144 in^2); e.g., minimum 7.5 x 15 cm (3 x 6 inch) and maximum 30 x 30 cm (12 x 12 inch).

A6.3 Procedure: Use a properly adjusted Type 2 electronic gage. Take ten gage readings randomly distributed in the top third of the panel. Compute the mean (average) and standard deviation of these ten readings. Similarly, take ten readings from the middle third and ten readings from the bottom third of the test panel and compute their means and standard deviations. Readings shall be taken at least 12 mm (one-half inch) from any edge and 25 mm (one inch) from any other gage reading.

Discard any unusually high or low gage reading, i.e., a reading that is more than three standard deviations from the mean. The DFT of the test panel is the average of the three means.

A6.4 Minimum Thickness: The average of the means shall be no less than the specified minimum thickness. No single mean shall be less than 80% of the specified minimum.

A6.5 Maximum Thickness: The average of the means shall be no more than the specified maximum thickness. No single mean shall be more than 120% of the specified maximum.

Item No. 21065

Joint Surface Preparation Standard

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

This NACE International (NACE)/The Society for Protective Coatings (SSPC) standard represents a consensus of those individual members who have reviewed this document, its scope, and provisions. It is intended to aid the manufacturer, the consumer, and the general public. Its acceptance does not in any respect preclude anyone, whether he or she has adopted the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not addressed in this standard. Nothing contained in this NACE/SSPC standard is to be construed as granting any right, by implication or otherwise, to manufacture, sell, or use in connection with any method, apparatus, or product covered by Letters Patent, or as indemnifying or protecting anyone against liability for infringement of Letters Patent. This standard represents current technology and should in no way be interpreted as a restriction on the use of better procedures or materials. Neither is this standard intended to apply in all cases relating to the subject. Unpredictable circumstances may negate the usefulness of this standard in specific instances. NACE and SSPC assume no responsibility for the interpretation or use of this standard by other parties and accept responsibility for only those official interpretations issued by NACE or SSPC in accordance with their governing procedures and policies which preclude the issuance of interpretations by individual volunteers.

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Foreword

This joint standard covers the use of blast cleaning abrasives to achieve a defined degree of cleaning of steel surfaces prior to the application of a protective coating or lining system. This standard is intended for use by coating or lining specifiers, applicators, inspectors, or others who may be responsible for defining a standard degree of surface cleanliness.

The focus of this standard is white metal blast cleaning. Near-white metal blast cleaning, commercial blast cleaning, industrial blast cleaning, and brush-off blast cleaning are addressed in separate standards.

White metal blast cleaning provides a greater degree of cleaning than near-white metal blast cleaning (NACE No. 2/SSPC-SP 10[1]).

The difference between a white metal blast and a near-white metal blast is that a white metal blast removes all of the coating, mill scale, rust, oxides, corrosion products, and other foreign matter from the surface. Near-white metal blasting allows light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coating to remain on no more than 5 percent of each unit area of surface as defined in NACE No. 2/SSPC-SP 10.

This joint standard was originally prepared in 1994 and reaffirmed in 1999 by the SSPC/NACE Task Group (TG) A on Surface Preparation by Abrasive Blast Cleaning. This joint TG includes members of both the SSPC Surface Preparation Committee and the NACE Unit Committee T-6G on Surface Preparation. It was reaffirmed in 2006 by NACE Specific Technology Group (STG) 04, Protective Coatings and Linings: Surface Preparation, and the SSPC Surface Preparation Committee.

In NACE/SSPC standards, the terms *shall, must, should,* and *may* are used in accordance with Paragraph 2.2.1.8 of the Agreement Between NACE International and SSPC: The Society for Protective Coatings. The terms *shall* and *must* are used to state mandatory requirements. The term *should* is used to state something considered good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

Joint Surface Preparation Standard

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

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Section 1: General

1.1 This joint standard covers the requirements for white metal blast cleaning of uncoated or coated steel surfaces by the use of abrasives. These requirements include the end condition of the surface and materials and procedures necessary to achieve and verify the end condition.

1.2 The mandatory requirements are described in Sections 1 to 9. Section 10, "Comments," and Appendix A, "Explanatory Notes," are not mandatory requirements of this standard.

1.3 Information about the function of white metal blast cleaning is in Paragraph A1 of Appendix A.

1.4 Information about use of this standard in maintenance coating work is in Paragraph A2 of Appendix A.

Section 2: Definitions

2.1 **White Metal Blast Cleaned Surface:** A white metal blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter.

2.1.1 Acceptable variations in appearance that do not affect surface cleanliness as defined in Paragraph 2.1 include variations caused by type of steel, original surface condition, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat-affected zones, blasting abrasives, and differences because of blasting technique.

2.1.2 SSPC-VIS 1[2] may be specified to supplement the written definition. In any dispute, the written definition set forth in this standard shall take precedence over reference photographs and comparators. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 3: Associated Documents

3.1 The latest issue, revision, or amendment of the documents listed in Paragraph 3.3 in effect on the date of invitation to bid shall govern unless otherwise specified.

3.2 If there is a conflict between the requirements of any of the documents listed in Paragraph 3.3 and this standard, the requirements of this standard shall prevail.

3.3 Documents cited in the mandatory sections of this standard include:

Document	Title
SSPC-AB 1[3]	Mineral and Slag Abrasives
SSPC-AB 2[4]	Cleanliness of Recycled Ferrous Metallic Abrasives
SSPC-AB 3[5]	Ferrous Metallic Abrasives
SSPC-SP 1[6]	Solvent Cleaning
SSPC-VIS 1	Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning

Section 4: Procedures Before Cleaning

4.1 Before blast cleaning, visible deposits of oil, grease, or other contaminants shall be removed in accordance with SSPC-SP 1 or other agreed-upon methods.

4.2 Before blast cleaning, surface imperfections such as sharp fins, sharp edges, weld spatter, or burning slag should be removed from the surface to the extent required by the procurement documents (project specification). Additional information on surface imperfections is in Paragraph A4 of Appendix A.

4.3 If reference photographs or comparators are specified to supplement the written standard, the condition of the steel prior to blast cleaning should be determined before the blasting commences. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 5: Blast Cleaning Methods and Operation

5.1 Clean, dry compressed air shall be used for nozzle blasting. Moisture separators, oil separators, traps, or other equipment may be necessary to achieve this requirement.

5.2 Any of the following methods of surface preparation may be used to achieve a white metal blast cleaned surface:

5.2.1 Dry abrasive blasting using compressed air, blast nozzles, and abrasive.

5.2.2 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with compressed air, blast nozzle, and abrasive, with or without vacuum for dust and abrasive recovery.

5.2.3 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with centrifugal wheels and abrasive.

5.3 Other methods of surface preparation (such as wet abrasive blast cleaning) may be used to achieve a white metal blast cleaned surface by mutual agreement between those responsible for establishing the requirements and those responsible for performing the work. Information on the use of inhibitors to prevent the formation of rust immediately after wet abrasive blast cleaning is in Paragraph A5 of Appendix A.

Section 6: Blast Cleaning Abrasives

6.1 The selection of abrasive size and type shall be based on the type, grade, and surface condition of the steel to be cleaned, the type of blast cleaning system used, the finished surface to be produced (cleanliness and surface profile [roughness]), and whether the abrasive will be recycled.

6.2 The cleanliness and size of recycled abrasives shall be maintained to ensure compliance with this standard.

6.3 The blast cleaning abrasive shall be dry and free of oil, grease, and other contaminants as determined by the test methods found in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

6.4 Any limitations on the use of specific abrasives, the quantity of contaminants, or the degree of allowable embedment shall be included in the procurement documents (project specification) covering the work, because abrasive embedment and abrasives containing contaminants may not be acceptable for some service requirements. Additional information on abrasive selection is in Paragraph A6 of Appendix A.

6.5 When a coating is specified, the cleaned surface shall be roughened to a degree suitable for the specified coating system. Additional information on surface profile and the film thickness of coating applied over the surface profile is in Paragraphs A7 and A8 of Appendix A.

Section 7: Procedures Following Blast Cleaning and Immediately Prior to Coating

7.1 Visible deposits of oil, grease, or other contaminants shall be removed according to SSPC-SP 1 or another method agreed upon by those parties responsible for establishing the requirements and those responsible for performing the work.

7.2 Dust and loose residues shall be removed from prepared surfaces by brushing; blowing off with clean, dry air; vacuum cleaning; or other methods agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

7.2.1 The presence of toxic metals in the abrasives or coating being removed may place restrictions on the methods of cleaning permitted. The chosen method shall comply with all applicable regulations.

7.2.2 Moisture separators, oil separators, traps, or other equipment may be necessary to achieve clean, dry air.

7.3 After blast cleaning, any remaining surface imperfections (e.g., sharp fins, sharp edges, weld spatter, burning slag, scabs, slivers) shall be removed to the extent required by the procurement documents (project specification). Any damage to the surface profile resulting from the removal of surface imperfections shall be corrected to meet the requirements of Paragraph 6.5. Additional information on surface imperfections is in Paragraph A4 of Appendix A.

7.4 Immediately prior to coating application, the entire surface shall comply with the degree of cleaning specified in this standard. Any visible rust that forms on the surface of

the steel after blast cleaning shall be removed by recleaning the rusted areas before coating. Information on chemical contamination, rust-back (rerusting), and the effect of dew point (surface condensation) is in Paragraphs A9, A10, and A11 of Appendix A.

Section 8: Inspection

8.1 Work performed and materials supplied under this standard are subject to inspection by a representative of those responsible for establishing the requirements. Materials and work areas shall be accessible to the inspector. The procedures and times of inspection shall be as agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

8.2 Conditions not complying with this standard shall be corrected. In the case of a dispute, an arbitration or settlement procedure established in the procurement documents (project specification) shall be followed. If no arbitration or settlement procedure is established, a procedure mutually agreeable to purchaser and supplier shall be used.

8.3 The procurement documents (project specification) should establish the responsibility for inspection and for any required affidavit certifying compliance with the specification.

Section 9: Safety and Environmental Requirements

9.1 Because abrasive blast cleaning is a hazardous operation, all work shall be conducted in compliance with applicable occupational and environmental health and safety rules and regulations.

Section 10: Comments (Nonmandatory)

10.1 Additional information and data relative to this standard are in Appendix A. Detailed information and data are presented in a separate document, SSPC-SP COM.[7] The recommendations in Appendix A and SSPC-SP COM are believed to represent good practice, but are not to be considered requirements of the standard. The sections of SSPC-SP COM that discuss subjects related to white metal blast cleaning are listed below.

Subject	Commentary Section
Abrasive Selection	6
Film Thickness	10
Maintenance Repainting	4.2
Reference Photographs	11
Rust-Back (Rerusting)	8.3
Surface Profile	6.2
Weld Spatter	4.4.1
Wet Abrasive Blast Cleaning	8.2

References

1. NACE No. 2/SSPC-SP 10 (latest revision), “Near-White Metal Blast Cleaning” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

2. SSPC-VIS 1 (latest revision), “Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning” (Pittsburgh, PA: SSPC).

3. SSPC-AB 1 (latest revision), “Mineral and Slag Abrasives” (Pittsburgh, PA: SSPC).

4. SSPC-AB 2 (latest revision), “Cleanliness of Recycled Ferrous Metallic Abrasives” (Pittsburgh, PA: SSPC).

5. SSPC-AB 3 (latest revision), “Ferrous Metallic Abrasives” (Pittsburgh, PA: SSPC).

6. SSPC-SP 1 (latest revision), “Solvent Cleaning” (Pittsburgh, PA: SSPC).

7. SSPC-SP COM (latest revision), “Surface Preparation Commentary for Steel and Concrete Substrates” (Pittsburgh, PA: SSPC).

8. SSPC-PA Guide 4 (latest revision), “Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems” (Pittsburgh, PA: SSPC).

9. "Visual Comparator for Surface Finishing of Welds Prior to Coating," Visual Aid for Use with NACE SP0178 (formerly RP0178)(latest revision) (Houston, TX: NACE).

10. NACE SP0178 (formerly RP0178) (latest revision), "Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service" (Houston, TX: NACE).

11. NACE Standard RP0287 (latest revision), "Field Measurement of Surface Profile of Abrasive Blast-Cleaned Steel Surfaces Using a Replica Tape" (Houston, TX: NACE).

12. ASTM(1) D 4417 (latest revision), "Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel" (West Conshohocken, PA: ASTM).

13. SSPC-PA 2 (latest revision), "Measurement of Dry Coating Thickness with Magnetic Gages" (Pittsburgh, PA: SSPC).

14. NACE No. 5/SSPC-SP 12 (latest revision), "Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

15. SSPC-Guide 15 (latest revision), "Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates" (Pittsburgh, PA: SSPC).

Appendix A: Explanatory Notes (Nonmandatory)

A1 FUNCTION: White metal blast cleaning (NACE No. 1/SSPC-SP 5) provides the greatest degree of cleaning. It should be used when the highest degree of blast cleaning is required. The primary functions of blast cleaning before coating are (a) to remove material from the surface that can cause early failure of the coating and (b) to obtain a suitable surface profile (roughness) to enhance the adhesion of the new coating system. The hierarchy of blasting standards is as follows: white metal blast cleaning, near-white metal blast cleaning, commercial blast cleaning, industrial blast cleaning, and brush-off blast cleaning.

A2 MAINTENANCE COATING WORK: When this standard is used in maintenance coating work, specific instructions should be provided on the extent of surface to be blast cleaned or spot blast cleaned to this degree of cleanliness. In these cases, this degree of cleaning applies to the entire specified area. For example, if all weld seams are to be cleaned in a maintenance operation, this degree of cleaning applies to 100 percent of all weld seams. If the entire structure is to be prepared, this degree of cleaning applies to 100 percent of the entire structure. SSPC-PA Guide 4[8] provides a description of accepted practices for retaining old sound coating, removing unsound coating, feathering, and spot cleaning.

A3 REFERENCE PHOTOGRAPHS AND COMPARATORS: SSPC-VIS 1 provides color photographs for the various grades of surface cleaning as a function of the initial condition of the steel. The photographs A SP 5, B SP 5, C SP 5, D SP 5, G_1 SP 5, G_2 SP 5, and G_3 SP 5 depict surfaces cleaned to white metal. In addition, the photographs A SP 5 M and A SP 5 N depict surfaces cleaned by various metallic and nonmetallic abrasives to SP 5 condition. The NACE "Visual Comparator for Surface Finishing of Welds Prior to Coating"[9] is a plastic weld replica that complements NACE SP0178.[10] Other available reference photographs and comparators are described in Section 11 of SSPC-SP COM.

A4 SURFACE IMPERFECTIONS: Surface imperfections can cause premature coating failure when the service is severe. Coatings tend to pull away from sharp edges and projections, leaving little or no coating to protect the underlying steel. Other features that are difficult to cover and protect properly include crevices, weld porosities, laminations, etc. The high cost of the methods to remedy surface imperfections (such as edge rounding and weld spatter removal) should be weighed against the costs of a potential coating failure.

Poorly adhering contaminants, such as weld slag residues, loose weld spatter, and some minor surface laminations, may be removed during the blast cleaning operation. Other surface defects (steel laminations, weld porosities, or deep corrosion pits) may not be evident until the surface cleaning has been completed. Repair of such surface defects should be planned properly because the timing of the repairs may occur before, during, or after the blast cleaning operation. Section 4.4 of SSPC-SP COM and NACE SP0178 contain additional information on surface imperfections.

A5 WET ABRASIVE BLAST CLEANING: Steel that is wet abrasive blast cleaned may rust rapidly. Clean water should be used for rinsing. It may be necessary to add inhibitors to the water or apply them to the surface immediately after blast cleaning to temporarily prevent rust formation. The use of inhibitors or the application of coating over slight discoloration should be in accordance with the requirements of the coating manufacturer. CAUTION: Some inhibitive treatments may interfere with the performance of certain coating systems.

(1) ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

A6 ABRASIVE SELECTION: Types of metallic and nonmetallic abrasives are discussed in SSPC-SP COM. Blasting abrasives may become embedded in, or leave residues on, the surface of the steel during cleaning. While such embedment or residues are normally not detrimental, care should be taken to ensure that the abrasive is free from detrimental amounts of water-soluble, solvent-soluble, acid-soluble, or other soluble contaminants (particularly if the cleaned steel is to be used in an immersion environment). Criteria for selecting and evaluating abrasives are in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

A7 SURFACE PROFILE: Surface profile is the roughness of the surface that results from abrasive blast cleaning. The profile height is dependent on the size, shape, type, and hardness of the abrasive, particle velocity and angle of impact, hardness of the surface, amount of abrasive recycling, and the proper maintenance of working mixtures of grit and/or shot.

The allowable minimum/maximum height of profile is usually dependent on the thickness of the coating to be applied. Large particle-sized abrasives (particularly metallic) can produce a surface profile that may be too high to be adequately covered by a single thin-film coat. Accordingly, the use of larger abrasives should be avoided in these cases. However, larger abrasives may be needed for thick-film coatings or to facilitate removal of thick coatings, heavy mill scale, or rust. If control of surface profile (minimum/maximum) is deemed to be significant to coating performance, it should be addressed in the procurement documents (project specification). Typical surface profile heights achieved with commercial abrasive media are shown in Table 6 of SSPC-SP COM. Surface profile should be measured in accordance with NACE Standard RP0287[11] or ASTM D 4417.[12]

A8 FILM THICKNESS: It is essential that ample coating be applied after blast cleaning to adequately cover the peaks of the surface profile. The dry-film thickness of the coating above the peaks of the profile should equal the thickness known to be needed for the desired protection. If the dry-film thickness over the peaks is inadequate, premature rust-through or coating failure will occur. To ensure that coating thicknesses are properly measured, the procedures in SSPC-PA 2[13] should be used.

A9 CHEMICAL CONTAMINATION: Steel contaminated with soluble salts (e.g., chlorides and sulfates) develops rust-back rapidly at intermediate and high levels of humidity. These soluble salts can be present on the steel surface prior to blast cleaning as a result of atmospheric contamination. In addition, contaminants can be deposited on the steel surface during blast cleaning if the abrasive is contaminated. Therefore, rust-back can be minimized by removing these salts from the steel surface and eliminating sources of recontamination during and after blast cleaning. Wet methods of removal are described in NACE No. 5/SSPC-SP 12.[14] Identification of the contaminants along with their concentrations may be obtained from laboratory and field tests as described in SSPC-Guide 15.[15]

A10 RUST-BACK: Rust-back (rerusting) occurs when freshly cleaned steel is exposed to moisture, contamination, or a corrosive atmosphere. The time interval between blast cleaning and rust-back varies greatly from one environment to another. Under mild ambient conditions, if chemical contamination (see Paragraph A9) is not present, it is best to blast clean and coat a surface on the same day. Severe conditions may require a more expeditious coating application to avoid contamination from fallout. Chemical contamination should be removed prior to coating.

A11 DEW POINT: Moisture condenses on any surface that is colder than the dew point of the surrounding air. It is therefore recommended that the temperature of the steel surface be at least 3°C (5°F) above the dew point during dry blast cleaning operations. It is advisable to visually inspect for moisture and periodically check the surface temperature and dew point during blast cleaning operations and to avoid the application of coating over a damp surface.

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Joint Surface Preparation Standard

NACE No. 2/SSPC-SP 10
Near-White Metal Blast Cleaning

This NACE International (NACE)/The Society for Protective Coatings (SSPC) standard represents a consensus of those individual members who have reviewed this document, its scope, and provisions. It is intended to aid the manufacturer, the consumer, and the general public. Its acceptance does not in any respect preclude anyone, whether he or she has adopted the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not addressed in this standard. Nothing contained in this NACE/SSPC standard is to be construed as granting any right, by implication or otherwise, to manufacture, sell, or use in connection with any method, apparatus, or product covered by Letters Patent, or as indemnifying or protecting anyone against liability for infringement of Letters Patent. This standard represents current technology and should in no way be interpreted as a restriction on the use of better procedures or materials. Neither is this standard intended to apply in all cases relating to the subject. Unpredictable circumstances may negate the usefulness of this standard in specific instances. NACE and SSPC assume no responsibility for the interpretation or use of this standard by other parties and accept responsibility for only those official interpretations issued by NACE or SSPC in accordance with their governing procedures and policies which preclude the issuance of interpretations by individual volunteers.

Users of this NACE/SSPC standard are responsible for reviewing appropriate health, safety, environmental, and regulatory documents and for determining their applicability in relation to this standard prior to its use. This NACE/SSPC standard may not necessarily address all potential health and safety problems or environmental hazards associated with the use of materials, equipment, and/or operations detailed or referred to within this standard. Users of this NACE/SSPC standard are also responsible for establishing appropriate health, safety, and environmental protection practices, in consultation with appropriate regulatory authorities if necessary, to achieve compliance with any existing applicable regulatory requirements prior to the use of this standard.

CAUTIONARY NOTICE: NACE/SSPC standards are subject to periodic review, and may be revised or withdrawn at any time in accordance with technical committee procedures. The user is cautioned to obtain the latest edition. NACE and SSPC require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of initial publication.

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Foreword

This joint standard covers the use of blast cleaning abrasives to achieve a defined degree of cleaning of steel surfaces prior to the application of a protective coating or lining system. This standard is intended for use by coating or lining specifiers, applicators, inspectors, or others who may be responsible for defining a standard degree of surface cleanliness.

The focus of this standard is near-white metal blast cleaning. White metal blast cleaning, commercial blast cleaning, industrial blast cleaning, and brush-off blast cleaning are addressed in separate standards.

Near-white metal blast cleaning provides a greater degree of cleaning than commercial blast cleaning (NACE No. 3/SSPC-SP 6[1]) but less than white metal blast cleaning (NACE No. 1/SSPC-SP 5[2]).

Near-white metal blast cleaning is used when the objective is to remove all rust, coating, and mill scale, but when the extra effort required to remove all stains of these materials is determined to be unwarranted. Staining shall be limited to no more than 5 percent of each unit area of surface.

Near-white metal blast cleaning allows staining on only 5 percent of each unit area of surface, while commercial blast cleaning allows staining on 33 percent of each unit area of surface. White metal blast cleaning does not permit any staining to remain on the surface.

This joint standard was originally prepared in 1994 and reaffirmed in 1999 by the SSPC/NACE Task Group (TG) A on Surface Preparation by Abrasive Blast Cleaning, and NACE Unit Committee T-6G on Surface Preparation. This joint TG includes members of both the SSPC Surface Preparation Committee and the NACE Unit Committee T-6G on Surface Preparation. It was reaffirmed in 2006 by NACE Specific Technology Group (STG) 04, Protective Coatings and Linings: Surface Preparation, and the SSPC Surface Preparation Committee.

In NACE/SSPC standards, the terms *shall, must, should,* and *may* are used in accordance with Paragraph 2.2.1.8 of the Agreement Between NACE International and SSPC: The Society for Protective Coatings. The terms *shall* and *must* are used to state mandatory requirements. The term *should* is used to state something considered good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

Joint Surface Preparation Standard

NACE No. 2/SSPC-SP 10
Near-White Metal Blast Cleaning

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Section 1: General

1.1 This joint standard covers the requirements for near-white metal blast cleaning of uncoated or coated steel surfaces by the use of abrasives. These requirements include the end condition of the surface and materials and procedures necessary to achieve and verify the end condition.

1.2 The mandatory requirements are described in Sections 1 to 9. Section 10, "Comments," and Appendix A, "Explanatory Notes," are not mandatory requirements of this standard.

1.3 Information about the function of near-white metal blast cleaning is in Paragraph A1 of Appendix A.

1.4 Information about use of this standard in maintenance coating work is in Paragraph A2 of Appendix A.

Section 2: Definitions

2.1 **Near-White Metal Blast Cleaned Surface:** A near-white metal blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter. Random staining shall be limited to no more than 5 percent of each unit area of surface (approximately 5,800 mm^2 [9.0 $in.^2$] (i.e., a square 76 mm x 76 mm [3.0 in. x 3.0 in.]), and may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coating.

2.1.1 Acceptable variations in appearance that do not affect surface cleanliness as defined in Paragraph 2.1 include variations caused by the type of steel, original surface condition, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat-affected zones, blasting abrasives, and differences because of blasting technique.

2.1.2 SSPC-VIS 1[3] may be specified to supplement the written definition. In any dispute, the written definition set forth in this standard shall take precedence over reference photographs and comparators. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 3: Associated Documents

3.1 The latest issue, revision, or amendment of the documents listed in Paragraph 3.3 in effect on the date of invitation to bid shall govern unless otherwise specified.

3.2 If there is a conflict between the requirements of any of the documents listed in Paragraph 3.3 and this standard, the requirements of this standard shall prevail.

3.3 Documents cited in the mandatory sections of this standard include:

Document	Title
SSPC-AB 1[4]	Mineral and Slag Abrasives
SSPC-AB 2[5]	Cleanliness of Recycled Ferrous Metallic Abrasives
SSPC-AB 3[6]	Ferrous Metallic Abrasives
SSPC-SP 1[7]	Solvent Cleaning
SSPC-VIS 1	Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning

Section 4: Procedures Before Cleaning

4.1 Before blast cleaning, visible deposits of oil, grease, or other contaminants shall be removed in accordance with SSPC-SP 1 or other agreed-upon methods.

4.2 Before blast cleaning, surface imperfections such as sharp fins, sharp edges, weld spatter, or burning slag should be removed from the surface to the extent required by the procurement documents (project specification). Additional information on surface imperfections is in Paragraph A4 of Appendix A.

4.3 If reference photographs or comparators are specified to supplement the written standard, the condition of the steel prior to blast cleaning should be determined before the blasting commences. Additional information on reference

photographs and comparators is in Paragraph A3 of Appendix A.

Section 5: Blast Cleaning Methods and Operation

5.1 Clean, dry compressed air shall be used for nozzle blasting. Moisture separators, oil separators, traps, or other equipment may be necessary to achieve this requirement.

5.2 Any of the following methods of surface preparation may be used to achieve a near-white metal blast cleaned surface:

5.2.1 Dry abrasive blasting using compressed air, blast nozzles, and abrasive.

5.2.2 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with compressed air, blast nozzle, and abrasive, with or without vacuum for dust and abrasive recovery.

5.2.3 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with centrifugal wheels and abrasive.

5.3 Other methods of surface preparation (such as wet abrasive blast cleaning) may be used to achieve a near-white metal blast cleaned surface by mutual agreement between those responsible for establishing the requirements and those responsible for performing the work. Information on the use of inhibitors to prevent the formation of rust immediately after wet abrasive blast cleaning is in Paragraph A5 of Appendix A.

Section 6: Blast Cleaning Abrasives

6.1 The selection of abrasive size and type shall be based on the type, grade, and surface condition of the steel to be cleaned, the type of blast cleaning system used, the finished surface to be produced (cleanliness and surface profile [roughness]), and whether the abrasive will be recycled.

6.2 The cleanliness and size of recycled abrasives shall be maintained to ensure compliance with this standard.

6.3 The blast cleaning abrasive shall be dry and free of oil, grease, and other contaminants as determined by the test methods found in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

6.4 Any limitations on the use of specific abrasives, the quantity of contaminants, or the degree of allowable embedment shall be included in the procurement documents (project specification) covering the work, because abrasive embedment and abrasives containing contaminants may not be acceptable for some service requirements. Additional information on abrasive selection is in Paragraph A6 of Appendix A.

6.5 When a coating is specified, the cleaned surface shall be roughened to a degree suitable for the specified coating system. Additional information on surface profile and the film thickness of coating applied over the surface profile is in Paragraphs A7 and A8 of Appendix A.

Section 7: Procedures Following Blast Cleaning and Immediately Prior to Coating

7.1 Visible deposits of oil, grease, or other contaminants shall be removed according to SSPC-SP 1 or another method agreed upon by those parties responsible for establishing the requirements and those responsible for performing the work.

7.2 Dust and loose residues shall be removed from prepared surfaces by brushing; blowing off with clean, dry air; vacuum cleaning; or other methods agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

7.2.1 The presence of toxic metals in the abrasives or coating being removed may place restrictions on the methods of cleaning permitted. The chosen method shall comply with all applicable regulations.

7.2.2 Moisture separators, oil separators, traps, or other equipment may be necessary to achieve clean, dry air.

7.3 After blast cleaning, any remaining surface imperfections (e.g., sharp fins, sharp edges, weld spatter, burning slag, scabs, slivers) shall be removed to the extent required by the procurement documents (project specification). Any damage to the surface profile resulting from the removal of surface imperfections shall be corrected to meet the requirements of Paragraph 6.5.

Additional information on surface imperfections is in Paragraph A4 of Appendix A.

7.4 Immediately prior to coating application, the entire surface shall comply with the degree of cleaning specified in this standard. Any visible rust that forms on the surface of the steel after blast cleaning shall be removed by recleaning the rusted areas before coating. Information on chemical contamination, rust-back (rerusting), and the effect of dew point (surface condensation) is in Paragraphs A9, A10, and A11 of Appendix A.

Section 8: Inspection

8.1 Work performed and materials supplied under this standard are subject to inspection by a representative of those responsible for establishing the requirements. Materials and work areas shall be accessible to the inspector. The procedures and times of inspection shall be as agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

8.2 Conditions not complying with this standard shall be corrected. In the case of a dispute, an arbitration or settlement procedure established in the procurement documents (project specification) shall be followed. If no arbitration or settlement procedure is established, a procedure mutually agreeable to purchaser and supplier shall be used.

8.3 The procurement documents (project specification) should establish the responsibility for inspection and for any required affidavit certifying compliance with the specification.

Section 9: Safety and Environmental Requirements

9.1 Because abrasive blast cleaning is a hazardous operation, all work shall be conducted in compliance with applicable occupational and environmental health and safety rules and regulations.

Section 10: Comments (Nonmandatory)

10.1 Additional information and data relative to this standard are in Appendix A. Detailed information and data are presented in a separate document, SSPC-SP COM.[8] The recommendations in Appendix A and SSPC-SP COM are believed to represent good practice, but are not to be considered requirements of the standard. The sections of SSPC-SP COM that discuss subjects related to near-white metal blast cleaning are listed below.

Subject	Commentary Section
Abrasive Selection	6
Film Thickness	10
Maintenance Repainting	4.2
Reference Photographs	11
Rust-Back (Rerusting)	8.3
Surface Profile	6.2
Weld Spatter	4.4.1
Wet Abrasive Blast Cleaning	8.2

References

1. NACE No. 3/SSPC-SP 6 (latest revision), “Commercial Blast Cleaning” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

2. NACE No. 1/SSPC-SP 5 (latest revision), “White Metal Blast Cleaning” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

3. SSPC-VIS 1 (latest revision), “Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning” (Pittsburgh, PA: SSPC).

4. SSPC-AB 1 (latest revision), “Mineral and Slag Abrasives” (Pittsburgh, PA: SSPC).

5. SSPC-AB 2 (latest revision), “Cleanliness of Recycled Ferrous Metallic Abrasives” (Pittsburgh, PA: SSPC).

6. SSPC-AB 3 (latest revision), “Ferrous Metallic Abrasives” (Pittsburgh, PA: SSPC).

7. SSPC-SP 1 (latest revision), “Solvent Cleaning” (Pittsburgh, PA: SSPC).

8. SSPC-SP COM (latest revision), “Surface Preparation Commentary for Steel and Concrete Substrates” (Pittsburgh, PA: SSPC).

9. SSPC-PA Guide 4 (latest revision), “Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems” (Pittsburgh, PA: SSPC).

10. NACE SP0178 (formerly RP0178) (latest revision), “Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service” (Houston, TX: NACE).

11. NACE Standard RP0287 (latest revision), “Field Measurement of Surface Profile of Abrasive Blast-CleanedSteel Surfaces Using a Replica Tape” (Houston, TX: NACE).

12. ASTM[(1)] D 4417 (latest revision), “Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel” (West Conshohocken, PA: ASTM).

13. SSPC-PA 2 (latest revision), “Measurement of Dry Coating Thickness with Magnetic Gages” (Pittsburgh, PA: SSPC).

14. NACE No. 5/SSPC-SP 12 (latest revision), “Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

15. SSPC-Guide 15 (latest revision), “Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates” (Pittsburgh, PA: SSPC).

Appendix A: Explanatory Notes (Nonmandatory)

A1 FUNCTION: Near-white metal blast cleaning (NACE No. 2/SSPC-SP 10) provides a greater degree of cleaning than commercial blast cleaning (NACE No. 3/SSPC-SP 6) but less than white metal blast cleaning (NACE No. 1/SSPC-SP 5). It should be used when a high degree of blast cleaning is required. The primary functions of blast cleaning before coating are (a) to remove material from the surface that can cause early failure of the coating and (b) to obtain a suitable surface profile (roughness) to enhance the adhesion of the new coating system. The hierarchy of blasting standards is as follows: white metal blast cleaning, near-white metal blast cleaning, commercial blast cleaning, industrial blast cleaning, and brush-off blast cleaning.

A2 MAINTENANCE COATING WORK: When this standard is used in maintenance coating work, specific instructions should be provided on the extent of surface to be blast cleaned or spot blast cleaned to this degree of cleanliness. In these cases, this degree of cleaning applies to the entire specified area. For example, if all weld seams are to be cleaned in a maintenance operation, this degree of cleaning applies to 100 percent of all weld seams. If the entire structure is to be prepared, this degree of cleaning applies to 100 percent of the entire structure. SSPC-PA Guide 4[9] provides a description of accepted practices for retaining old sound coating, removing unsound coating, feathering, and spot cleaning.

A3 REFERENCE PHOTOGRAPHS AND COMPARATORS: SSPC-VIS 1 provides color photographs for the various grades of surface cleaning as a function of the initial condition of the steel. The photographs A SP 10, B SP 10, C SP 10, D SP 10, G_1 SP 10, G_2 SP 10, and G_3 SP 10 depict surfaces cleaned to near-white metal. Other available reference photographs and comparators are described in Section 11 of SSPC-SP COM.

A4 SURFACE IMPERFECTIONS: Surface imperfections can cause premature coating failure when the service is severe. Coatings tend to pull away from sharp edges and projections, leaving little or no coating to protect the underlying steel. Other features that are difficult to cover and protect properly include crevices, weld porosities, laminations, etc. The high cost of the methods to remedy surface imperfections (such as edge rounding and weld spatter removal) should be weighed against the costs of a potential coating failure.

Poorly adhering contaminants, such as weld slag residues, loose weld spatter, and some minor surface laminations, may be removed during the blast cleaning operation. Other surface defects (steel laminations, weld porosities, or deep corrosion pits) may not be evident until the surface cleaning has been completed. Repair of such surface defects should be planned properly because the timing of the repairs may occur before, during, or after the blast cleaning operation. Section 4.4 of SSPC-SP COM and NACE SP0178[10] contain additional information on surface imperfections.

A5 WET ABRASIVE BLAST CLEANING: Steel that is wet abrasive blast cleaned may rust rapidly. Clean water should be used for rinsing. It may be necessary to add inhibitors to the water or apply them to the surface immediately after blast cleaning to temporarily prevent rust formation. The use of inhibitors or the application of coating over slight discoloration should be in accordance with the requirements of the coating manufacturer.

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CAUTION: Some inhibitive treatments may interfere with the performance of certain coating systems.

A6 ABRASIVE SELECTION: Types of metallic and nonmetallic abrasives are discussed in SSPC-SP COM. Blasting abrasives may become embedded in, or leave residues on, the surface of the steel during cleaning. While such embedment or residues are normally not detrimental, care should be taken to ensure that the abrasive is free from detrimental amounts of water-soluble, solvent-soluble, acid-soluble, or other soluble contaminants (particularly if the cleaned steel is to be used in an immersion environment). Criteria for selecting and evaluating abrasives are in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

A7 SURFACE PROFILE: Surface profile is the roughness of the surface that results from abrasive blast cleaning. The profile height is dependent on the size, shape, type, and hardness of the abrasive, particle velocity and angle of impact, hardness of the surface, amount of abrasive recycling, and the proper maintenance of working mixtures of grit and/or shot.

The allowable minimum/maximum height of profile is usually dependent on the thickness of the coating to be applied. Large particle-sized abrasives (particularly metallic) can produce a surface profile that may be too high to be adequately covered by a single thin-film coat. Accordingly, the use of larger abrasives should be avoided in these cases. However, larger abrasives may be needed for thick-film coatings or to facilitate removal of thick coatings, heavy mill scale, or rust. If control of surface profile (minimum/maximum) is deemed to be significant to coating performance, it should be addressed in the procurement documents (project specification). Typical surface profile heights achieved with commercial abrasive media are shown in Table 6 of SSPC-SP COM. Surface profile should be measured in accordance with NACE Standard RP0287[11] or ASTM D 4417.[12]

A8 FILM THICKNESS: It is essential that ample coating be applied after blast cleaning to adequately cover the peaks of the surface profile. The dry-film thickness of the coating above the peaks of the profile should equal the thickness known to be needed for the desired protection. If the dry-film thickness over the peaks is inadequate, premature rust-through or coating failure will occur. To ensure that coating thicknesses are properly measured, the procedures in SSPC-PA 2[13] should be used.

A9 CHEMICAL CONTAMINATION: Steel contaminated with soluble salts (e.g., chlorides and sulfates) develops rust-back rapidly at intermediate and high levels of humidity. These soluble salts can be present on the steel surface prior to blast cleaning as a result of atmospheric contamination. In addition, contaminants can be deposited on the steel surface during blast cleaning if the abrasive is contaminated. Therefore, rust-back can be minimized by removing these salts from the steel surface and eliminating sources of recontamination during and after blast cleaning. Wet methods of removal are described in NACE No. 5/SSPC-SP 12.[14] Identification of the contaminants along with their concentrations may be obtained from laboratory and field tests as described in SSPC-Guide 15.[15]

A10 RUST-BACK: Rust-back (rerusting) occurs when freshly cleaned steel is exposed to moisture, contamination, or a corrosive atmosphere. The time interval between blast cleaning and rust-back varies greatly from one environment to another. Under mild ambient conditions, if chemical contamination (see Paragraph A9) is not present, it is best to blast clean and coat a surface on the same day. Severe conditions may require a more expeditious coating application to avoid contamination from fallout. Chemical contamination should be removed prior to coating.

A11 DEW POINT: Moisture condenses on any surface that is colder than the dew point of the surrounding air. It is therefore recommended that the temperature of the steel surface be at least 3°C (5°F) above the dew point during dry blast cleaning operations. It is advisable to visually inspect for moisture and periodically check the surface temperature and dew point during blast cleaning operations and to avoid the application of coating over a damp surface.

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Joint Surface Preparation Standard

NACE No. 3/SSPC-SP 6
Commercial Blast Cleaning

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Foreword

This joint standard covers the use of blast cleaning abrasives to achieve a defined degree of cleaning of steel surfaces prior to the application of a protective coating or lining system. This standard is intended for use by coating or lining specifiers, applicators, inspectors, or others who may be responsible for defining a standard degree of surface cleanliness.

The focus of this standard is commercial blast cleaning. White metal blast cleaning, near-white metal blast cleaning, industrial blast cleaning, and brush-off blast cleaning are addressed in separate standards.

Commercial blast cleaning provides a greater degree of cleaning than industrial blast cleaning (NACE No. 8/SSPC-SP 14[1]) but less than near-white metal blast cleaning (NACE No. 2/SSPC-SP 10[2]).

Commercial blast cleaning is used when the objective is to remove all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter, leaving staining or shadows on no more than 33 percent of each unit area of surface.

The difference between a commercial blast cleaning and a near-white metal blast cleaning is in the amount of staining permitted to remain on the surface. Commercial blast cleaning allows stains or shadows on 33 percent of each unit area of surface. Near-white metal blast cleaning allows staining or shadows on only 5 percent of each unit area of surface.

The difference between a commercial blast cleaning and an industrial blast cleaning is that a commercial blast cleaning removes all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter from all surfaces and allows stains to remain on 33 percent of each unit area of surface, while industrial blast cleaning allows defined mill scale, coating, and rust to remain on less than 10 percent of each unit area of surface and allows defined stains to remain on all surfaces.

This joint standard was originally prepared in 1994 and reaffirmed in 1999 by the SSPC/NACE Task Group (TG) A on Surface Preparation by Abrasive Blast Cleaning. This joint TG includes members of both the SSPC Surface Preparation Committee and the NACE Unit Committee T-6G on Surface Preparation. It was reaffirmed in 2006 by NACE Specific Technology Group (STG) 04, Protective Coatings and Linings: Surface Preparation, and the SSPC Surface Preparation Committee.

In NACE/SSPC standards, the terms *shall, must, should,* and *may* are used in accordance with Paragraph 2.2.1.8 of the Agreement Between NACE International and SSPC: The Society for Protective Coatings. The terms *shall* and *must* are used to state mandatory requirements. The term *should* is used to state something considered good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

Joint Surface Preparation Standard

NACE No. 3/SSPC-SP 6
Commercial Blast Cleaning

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Section 1: General

1.1 This joint standard covers the requirements for commercial blast cleaning of uncoated or coated steel surfaces by the use of abrasives. These requirements include the end condition of the surface and materials and procedures necessary to achieve and verify the end condition.

1.2 The mandatory requirements are described in Sections 1 to 9. Section 10, "Comments," and Appendix A, "Explanatory Notes," are not mandatory requirements of this standard.

1.3 Information about the function of commercial blast cleaning is in Paragraph A1 of Appendix A.

1.4 Information about use of this standard in maintenance coating work is in Paragraph A2 of Appendix A.

Section 2: Definitions

2.1 **Commercial Blast Cleaned Surface:** A commercial blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter. Random staining shall be limited to no more than 33 percent of each unit area of surface (approximately 5,800 mm^2 [9.0 $in.^2$]) (i.e., a square 76 mm x 76 mm [3.0 in. x 3.0 in.]) and may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coating.

2.1.1 Acceptable variations in appearance that do not affect surface cleanliness as defined in Paragraph 2.1 include variations caused by type of steel, original surface condition, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat-affected zones, blasting abrasives, and differences because of blasting technique.

2.1.2 SSPC-VIS 1[3] may be specified to supplement the written definition. In any dispute, the written definition set forth in this standard shall take precedence over reference photographs and comparators. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 3: Associated Documents

3.1 The latest issue, revision, or amendment of the documents listed in Paragraph 3.3 in effect on the date of invitation to bid shall govern unless otherwise specified.

3.2 If there is a conflict between the requirements of any of the documents listed in Paragraph 3.3 and this standard, the requirements of this standard shall prevail.

3.3 Documents cited in the mandatory sections of this standard include:

Document	Title
SSPC-AB 1[4]	Mineral and Slag Abrasives
SSPC-AB 2[5]	Cleanliness of Recycled Ferrous Metallic Abrasives
SSPC-AB 3[6]	Ferrous Metallic Abrasives
SSPC-SP 1[7]	Solvent Cleaning
SSPC-VIS 1	Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning

Section 4: Procedures Before Cleaning

4.1 Before blast cleaning, visible deposits of oil, grease, or other contaminants shall be removed in accordance with SSPC-SP 1 or other agreed-upon methods.

4.2 Before blast cleaning, surface imperfections such as sharp fins, sharp edges, weld spatter, or burning slag should be removed from the surface to the extent required by the procurement documents (project specification). Additional information on surface imperfections is in Paragraph A4 of Appendix A.

4.3 If reference photographs or comparators are specified to supplement the written standard, the condition of the steel prior to blast cleaning should be determined before the blasting commences. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 5: Blast Cleaning Methods and Operation

5.1 Clean, dry compressed air shall be used for nozzle blasting. Moisture separators, oil separators, traps, or other equipment may be necessary to achieve this requirement.

5.2 Any of the following methods of surface preparation may be used to achieve a commercial blast cleaned surface:

5.2.1 Dry abrasive blasting using compressed air, blast nozzles, and abrasive.

5.2.2 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with compressed air, blast nozzle, and abrasive, with or without vacuum for dust and abrasive recovery.

5.2.3 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with centrifugal wheels and abrasive.

5.3 Other methods of surface preparation (such as wet abrasive blast cleaning) may be used to achieve a commercial blast cleaned surface by mutual agreement between those responsible for establishing the requirements and those responsible for performing the work. Information on the use of inhibitors to prevent the formation of rust immediately after wet abrasive blast cleaning is in Paragraph A5 of Appendix A.

Section 6: Blast Cleaning Abrasives

6.1 The selection of abrasive size and type shall be based on the type, grade, and surface condition of the steel to be cleaned, the type of blast cleaning system used, the finished surface to be produced (cleanliness and surface profile [roughness]), and whether the abrasive will be recycled.

6.2 The cleanliness and size of recycled abrasives shall be maintained to ensure compliance with this standard.

6.3 The blast cleaning abrasive shall be dry and free of oil, grease, and other contaminants as determined by the test methods found in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

6.4 Any limitations on the use of specific abrasives, the quantity of contaminants, or the degree of allowable embedment shall be included in the procurement documents (project specification) covering the work, because abrasive embedment and abrasives containing contaminants may not be acceptable for some service requirements. Additional information on abrasive selection is in Paragraph A6 of Appendix A.

6.5 When a coating is specified, the cleaned surface shall be roughened to a degree suitable for the specified coating system. Additional information on surface profile and the film thickness of coating applied over the surface profile is in Paragraphs A7 and A8 of Appendix A.

Section 7: Procedures Following Blast Cleaning and Immediately Prior to Coating

7.1 Visible deposits of oil, grease, or other contaminants shall be removed according to SSPC-SP 1 or another method agreed upon by those parties responsible for establishing the requirements and those responsible for performing the work.

7.2 Dust and loose residues shall be removed from prepared surfaces by brushing; blowing off with clean, dry air; vacuum cleaning; or other methods agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

7.2.1 The presence of toxic metals in the abrasives or coating being removed may place restrictions on the methods of cleaning permitted. The chosen method shall comply with all applicable regulations.

7.2.2 Moisture separators, oil separators, traps, or other equipment may be necessary to achieve clean, dry air.

7.3 After blast cleaning, any remaining surface imperfections (e.g., sharp fins, sharp edges, weld spatter, burning slag, scabs, slivers) shall be removed to the extent required by the procurement documents (project specification). Any damage to the surface profile resulting from the removal of surface imperfections shall be corrected to meet the requirements of Paragraph 6.5. Additional information on surface imperfections is in Paragraph A4 of Appendix A.

7.4 Immediately prior to coating application, the entire surface shall comply with the degree of cleaning specified in this standard. Any visible rust that forms on the surface of

the steel after blast cleaning shall be removed by recleaning the rusted areas before coating. Information on chemical contamination, rust-back (rerusting), and the effect of dew point (surface condensation) is in Paragraphs A9, A10, and A11 of Appendix A.

Section 8: Inspection

8.1 Work performed and materials supplied under this standard are subject to inspection by a representative of those responsible for establishing the requirements. Materials and work areas shall be accessible to the inspector. The procedures and times of inspection shall be as agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

8.2 Conditions not complying with this standard shall be corrected. In the case of a dispute, an arbitration or settlement procedure established in the procurement documents (project specification) shall be followed. If no arbitration or settlement procedure is established, a procedure mutually agreeable to purchaser and supplier shall be used.

8.3 The procurement documents (project specification) should establish the responsibility for inspection and for any required affidavit certifying compliance with the specification.

Section 9: Safety and Environmental Requirements

9.1 Because abrasive blast cleaning is a hazardous operation, all work shall be conducted in compliance with applicable occupational and environmental health and safety rules and regulations.

Section 10: Comments (Nonmandatory)

10.1 Additional information and data relative to this standard are in Appendix A. Detailed information and data are presented in a separate document, SSPC-SP COM.[8] The recommendations in Appendix A and SSPC-SP COM are believed to represent good practice, but are not to be considered requirements of the standard. The sections of SSPC-SP COM that discuss subjects related to commercial blast cleaning are listed below.

Subject	Commentary Section
Abrasive Selection	6
Film Thickness	10
Maintenance Repainting	4.2
Reference Photographs	11
Rust-Back (Rerusting)	8.3
Surface Profile	6.2
Weld Spatter	4.4.1
Wet Abrasive Blast Cleaning	8.2

References

1. NACE No. 8/SSPC-SP 14 (latest revision), “Industrial Blast Cleaning” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

2. NACE No. 2/SSPC-SP 10 (latest revision), “Near-White Metal Blast Cleaning” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

3. SSPC-VIS 1 (latest revision), “Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning” (Pittsburgh, PA: SSPC).

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9. SSPC-PA Guide 4 (latest revision), "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems" (Pittsburgh, PA: SSPC).

10. NACE SP0178 (formerly RP0178) (latest revision), "Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service" (Houston, TX: NACE).

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15. SSPC-Guide 15 (latest revision), "Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates" (Pittsburgh, PA: SSPC).

Appendix A: Explanatory Notes (Nonmandatory)

A1 FUNCTION: Commercial blast cleaning (NACE No. 3/SSPC-SP 6) provides a greater degree of cleaning than industrial blast cleaning (NACE No. 8/SSPC-SP 14) but less than near-white metal blast cleaning (NACE No. 2/SSPC-SP 10). It should be specified only when a compatible coating will be applied. The primary functions of blast cleaning before coating are (a) to remove material from the surface that can cause early failure of the coating and (b) to obtain a suitable surface profile (roughness) to enhance the adhesion of the new coating system. The hierarchy of blasting standards is as follows: white metal blast cleaning, near-white metal blast cleaning, commercial blast cleaning, industrial blast cleaning, and brush-off blast cleaning.

A2 MAINTENANCE COATING WORK: When this standard is used in maintenance coating work, specific instructions should be provided on the extent of surface to be blast cleaned or spot blast cleaned to this degree of cleanliness. In these cases, this degree of cleaning applies to the entire specified area. For example, if all weld seams are to be cleaned in a maintenance operation, this degree of cleaning applies to 100 percent of all weld seams. If the entire structure is to be prepared, this degree of cleaning applies to 100 percent of the entire structure. SSPC-PA Guide 4[9] provides a description of accepted practices for retaining old sound coating, removing unsound coating, feathering, and spot cleaning.

A3 REFERENCE PHOTOGRAPHS AND COMPARATORS: SSPC-VIS 1 provides color photographs for the various grades of surface cleaning as a function of the initial condition of the steel. The photographs B SP 6, C SP 6, D SP 6, G_1 SP 6, G_2 SP 6, and G_3 SP 6 depict surfaces cleaned to commercial grade. Other available reference photographs and comparators are described in Section 11 of SSPC-SP COM.

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Poorly adhering contaminants, such as weld slag residues, loose weld spatter, and some minor surface laminations, may be removed during the blast cleaning operation. Other surface defects (steel laminations, weld porosities, or deep corrosion pits) may not be evident until the surface cleaning has been completed. Repair of such surface defects should be planned properly because the timing of the repairs may occur before, during, or after the blast cleaning operation. Section 4.4 of SSPC-SP COM and NACE SP0178[10] contain additional information on surface imperfections.

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A6 ABRASIVE SELECTION: Types of metallic and nonmetallic abrasives are discussed in SSPC-SP COM. Blasting abrasives may become embedded in, or leave residues on, the surface of the steel during cleaning. While such embedment or residues are normally not detrimental, care should be taken to ensure that the abrasive is free from detrimental amounts of water-soluble, solvent-soluble, acid-soluble, or other soluble contaminants (particularly if the cleaned steel is to be used in an immersion environment). Criteria for selecting and evaluating abrasives are in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

A7 SURFACE PROFILE: Surface profile is the roughness of the surface that results from abrasive blast cleaning. The profile height is dependent on the size, shape, type, and hardness of the abrasive, particle velocity and angle of impact, hardness of the surface, amount of abrasive recycling, and the proper maintenance of working mixtures of grit and/or shot.

The allowable minimum/maximum height of profile is usually dependent on the thickness of the coating to be applied. Large particle-sized abrasives (particularly metallic) can produce a surface profile that may be too high to be adequately covered by a single thin-film coat. Accordingly, the use of larger abrasives should be avoided in these cases. However, larger abrasives may be needed for thick-film coatings or to facilitate removal of thick coatings, heavy mill scale, or rust. If control of surface profile (minimum/maximum) is deemed to be significant to coating performance, it should be addressed in the procurement documents (project specification). Typical surface profile heights achieved with commercial abrasive media are shown in Table 6 of SSPC-SP COM. Surface profile should be measured in accordance with NACE Standard RP0287[11] or ASTM D 4417.[12]

A8 FILM THICKNESS: It is essential that ample coating be applied after blast cleaning to adequately cover the peaks of the surface profile. The dry-film thickness of the coating above the peaks of the profile should equal the thickness known to be needed for the desired protection. If the dry-film thickness over the peaks is inadequate, premature rust-through or coating failure will occur. To ensure that coating thicknesses are properly measured, the procedures in SSPC-PA 2[13] should be used.

A9 CHEMICAL CONTAMINATION: Steel contaminated with soluble salts (e.g., chlorides and sulfates) develops rust-back rapidly at intermediate and high levels of humidity. These soluble salts can be present on the steel surface prior to blast cleaning as a result of atmospheric contamination. In addition, contaminants can be deposited on the steel surface during blast cleaning if the abrasive is contaminated. Therefore, rust-back can be minimized by removing these salts from the steel surface and eliminating sources of recontamination during and after blast cleaning. Wet methods of removal are described in NACE No. 5/SSPC-SP 12.[14] Identification of the contaminants along with their concentrations may be obtained from laboratory and field tests as described in SSPC-Guide 15.[15]

A10 RUST-BACK: Rust-back (rerusting) occurs when freshly cleaned steel is exposed to moisture, contamination, or a corrosive atmosphere. The time interval between blast cleaning and rust-back varies greatly from one environment to another. Under mild ambient conditions, if chemical contamination (see Paragraph A9) is not present, it is best to blast clean and coat a surface on the same day. Severe conditions may require a more expeditious coating application to avoid contamination from fallout. Chemical contamination should be removed prior to coating.

A11 DEW POINT: Moisture condenses on any surface that is colder than the dew point of the surrounding air. It is therefore recommended that the temperature of the steel surface be at least 3°C (5°F) above the dew point during dry blast cleaning operations. It is advisable to visually inspect for moisture and periodically check the surface temperature and dew point during blast cleaning operations and to avoid the application of coating over a damp surface.

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Joint Surface Preparation Standard

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

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Foreword

This joint standard covers the use of blast cleaning abrasives to achieve a defined degree of cleaning of steel surfaces prior to the application of a protective coating or lining system. This standard is intended for use by coating or lining specifiers, applicators, inspectors, or others who may be responsible for defining a standard degree of surface cleanliness.

The focus of this standard is brush-off blast cleaning. White metal blast cleaning, near-white metal blast cleaning, commercial blast cleaning, and industrial blast cleaning are addressed in separate standards.

Brush-off blast cleaning provides a lesser degree of cleaning than industrial blast cleaning (NACE No. 8/SSPC-SP 14[1]). The difference between an industrial blast cleaning and a brush-off blast cleaning is that the objective of a brush-off blast cleaning is to allow as much of an existing adherent coating to remain as possible and to roughen the surface prior to coating application, whereas the purpose of the industrial blast cleaning is to remove most of the coating, mill scale, and rust, while the extra effort required to remove every trace of these is determined to be unwarranted.

This joint standard was originally prepared in 1994 and revised in 2000 by the SSPC/NACE Task Group (TG) A on Surface Preparation by Abrasive Blast Cleaning. This joint TG includes members of both the SSPC Surface Preparation Committee and the NACE Unit Committee T-6G on Surface Preparation. It was reaffirmed in 2006 by NACE Specific Technology Group (STG) 04, Protective Coatings and Linings: Surface Preparation, and the SSPC Surface Preparation Committee.

In NACE/SSPC standards, the terms *shall, must, should,* and *may* are used in accordance with Paragraph 2.2.1.8 of the Agreement Between NACE International and SSPC: The Society for Protective Coatings. The terms *shall* and *must* are used to state mandatory requirements. The term *should* is used to state something considered good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

Joint Surface Preparation Standard

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

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Section 1: General

1.1 This joint standard covers the requirements for brush-off blast cleaning of uncoated or coated steel surfaces by the use of abrasives. These requirements include the end condition of the surface and materials and procedures necessary to achieve and verify the end condition.

1.2 The mandatory requirements are described in Sections 1 to 9. Section 10, "Comments," and Appendix A, "Explanatory Notes," are not mandatory requirements of this standard.

1.3 Information about the function of brush-off blast cleaning is in Paragraph A1 of Appendix A.

1.4 Information about use of this standard in maintenance coating work is in Paragraph A2 of Appendix A.

Section 2: Definitions

2.1 **Brush-Off Blast Cleaned Surface:** A brush-off blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, loose mill scale, loose rust, and loose coating. Tightly adherent mill scale, rust, and coating may remain on the surface. Mill scale, rust, and coating are considered tightly adherent if they cannot be removed by lifting with a dull putty knife after abrasive blast cleaning has been performed.

2.1.1 The entire surface shall be subjected to the abrasive blast. The remaining mill scale, rust, or coating shall be tight. Flecks of the underlying steel need not be exposed whenever the original substrate consists of intact coating.

2.1.2 SSPC-VIS 1[2] may be specified to supplement the written definition. In any dispute, the written definition set forth in this standard shall take precedence over reference photographs and comparators. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 3: Associated Documents

3.1 The latest issue, revision, or amendment of the documents listed in Paragraph 3.3 in effect on the date of invitation to bid shall govern unless otherwise specified.

3.2 If there is a conflict between the requirements of any of the documents listed in Paragraph 3.3 and this standard, the requirements of this standard shall prevail.

3.3 Documents cited in the mandatory sections of this standard include:

Document	Title
SSPC-AB 1[3]	Mineral and Slag Abrasives
SSPC-AB 2[4]	Cleanliness of Recycled Ferrous Metallic Abrasives
SSPC-AB 3[5]	Ferrous Metallic Abrasives
SSPC-SP 1[6]	Solvent Cleaning
SSPC-VIS 1	Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning

Section 4: Procedures Before Cleaning

4.1 Before blast cleaning, visible deposits of oil, grease, or other contaminants shall be removed in accordance with SSPC-SP 1 or other agreed-upon methods.

4.2 Before blast cleaning, surface imperfections such as sharp fins, sharp edges, weld spatter, or burning slag should be removed from the surface to the extent required by the procurement documents (project specification). Additional information on surface imperfections is in Paragraph A4 of Appendix A.

4.3 If reference photographs or comparators are specified to supplement the written standard, the condition of the steel prior to blast cleaning should be determined before the blasting commences. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 5: Blast Cleaning Methods and Operation

5.1 Clean, dry compressed air shall be used for nozzle blasting. Moisture separators, oil separators, traps, or other equipment may be necessary to achieve this requirement.

5.2 Any of the following methods of surface preparation may be used to achieve a brush-off blast cleaned surface:

5.2.1 Dry abrasive blasting using compressed air, blast nozzles, and abrasive.

5.2.2 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with compressed air, blast nozzle, and abrasive, with or without vacuum for dust and abrasive recovery.

5.2.3 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with centrifugal wheels and abrasive.

5.3 Other methods of surface preparation (such as wet abrasive blast cleaning) may be used to achieve a brush-offl blast cleaned surface by mutual agreement between those responsible for establishing the requirements and those responsible for performing the work. Information on the use of inhibitors to prevent the formation of rust immediately after wet abrasive blast cleaning is in Paragraph A5 of Appendix A.

Section 6: Blast Cleaning Abrasives

6.1 The selection of abrasive size and type shall be based on the type, grade, and surface condition of the steel to be cleaned, the type of blast cleaning system used, the finished surface to be produced (cleanliness and surface profile [roughness]), and whether the abrasive will be recycled.

6.2 The cleanliness and size of recycled abrasives shall be maintained to ensure compliance with this standard.

6.3 The blast cleaning abrasive shall be dry and free of oil, grease, and other contaminants as determined by the test methods found in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

6.4 Any limitations on the use of specific abrasives, the quantity of contaminants, or the degree of allowable embedment shall be included in the procurement documents (project specification) covering the work, because abrasive embedment and abrasives containing contaminants may not be acceptable for some service requirements. Additional information on abrasive selection is in Paragraph A6 of Appendix A.

6.5 When a coating is specified, the cleaned surface shall be roughened to a degree suitable for the specified coating system. Additional information on surface profile and the film thickness of coating applied over the surface profile is in Paragraphs A7 and A8 of Appendix A.

Section 7: Procedures Following Blast Cleaning and Immediately Prior to Coating

7.1 Visible deposits of oil, grease, or other contaminants shall be removed according to SSPC-SP 1 or another method agreed upon by those parties responsible for establishing the requirements and those responsible for performing the work.

7.2 Dust and loose residues shall be removed from prepared surfaces by brushing; blowing off with clean, dry air; vacuum cleaning; or other methods agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

7.2.1 The presence of toxic metals in the abrasives or coating being removed may place restrictions on the methods of cleaning permitted. The chosen method shall comply with all applicable regulations.

7.2.2 Moisture separators, oil separators, traps, or other equipment may be necessary to achieve clean, dry air.

7.3 After blast cleaning, any remaining surface imperfections (e.g., sharp fins, sharp edges, weld spatter, burning slag, scabs, slivers) shall be removed to the extent required by the procurement documents (project specification). Any damage to the surface profile resulting from the removal of surface imperfections shall be corrected to meet the requirements of Paragraph 6.5. Additional information on surface imperfections is in Paragraph A4 of Appendix A.

7.4 Immediately prior to coating application, the entire surface shall comply with the degree of cleaning specified in this standard. Information on chemical contamination, rust-back (rerusting), and the effect of dew point (surface condensation) is in Paragraphs A9, A10, and A11 of Appendix A.

Section 8: Inspection

8.1 Work performed and materials supplied under this standard are subject to inspection by a representative of those responsible for establishing the requirements. Materials and work areas shall be accessible to the inspector. The procedures and times of inspection shall be as agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

8.2 Conditions not complying with this standard shall be corrected. In the case of a dispute, an arbitration or settlement procedure established in the procurement documents (project specification) shall be followed. If no arbitration or settlement procedure is established, a procedure mutually agreeable to purchaser and supplier shall be used.

8.3 The procurement documents (project specification) should establish the responsibility for inspection and for any required affidavit certifying compliance with the specification.

Section 9: Safety and Environmental Requirements

9.1 Because abrasive blast cleaning is a hazardous operation, all work shall be conducted in compliance with applicable occupational and environmental health and safety rules and regulations.

Section 10: Comments (Nonmandatory)

10.1 Additional information and data relative to this standard are in Appendix A. Detailed information and data are presented in a separate document, SSPC-SP COM.[7] The recommendations in Appendix A and SSPC-SP COM are believed to represent good practice, but are not to be considered requirements of the standard. The sections of SSPC-SP COM that discuss subjects related to brush-off blast cleaning are listed below.

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Abrasive Selection	6
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Wet Abrasive Blast Cleaning	8.2

References

1. NACE No. 8/SSPC-SP 14 (latest revision), “Industrial Blast Cleaning” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

2. SSPC-VIS 1 (latest revision), “Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning” (Pittsburgh, PA: SSPC).

3. SSPC-AB 1 (latest revision), “Mineral and Slag Abrasives” (Pittsburgh, PA: SSPC).

4. SSPC-AB 2 (latest revision), “Cleanliness of Recycled Ferrous Metallic Abrasives” (Pittsburgh, PA: SSPC).

5. SSPC-AB 3 (latest revision), “Ferrous Metallic Abrasives” (Pittsburgh, PA: SSPC).

6. SSPC-SP 1 (latest revision), “Solvent Cleaning” (Pittsburgh, PA: SSPC).

7. SSPC-SP COM (latest revision), “Surface Preparation Commentary for Steel and Concrete Substrates” (Pittsburgh, PA: SSPC).

8. SSPC-PA Guide 4 (latest revision), “Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems” (Pittsburgh, PA: SSPC).

9. NACE SP0178 (formerly RP0178) (latest revision), “Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service” (Houston, TX: NACE).

10. NACE Standard RP0287 (latest revision), “Field Measurement of Surface Profile of Abrasive Blast-Cleaned Steel Surfaces Using a Replica Tape” (Houston, TX: NACE).

11. ASTM[1] D 4417 (latest revision), "Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel" (West Conshohocken, PA: ASTM).

12. SSPC-PA 2 (latest revision), "Measurement of Dry Coating Thickness with Magnetic Gages" (Pittsburgh, PA: SSPC).

13. NACE No. 5/SSPC-SP 12 (latest revision), "Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

14. SSPC-Guide 15 (latest revision), "Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates" (Pittsburgh, PA: SSPC).

Appendix A: Explanatory Notes (Nonmandatory)

A1 FUNCTION: Brush-off blast cleaning (NACE No. 4/SSPC-SP 7) provides a lesser degree of cleaning than industrial blast cleaning (NACE No. 8/SSPC-SP 14). It should be used when the service environment is mild enough to permit tight mill scale, coating, rust, and other foreign matter to remain on the surface. The primary functions of blast cleaning before coating are (a) to remove material from the surface that can cause early failure of the coating and (b) to obtain a suitable surface profile (roughness) to enhance the adhesion of the new coating system. The hierarchy of blasting standards is as follows: white metal blast cleaning, near-white metal blast cleaning, commercial blast cleaning, industrial blast cleaning, and brush-off blast cleaning.

A2 MAINTENANCE COATING WORK: When this standard is used in maintenance coating work, specific instructions should be provided on the extent of surface to be blast cleaned or spot blast cleaned to this degree of cleanliness. In these cases, this degree of cleaning applies to the entire specified area. For example, if all weld seams are to be cleaned in a maintenance operation, this degree of cleaning applies to 100 percent of all weld seams. If the entire structure is to be prepared, this degree of cleaning applies to 100 percent of the entire structure. SSPC-PA Guide 4[8] provides a description of accepted practices for retaining old sound coating, removing unsound coating, feathering, and spot cleaning.

A3 REFERENCE PHOTOGRAPHS AND COMPARATORS: SSPC-VIS 1 provides color photographs for the various grades of surface cleaning as a function of the initial condition of the steel. The photographs A SP 7, B SP 7, C SP 7, D SP 7, G_1 SP 7, G_2 SP 7, and G_3 SP 7 depict surfaces cleaned to brush-off blast grade. Other available reference photographs and comparators are described in Section 11 of SSPC-SP COM.

A4 SURFACE IMPERFECTIONS: Surface imperfections can cause premature coating failure when the service is severe. Coatings tend to pull away from sharp edges and projections, leaving little or no coating to protect the underlying steel. Other features that are difficult to cover and protect properly include crevices, weld porosities, laminations, etc. The high cost of the methods to remedy surface imperfections (such as edge rounding and weld spatter removal) should be weighed against the costs of a potential coating failure.

Poorly adhering contaminants, such as weld slag residues, loose weld spatter, and some minor surface laminations, may be removed during the blast cleaning operation. Other surface defects (steel laminations, weld porosities, or deep corrosion pits) may not be evident until the surface cleaning has been completed. Repair of such surface defects should be planned properly because the timing of the repairs may occur before, during, or after the blast cleaning operation. Section 4.4 of SSPC-SP COM and NACE SP0178[9] contain additional information on surface imperfections.

A5 WET ABRASIVE BLAST CLEANING: Steel that is wet abrasive blast cleaned may rust rapidly. Clean water should be used for rinsing. It may be necessary to add inhibitors to the water or apply them to the surface immediately after blast cleaning to temporarily prevent rust formation. The use of inhibitors or the application of coating over slight discoloration should be in accordance with the requirements of the coating manufacturer. CAUTION: Some inhibitive treatments may interfere with the performance of certain coating systems.

A6 ABRASIVE SELECTION: Types of metallic and nonmetallic abrasives are discussed in SSPC-SP COM. Blasting abrasives may become embedded in, or leave residues on, the surface of the steel during cleaning.

[1] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

While such embedment or residues are normally not detrimental, care should be taken to ensure that the abrasive is free from detrimental amounts of water-soluble, solvent-soluble, acid-soluble, or other soluble contaminants (particularly if the cleaned steel is to be used in an immersion environment). Criteria for selecting and evaluating abrasives are in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

A7 SURFACE PROFILE: Surface profile is the roughness of the surface that results from abrasive blast cleaning. The profile height is dependent on the size, shape, type, and hardness of the abrasive, particle velocity and angle of impact, hardness of the surface, amount of abrasive recycling, and the proper maintenance of working mixtures of grit and/or shot.

The allowable minimum/maximum height of profile is usually dependent on the thickness of the coating to be applied. Large particle-sized abrasives (particularly metallic) can produce a surface profile that may be too high to be adequately covered by a single thin-film coat. Accordingly, the use of larger abrasives should be avoided in these cases. However, larger abrasives may be needed for thick-film coatings or to facilitate removal of thick coatings, heavy mill scale, or rust. If control of surface profile (minimum/maximum) is deemed to be significant to coating performance, it should be addressed in the procurement documents (project specification). Typical surface profile heights achieved with commercial abrasive media are shown in Table 6 of SSPC-SP COM. Surface profile should be measured in accordance with NACE Standard RP0287[10] or ASTM D 4417.[11]

A8 FILM THICKNESS: It is essential that ample coating be applied after blast cleaning to adequately cover the peaks of the surface profile. The dry-film thickness of the coating above the peaks of the profile should equal the thickness known to be needed for the desired protection. If the dry-film thickness over the peaks is inadequate, premature rust-through or coating failure will occur. To ensure that coating thicknesses are properly measured, the procedures in SSPC-PA 2[12] should be used.

A9 CHEMICAL CONTAMINATION: Steel contaminated with soluble salts (e.g., chlorides and sulfates) develops rust-back rapidly at intermediate and high levels of humidity. These soluble salts can be present on the steel surface prior to blast cleaning as a result of atmospheric contamination. In addition, contaminants can be deposited on the steel surface during blast cleaning if the abrasive is contaminated. Therefore, rust-back can be minimized by removing these salts from the steel surface and eliminating sources of recontamination during and after blast cleaning. Wet methods of removal are described in NACE No. 5/SSPC-SP 12.[13] Identification of the contaminants along with their concentrations may be obtained from laboratory and field tests as described in SSPC-Guide 15.[14]

A10 RUST-BACK: Rust-back (rerusting) occurs when freshly cleaned steel is exposed to moisture, contamination, or a corrosive atmosphere. The time interval between blast cleaning and rust-back varies greatly from one environment to another. Under mild ambient conditions, if chemical contamination (see Paragraph A9) is not present, it is best to blast clean and coat a surface on the same day. Severe conditions may require a more expeditious coating application to avoid contamination from fallout. Chemical contamination should be removed prior to coating.

A11 DEW POINT: Moisture condenses on any surface that is colder than the dew point of the surrounding air. It is therefore recommended that the temperature of the steel surface be at least 3°C (5°F) above the dew point during dry blast cleaning operations. It is advisable to visually inspect for moisture and periodically check the surface temperature and dew point during blast cleaning operations and to avoid the application of coating over a damp surface.

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Joint Surface Preparation Standard

NACE No. 5/SSPC-SP 12
Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating

This NACE International (NACE)/SSPC: The Society for Protective Coatings standard represents a consensus of those individual members who have reviewed this document, its scope, and provisions. It is intended to aid the manufacturer, the consumer, and the general public. Its acceptance does not in any respect preclude anyone, whether he has adopted the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not addressed in this standard. Nothing contained in this NACE/SSPC standard is to be construed as granting any right, by implication or otherwise, to manufacture, sell, or use in connection with any method, apparatus, or product covered by Letters Patent, or as indemnifying or protecting anyone against liability for infringement of Letters Patent. This standard represents current technology and should in no way be interpreted as a restriction on the use of better procedures or materials. Neither is this standard intended to apply in all cases relating to the subject. Unpredictable circumstances may negate the usefulness of this standard in specific instances. NACE and SSPC assume no responsibility for the interpretation or use of this standard by other parties and accept responsibility for only those official interpretations issued by NACE or SSPC in accordance with their governing procedures and policies which preclude the issuance of interpretations by individual volunteers.

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Foreword

This joint standard describes the surface preparation technique known as waterjetting. This technique provides an alternative method of removing coating systems or other materials from metal surfaces, including lead-based paint systems, prior to the application of a protective coating or lining system. This standard is intended for use by coating or lining specifiers, applicators, inspectors, or others whose responsibility it may be to define a standard degree of surface cleanliness. Since publication of NACE Standard RP0172,[1] surface preparation using waterjetting equipment has found acceptance as a viable method.

Waterjetting can be effective in removing water-soluble surface contaminants that may not be removed by dry abrasive blasting alone, specifically, those contaminants found at the bottom of pits of severely corroded metallic substrates. Waterjetting also helps to remove surface grease and oil, rust, shot-creting spatter, and existing coatings and linings. Waterjetting is also used in areas where abrasive blasting is not a feasible method of surface preparation.

The use of a high-pressure water stream to strip existing coatings and clean the surface has advantages over open dry abrasive blasting with respect to worker respiratory exposure and work area air quality. Respiratory requirements for waterjetting may be less stringent than for other methods of surface preparation.

Waterjetting does not provide the primary anchor pattern on steel known to the coatings industry as “profile.” The coatings industry uses waterjetting primarily for recoating or relining projects in which there is an adequate preexisting profile. Waterjetting has application in a broad spectrum of industries. It is used when high-performance coatings require extensive surface preparation and/or surface decontamination.

This standard was originally prepared by NACE/SSPC Joint Task Group TGD. It was technically revised in 2002 by Task Group 001 on Surface Preparation by High-Pressure Waterjetting. This Task Group is administered by Specific Technology Group (STG) 04 on Protective Coatings and Linings—Surface Preparation, and is sponsored by STG 02 on Protective Coatings and Linings—Atmospheric, and STG 03 on Protective Coatings and Linings—Immersion/Buried. This standard is issued by NACE International under the auspices of STG 04, and by SSPC Group Committee C.2 on Surface Preparation.

Joint Surface Preparation Standard

NACE No. 5/SSPC-SP 12
Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating

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Section 1: General

1.1 This standard describes the use of waterjetting to achieve a defined degree of cleaning of surfaces prior to the application of a protective coating or lining system. These requirements include the end condition of the surface plus materials and procedures necessary to verify the end condition. This standard is limited in scope to the use of water only.

1.2 This standard is written primarily for applications in which the substrate is carbon steel. However, waterjetting can be used on nonferrous substrates such as bronze, aluminum, and other metals such as stainless steel. This standard does not address the cleaning of concrete. Cleaning of concrete is discussed in NACE No. 6/SSPC SP-13.[2]

1.3 Appendices A, B, and C give additional information on waterjetting equipment, production rates, procedures, and principles.

1.4 Visual Reference Photographs: NACE VIS 7/SSPC-VIS 4, "Guide and Reference Photographs for Steel Surfaces Prepared by Waterjetting,"[3] provides color photographs for the various grades of surface preparation as a function of the initial condition of the steel. The latest issue of the reference photographs should be used.

Section 2: Definitions

2.1 This section provides basic waterjetting definitions. Additional definitions relevant to waterjetting are contained in the WaterJet Technology Association's[(1)] "Recommended Practices for the Use of Manually Operated High-Pressure Waterjetting Equipment."[4]

2.1.1 **Waterjetting (WJ):** Use of standard jetting water discharged from a nozzle at pressures of 70 MPa (10,000 psig) or greater to prepare a surface for coating or inspection. Waterjetting uses a pressurized stream of water with a velocity that is greater than 340 m/s (1,100 ft/s) when exiting the orifice. Waterjetting does not produce an etch or profile of the magnitude currently recognized by the coatings industry. Rather, it exposes the original abrasive-blasted surface profile if one exists.

2.1.2 **Water Cleaning (WC):** Use of pressurized water discharged from a nozzle to remove unwanted matter from a surface.

2.1.3 **Standard Jetting Water:** Water of sufficient purity and quality that it does not impose additional contaminants on the surface being cleaned and does not contain sediments or other impurities that are destructive to the proper functioning of waterjetting equipment.

2.1.4 **Low-Pressure Water Cleaning (LP WC)**: Water cleaning performed at pressures less than 34 MPa (5,000 psig). This is also called "power washing" or "pressure washing."

2.1.5 **High-Pressure Water Cleaning (HP WC):** Water cleaning performed at pressures from 34 to 70 MPa (5,000 to 10,000 psig).

2.1.6 **High-Pressure Waterjetting (HP WJ):** Waterjetting performed at pressures from 70 to 210 MPa (10,000 to 30,000 psig).

2.1.7 **Ultrahigh-Pressure Waterjetting (UHP WJ):** Waterjetting performed at pressures above 210 MPa (30,000 psig).

2.1.8 **Nonvisible Contamination (NV):** Nonvisible contamination is the presence of organic matter, such as very thin films of oil and grease, and/or soluble ionic materials such as chlorides, ferrous salts, and sulfates that remain on the substrate after cleaning.

2.1.9 **Visible Surface Cleanliness (VC):** Visible surface cleanliness is the visible condition of the substrate, when viewed without magnification, after cleaning.

Section 3: Surface Cleanliness Requirements

3.1 Table 1 lists four definitions of surface cleanliness in terms of visible contaminants. A surface shall be prepared to one of these four visual conditions prior to recoating.

3.1.1 As part of the surface preparation, deposits of oil, grease, and foreign matter must be removed by waterjetting, by water cleaning, by steam cleaning, by methods in accordance with SSPC-SP 1,[5] or by

[(1)] WaterJet Technology Association, 917 Locust Street, Suite 1100, St. Louis, MO 63101-1419.

another method agreed upon by the contracting parties.

3.1.2 NOTE: Direct correlation to existing dry media blasting standards is inaccurate or inappropriate when describing the capabilities of water cleaning and the visible results achieved by water cleaning.

3.1.3 The entire surface to be prepared for coating shall be subjected to the cleaning method.

3.1.4 For WJ-4 (see Table 1) any remaining mill scale, rust, coating, or foreign materials shall be tightly adherent. All of the underlying metal need not be exposed.

3.1.5 Photographs may be specified to supplement the written definition. In any dispute, the written standards shall take precedence over visual reference photographs or visual standards such as NACE VIS 7/SSPC-VIS 4.[3]

3.2 Table 2 lists definitions of flash rusted surfaces (See Section 4). When deemed necessary, a surface should be prepared to one of these flash rusted surface conditions prior to recoating.

3.3 The specifier shall use one of the visual surface preparation definitions (WJ-1 to WJ-4 in Table 1) and, when deemed necessary, one of the flash rust definitions.

3.3.1 The following is an example of a specification statement:

"All surfaces to be recoated shall be cleaned to NACE No. 5/SSPC-SP 12, WJ-2/L, Very Thorough or Substantial Cleaning, Light Flash Rusting."

3.4 Appendix A contains information on nonvisible surface contaminants. In addition to the requirements given in Paragraph 3.1, the specifier should consider whether a surface should be prepared not to exceed the maximum level of nonvisible surface contamination prior to recoating. A suggested specification statement for nonvisible contaminants is given in Appendix A.

Table 1: Visual Surface Preparation Definitions

Term	Description of Surface
WJ-1	**Clean to Bare Substrate:** A WJ-1 surface shall be cleaned to a finish which, when viewed without magnification, is free of all visible rust, dirt, previous coatings, mill scale, and foreign matter. Discoloration of the surface may be present.[(A, B, C)]
WJ-2	**Very Thorough or Substantial Cleaning:** A WJ-2 surface shall be cleaned to a matte (dull, mottled) finish which, when viewed without magnification, is free of all visible oil, grease, dirt, and rust except for randomly dispersed stains of rust, tightly adherent thin coatings, and other tightly adherent foreign matter. The staining or tightly adherent matter is limited to a maximum of 5% of the surface.[(A, B, C)]
WJ-3	**Thorough Cleaning:** A WJ-3 surface shall be cleaned to a matte (dull, mottled) finish which, when viewed without magnification, is free of all visible oil, grease, dirt, and rust except for randomly dispersed stains of rust, tightly adherent thin coatings, and other tightly adherent foreign matter. The staining or tightly adherent matter is limited to a maximum of 33% of the surface.[(A, B, C)]
WJ-4	**Light Cleaning:** A WJ-4 surface shall be cleaned to a finish which, when viewed without magnification, is free of all visible oil, grease, dirt, dust, loose mill scale, loose rust, and loose coating. Any residual material shall be tightly adherent.[(C)]

[(A)] Surfaces cleaned by LP WC, HP WC, HP WJ, or UHP WJ do not exhibit the hue of a dry abrasive blasted steel surface. After waterjetting, the matte finish color of clean steel surface immediately turns to a golden hue unless an inhibitor is used or environmental controls are employed.[6] On older steel surfaces that have areas of coating and areas that are coating-free, the matte finish color varies even though all visible surface material has been removed. Color variations in steel can range from light gray to dark brown/black.

Steel surfaces show variations in texture, shade, color, tone, pitting, flaking, and mill scale that should be considered during the cleaning process. Acceptable variations in appearance that do not affect surface cleanliness include variations caused by type of steel or other metals, original surface condition, thickness of the steel, weld metal, mill fabrication marks, heat treating, heat-affected zones, and differences in the initial abrasive blast cleaning or in the waterjet cleaning pattern.

The gray or brown-to-black discoloration seen on corroded and pitted steel after waterjetting cannot be removed by further waterjetting. A brown-black discoloration of ferric oxide may remain as a tightly adherent thin film on corroded and pitted steel and is not considered part of the percentage staining.

[(B)] Waterjetting at pressures in excess of 240 MPa (35,000 psig) is capable of removing tightly adherent mill scale, but production rates are not always cost effective.

[(C)] Mill scale, rust, and coating are considered tightly adherent if they cannot be removed by lifting with a dull putty knife. (See NACE No. 4/SSPC-SP 7[7]).

Section 4: Flash Rusted Surface Requirements

4.1 Table 2 lists four definitions of flash rusted surface requirements. *Flash rust* or *water bloom* is a light oxidation of the steel that occurs as waterjetted carbon steel dries. With the exception of stainless steel surfaces, any steel surface may show flash rust within 0.5 to 2 hours, or longer depending on environmental conditions, after cleaning by water. Flash rust quickly changes the appearance. Flash rust may be reduced or eliminated by physical or chemical methods. The color of the flash rust may vary depending on the age and composition of the steel and the time-of-wetness of the substrate prior to drying. With time, the flash rust changes from a yellow-brown, well adherent, light rust to a red-brown, loosely adherent, heavy rust.

4.2 It is a common practice to remove heavy flash rust by low-pressure water cleaning. The visual appearance of steel that has heavily flash rusted after initial cleaning and is then recleaned by low-pressure water cleaning (up to 34 MPa [5,000 psig]) has a different appearance than the original light flash rusted steel depicted in NACE VIS 7/SSPC-VIS 4.

4.3 The coating manufacturer should be consulted to ascertain the tolerance of the candidate coatings to visual cleanliness, nonvisible contaminants, and the amount of flash rust commensurate with the in-service application. These conditions should be present at the time of recoating.

4.4 The following is an example of a specification statement concerning flash rust:

"At the time of the recoating, the amount of flash rust shall be no greater than moderate (M) as defined in NACE No. 5/SSPC-SP 12."

Table 2: Flash Rusted Surface Definitions

Term	Description of Surface
No Flash Rust	A steel surface which, when viewed without magnification, exhibits no visible flash rust.
Light (L)	A surface which, when viewed without magnification, exhibits small quantities of a yellow-brown rust layer through which the steel substrate may be observed. The rust or discoloration may be evenly distributed or present in patches, but it is tightly adherent and not easily removed by lightly wiping with a cloth.
Moderate (M)	A surface which, when viewed without magnification, exhibits a layer of yellow-brown rust that obscures the original steel surface. The rust layer may be evenly distributed or present in patches, but it is reasonably well adherent and leaves light marks on a cloth that is lightly wiped over the surface.
Heavy (H)	A surface which, when viewed without magnification, exhibits a layer of heavy red-brown rust that hides the initial surface condition completely. The rust may be evenly distributed or present in patches, but the rust is loosely adherent, easily comes off, and leaves significant marks on a cloth that is lightly wiped over the surface.

Section 5: Occupational and Environmental Requirements

5.1 Because waterjet cleaning is a hazardous operation, all work shall be conducted in compliance with all applicable occupational health and safety rules and environmental regulations.

Section 6: Cautionary Notes

6.1 Waterjetting can be destructive to nonmetallic surfaces. Soft wood, insulation, electric installations, and instrumentation must be protected from direct and indirect water streams.

6.2 Water used in waterjetting units must be clean and free of erosive silts or other contaminants that damage pump valves and/or leave deposits on the surface being cleaned. The cleaner the water, the longer the service life of the waterjetting equipment.

6.3 Any detergents or other types of cleaners used in conjunction with waterjetting shall be removed from surfaces prior to applying a coating.

6.4 Compatibility of the detergents with the special seals and high-alloy metals of the waterjetting equipment must be carefully investigated to ensure that WJ machines are not damaged.

6.5 If inhibitors are to be used with the standard jetting water, the manufacturer of the waterjetting equipment shall be consulted to ensure compatibility of inhibitors with the equipment.

6.6 The coatings manufacturer shall be consulted to ensure the compatibility of inhibitors with the coatings.

6.7 If effluent jetting water is captured for reuse in the jetting method, caution should be used to avoid introducing any removed contaminants back to the cleaned substrate. The effluent water should be treated to remove suspended particulate, hydrocarbons, chlorides, hazardous materials, or other by-products of the surface preparation procedures. The water should be placed in a clean water holding tank and tested to determine the content of possible contamination prior to reintroduction into the jetting stream. If detergents or degreasers are used prior to surface preparation, these waste streams should be segregated from the effluent jetting water to avoid contamination and possible equipment damage.

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2 NACE No. 6/SSPC-SP 13 (latest revision), "Surface Preparation of Concrete" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

3. NACE VIS 7/SSPC-VIS 4 (latest revision), "Guide and Visual Reference Photographs for Steel Cleaned by Waterjetting" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

4. "Recommended Practices for the Use of Manually Operated High-Pressure Waterjetting Equipment," (St. Louis, MO: WaterJet Technology Association, 1987).

5. SSPC-SP 1 (latest revision), "Solvent Cleaning" (Pittsburgh, PA: SSPC).

6. NACE Publication 6A192/SSPC-TR 3 (latest revision), "Dehumidification and Temperature Control During Surface Preparation, Application, and Curing for Coatings/Linings of Steel Tanks, Vessels, and Other Enclosed Spaces" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

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[2] International Organization for Standardization (ISO), 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.
[3] Federal Highway Administration (FHWA), 400 7th St. SW, Washington, DC 20590.
[4] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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NOTE: Appendices A, B, and C provide explanatory notes. They provide additional information on waterjetting.

Appendix A: Surface Cleanliness Conditions of Nonvisible Contaminants and Procedures for Extracting and Analyzing Soluble Salts

A1.1 For the purpose of this appendix, the list of non-visible contaminants is limited to water-soluble chlorides, iron-soluble salts, and sulfates. The contracting parties should be aware that other nonvisible contaminants may have an effect on the coating performance.[8] The specifier should determine whether, and to what condition, nonvisible chemical contaminants should be specified. Section 3 contains additional information on surface cleanliness conditions.

A1.2 The level of nonvisible contaminants that may remain on the surface is usually expressed as mass per unit area, for example, $\mu g/cm^2$ (grains/in.^{2}) or mg/m^2 (grains/yd^2) (1 $\mu g/cm^2$ = 10 mg/m^2 = 0.0001 grains/in.^{2} = 0.13 grains/yd^2).

A1.3 Coatings manufacturers should be consulted for recommendations of maximum surface contamination allowed. The specification should read as follows:

> "Immediately prior to the application of the coating, the surface shall not contain more than xx $\mu g/cm^2$ (grains/in.^{2}) of the specific contaminant (e.g., chloride) when tested with a specified method as agreed upon by contracting parties."

A1.4 The contracting parties shall agree on the test method or procedure to be used for determining the level of nonvisible contaminants.

Note: NACE and ISO committees are currently (2002) developing recommendations for the level of nonvisible contaminants that may be tolerated by different types of coatings in various services.

Table A1: Description of Nonvisible Surface Cleanliness Definitions[(A)] (NV)

Term	Description of Surface
NV-1	An NV-1 surface shall be free of detectable levels of soluble contaminants, as verified by field or laboratory analysis using reliable, reproducible test methods.
NV-2	An NV-2 surface shall have less than 7 $\mu g/cm^2$ (0.0007 grains/in.^{2}) of chloride contaminants, less than 10 $\mu g/cm^2$ (0.001 grains/in.^{2}) of soluble ferrous ion levels, or less than 17 $\mu g/cm^2$ (0.0017 grains/in.^{2}) of sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test methods.
NV-3	An NV-3 surface shall have less than 50 $\mu g/cm^2$ (0.005 grains/in.^{2}) of chloride or sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test methods.

[(A)] Additional information on suitable procedures for extracting and analyzing soluble salts is available in NACE Publication 6G186,[8] and SSPC-TU 4.[9]

A2.1 Procedure for Extracting Soluble Salts by Swabbing

The following procedures may be used to extract the soluble salts from the surface:

(a) SSPC Swabbing Method[9]
(b) Procedure described in ISO 8502-5, Section 5.1, "Washing of the Test Area"[10]
(c) Any suitable controlled washing procedures available and agreed to by the contracting parties. During the washing procedure, clean plastic or rubber gloves should be worn to ensure that the wash water is not accidentally contaminated.

A2.2 Procedure for Extracting Soluble Salts by Surface Cells

(a) Limpet Cell Method[11]
(b) Surface Conductivity Cell Method[9,11]
(c) Nonrigid Extraction Cell Method[9,11, 12]

A2.3 Procedure for Field Analysis of Chloride Ions

The extract retrieved using the procedures in Paragraphs A2.1 and A2.2 may be analyzed using one of the following methods:

(a) Chloride Chemical Test Strips[9]
(b) Chloride Chemical Titration Kit[9]
(c) Ion Detection Tube Method[9,10]

The following laboratory method is available as a referee method:

(a) Specific Chloride Ion Electrode[9,11,13]

A2.4 Procedure for Field Analysis of Sulfate Ions

The extract retrieved using the procedures in Paragraphs A2.1 and A2.2 may be analyzed using one of the following methods:

(a) Turbidity Field Comparator Methods[9, 11]
(b) Turbidity Method[9,11]
(c) Standard Test Method for Sulfate Ion in Water[14]

A2.5 Procedure for Field Analysis of Soluble Iron Salts

The extract retrieved using the procedures in Paragraph A2.1 or A2.2 may be analyzed using one of the following methods:

(a) Ferrous Chemical Test Strips[9,11]
(b) Semiquantitative Test for Ferrous Ions[8]
(c) Field Colorimetric Comparator Methods

A2.5.1 Papers treated with potassium ferricyanide may be used for the qualitative field detection of ferrous ions.[8,9]

Appendix B: Waterjetting Equipment

B1.1 The commercial waterjet unit can be mounted on a skid, trailer, or truck; can be equipped with various prime movers (diesel, electric motor, etc.); and usually consists of a pump, hoses, and various tools. The tools can be hand-held or mounted on a robot (or traversing mechanism). Water is propelled through a single jet, a fan jet, or multiple rotating jets. Rotation is provided by small electric, air, or hydraulic motors, or by slightly inclined orifices in a multiple-orifice nozzle.

B1.2 The units operate at pressures up to 240 to 290 MPa (35,000 to 42,000 psig), using a hydraulic hose with a minimum bursting strength of 2.5 times the capability of its maximum-rated operating strength.

B1.3 A water flow rate of 4 to 53 L/min (1 to 14 gal/min) is typical.

B1.4 Pressure loss is a function of the flow rate of the water through the hose and the inside diameter of the hose. The manufacturer should be consulted for specific information on potential pressure loss for each type of equipment.

B1.5 Waterjets are produced by orifices, or tips, that can have different forms. The higher the pressure, the more limited is the choice of forms. Round jets are most commonly used, but orifices of other shapes are available. Tips can be designed to produce multiple jets of water that are normally rotated to achieve higher material removal rates. Interchangeable nozzle tips should be used to produce the desired streams. The manufacturer shall be consulted for specific recommendations.

B1.6 The distance from the nozzle to the work piece substrate (standoff distance) is critical for effective cleaning with any of the water methods. Excessive standoff does not produce the desired cleaning.

Appendix C: Principles of Waterjetting

NACE No. 5/SSPC-SP 12 is a performance specification, not a process specification. Appendix C is not intended to be used as an equipment specification.

C1 Commentary on Production Rates

C1.1 Operator skill and the condition of the steel surface affect waterjetting production rates.[15,16,17] Regardless of the surface conditions, production rates usually improve when:

(a) The operator gains additional experience with high- and ultrahigh-pressure waterjetting; or

(b) Mechanized, automated waterjetting equipment is used.

C1.1.1 New metal with tightly adhering mill scale requires the highest level of operator skill and concentration to produce a clean surface by waterjetting. Older, more corroded, or previously coated surfaces require an average level of skill and concentration to achieve desired results. This is the opposite of abrasive blasting, when poor surface conditions require the highest levels of operator skill and concentration.

C1.2 As a general rule, production and ease of removal increase as the waterjetting pressure increases.

C1.3 Cleanup time to remove waste material should be considered when determining the overall production rate.

C2 Commentary on Waterjetting Parameters

C2.1 The specifier should describe the final condition of the substrate. Depending on the initial condition of the area and materials to be cleaned, the method to achieve Visible Conditions WJ-1, WJ-2, WJ-3, or WJ-4 may be LP WC, HP WC, HP WJ, or UHP WJ. The method of water cleaning or waterjetting ultimately is based on the capabilities of the equipment and its components. Dwell time, transverse rate, pressure, flow, stand-off distances, the number of nozzles, and rotation speed all interact in determining what material will remain and what will be removed.

C2.2 There are two thoughts on increasing production rates during the removal of materials by pressurized water. First, determine the threshold pressure at which the material will just be removed. The user can then either increase the flow to achieve adequate production rates or increase the pressure by a factor no greater than three over the threshold pressure. These two methods do not necessarily yield the same result.[18]

C2.3 Details of the calculations in Table C1 are standard to the waterjetting industry and are beyond the scope of this standard.[19]

C2.4 Removal of degraded coating is coupled to thorough stressing of the remaining coating. The jet energy is the work done when the jet stream vertically impacts the coating surface. Energy is normally measured in kilojoules. The shear stress is developed against the vertical pit walls and larger fractures created on the eroded coating surface. This can, in gross terms, be thought of as a hydraulic load.

C2.5 Flexure stressing is induced by repetitive loading and unloading of the coatings systems by the jet streams as they pass over the surface. The rapid loading and unloading is vital to finding areas of low adherence and nonvisible adherence defects in the coating system.[19]

C2.6 Characteristics of typical pressurized water systems are included in Table C1.

Table C1: Typical Pressurized Water Systems

Pressure at Nozzle	70 MPa (10,000 psig)	140 MPa (20,000 psig)	280 MPa (40,000 psig)
Number of Tips	2	2	5
Diameter	1.0 mm (0.040 in.)	0.69 mm (0.027 in.)	0.28 mm (0.011 in.)
Flow	12.9 L/min (3.42 gpm)	8.3 L/min (2.2 gpm)	2.0 L/min (0.52 gpm)
Cross-Sectional Area	0.81 mm^2 (0.0013 $in.^2$)	0.37 mm^2 (0.00060 $in.^2$)	0.065 mm^2 (0.00010 $in.^2$)
Jet Velocity	360 m/s (1,180 ft/s)	520 m/s (1,700 ft/s)	730 m/s (2,400 ft/s)
Impact Force (per tip)	8.1 kg (18 lb)	7.7 kg (17 lb)	2.4 kg (5.3 lb)
Jet Energy	141 kJ (134 BTU)	189 kJ (179 BTU)	89 kJ (81 BTU)
Energy Intensity (energy/ cross-sectional area)	175 kJ/mm^2 (107,000 $BTU/in.^2$)	513 kJ/mm^2 (314,000 $BTU/in.^2$)	1,401 kJ/mm^2 (857,000 $BTU/in.^2$)

C2.7 In field terms, the 70-MPa (10,000-psig) jets may not significantly erode the coatings. Therefore, they are typically used for partial removal or for cleaning loose detrital material. The 140-MPa (20,000-psig) jets erode the coatings fairly rapidly and are typically used for partial removal. The 280-MPa (40,000-psig) jets erode and destroy coatings very fast and are typically used when most or all of the coating is to be removed (WJ-1 or WJ-2).

C2.8 Application judgment is employed by operators or users who make the decisions concerning which type of jetting water to use:

(a) HP WC (the water's flow rate is the predominant energy characteristic);

(b) HP WJ (pressure [i.e., the velocity of the water] and flow rate are equally important); or

(c) UHP WJ (the pressure [i.e., the velocity of the water] is the dominant energy characteristic).

C2.9 As water passes through the orifice, potential energy (pressure) is converted to kinetic energy. The energy increases linearly with the mass flow, but increases with the square of the velocity, as shown in Equation (C1).

$$Kinetic\ Energy = \frac{1}{2}mv^2 \qquad \text{(C1)}$$

where

m = mass (derived from water volume)
v = velocity (derived from pressure)

In order to calculate the kinetic energy from flow rates and velocity, a time period must be selected. A time period of 10 milliseconds is used for Equation (C1).

C2.10 The threshold pressure[5] of a coating must also be determined. In general, the tougher or harder the coating (i.e., the more resistant to testing by a pocket knife), the higher the threshold pressure; the softer and more jelly-like the coating, the lower the threshold pressure.

C2.10.1 Once the threshold pressure is achieved or exceeded, the production rate increases dramatically. Therefore, waterjetting production rates are affected by two conditions:

(a) Erosion at pressures lower than the threshold pressure, and

(b) Waterjet cutting and erosion at pressures greater than the threshold pressure.

[5] *Threshold pressure* is defined as the minimum pressure required to penetrate the material.[20]

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Joint Surface Preparation Standard

NACE No. 6/SSPC-SP 13
Surface Preparation of Concrete

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Foreword

This standard covers the preparation of concrete surfaces prior to the application of protective coating or lining systems. This standard should be used by specifiers, applicators, inspectors, and others who are responsible for defining a standard degree of cleanliness, strength, profile, and dryness of prepared concrete surfaces.

This standard was originally prepared in 1997 by NACE/SSPC Joint Task Group F on Surface Preparation of Concrete. It was reaffirmed in 2003 by NACE Specific Technology Group 04 on Protective Coatings and Linings—Surface Preparation and SSPC Group Committee C.2 on Surface Preparation. This standard is issued by NACE International under the auspices of STG 04, and by SSPC Group Committee C.2.

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Section 1: General

1.1 This standard gives requirements for surface preparation of concrete by mechanical, chemical, or thermal methods prior to the application of bonded protective coating or lining systems.

1.2 The requirements of this standard are applicable to all types of cementitious surfaces including cast-in-place concrete floors and walls, precast slabs, masonry walls, and shotcrete surfaces.

1.3 An acceptable prepared concrete surface should be free of contaminants, laitance, loosely adhering concrete, and dust, and should provide a sound, uniform substrate suitable for the application of protective coating or lining systems.

1.4 When required, a minimum concrete surface strength, maximum surface moisture content, and surface profile range should be specified in the procurement documents (project specifications).

1.5 The mandatory requirements of this standard are given in Sections 1 to 7 as follows:

Section 1:	General
Section 2:	Definitions
Section 3:	Inspection Procedures Prior to Surface Preparation
Section 4:	Surface Preparation
Section 5:	Inspection and Classification of Prepared Concrete Surfaces
Section 6:	Acceptance Criteria
Section 7:	Safety and Environmental Requirements

1.6 Appendix A does not contain mandatory requirements.

Section 2: Definitions

Coating: See *Protective Coating or Lining System*.

Concrete: A material made from hydraulic cement and inert aggregates, such as sand and gravel, which is mixed with water to a workable consistency and placed by various methods to harden and gain strength.

Curing (Concrete): Action taken to maintain moisture and temperature conditions in a freshly placed cementitious mixture to allow hydraulic cement hydration so that potential properties of the mixture may develop.

Curing Compound (Membrane Curing Compound): A liquid that can be applied as a coating to the surface of newly placed concrete to retard the loss of water.[1]

Efflorescence: A white crystalline or powdery deposit on the surface of concrete. Efflorescence results from leaching of lime or calcium hydroxide out of a permeable concrete mass over time by water, followed by reaction with carbon dioxide and acidic pollutants.[2]

Fin: A narrow linear projection on a formed concrete surface, resulting from mortar flowing into spaces in the form work.[1]

Finish: The texture of a surface after consolidating and finishing operations have been performed.[1]

Finishing: Leveling, smoothing, consolidating, and otherwise treating surfaces of fresh or recently placed concrete or mortar to produce desired appearance and service.[1]

Hardener (Concrete): A chemical (including certain fluorosilicates or sodium silicate) applied to concrete floors to reduce wear and dusting.[1]

High-Pressure Water Cleaning (HP WC): Water cleaning performed at pressures from 34 to 70 MPa (5,000 to 10,000 psig).[3]

High-Pressure Waterjetting (HP WJ): Waterjetting performed at pressures from 70 to 210 MPa (10,000 to 30,000 psig).[3]

Honeycomb: Voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles.[1]

Laitance: A thin, weak, brittle layer of cement and aggregate fines on a concrete surface. The amount of laitance is influenced by the type and amount of admixtures, the degree of working, and the amount of water in the concrete.[2]

Lining: See *Protective Coating or Lining System*.

Placing: The deposition, distribution, and consolidation of freshly mixed concrete in the place where it is to harden.[1]

Porosity: Small voids that allow fluids to penetrate an otherwise impervious material.

Protective Coating or Lining System (Coating): For the purposes of this standard, protective coating or lining systems (also called *protective barrier systems*) are bonded thermoset, thermoplastic, inorganic, organic/inorganic hy-

brids, or metallic materials applied in one or more layers by various methods such as brush, roller, trowel, spray, and thermal spray. They are used to protect concrete from degradation by chemicals, abrasion, physical damage, and the subsequent loss of structural integrity. Other potential functions include containing chemicals, preventing staining of concrete, and preventing liquids from being contaminated by concrete.

Release Agents (Form-Release Agents): Materials used to prevent bonding of concrete to a surface.[1]

Sealer (Sealing Compound): A liquid that is applied as a coating to a concrete surface to prevent or decrease the penetration of liquid or gaseous media during exposure. Some curing compounds also function as sealers.

Soundness: A qualitative measure of the suitability of the concrete to perform as a solid substrate or base for a coating or patching material. Sound concrete substrates usually exhibit strength and cohesiveness without excessive voids or cracks.

Spalling (Concrete): The development of spalls which are fragments, usually in the shape of a flake, detached from a larger mass by a blow, by the action of weather, by pressure, or by expansion within the larger mass.[1]

Surface Porosity: Porosity or permeability at the concrete surface that may absorb vapors, moisture, chemicals, and coating liquids.

Surface Preparation: The method or combination of methods used to clean a concrete surface, remove loose and weak materials and contaminants from the surface, repair the surface, and roughen the surface to promote adhesion of a protective coating or lining system.

Surface Profile (Texture): Surface contour as viewed from edge.

Surface Air Voids: Cavities visible on the surface of a solid.

Section 3: Inspection Procedures Prior to Surface Preparation

3.1 Concrete shall be inspected prior to surface preparation to determine the condition of the concrete and to determine the appropriate method or combination of methods to be used for surface preparation to meet the requirements of the coating system to be applied. Inherent variations in surface conditions seen in walls and ceilings versus those in floors should be considered when choosing surface preparation methods and techniques. For example, walls and ceilings are much more likely than floors to contain surface air voids, fins, form-release agents, and honeycombs.

3.2 Visual Inspection

All concrete surfaces to be prepared and coated shall be visually inspected for signs of concrete defects, physical damage, chemical damage, contamination, and excess moisture.

3.3 Concrete Cure

All concrete should be cured using the procedures described in ACI[(1)] 308.[4] Curing requirements include maintaining sufficient moisture and temperatures for a minimum time period. Surface preparation performed on insufficiently cured or low-strength concrete may create an excessively coarse surface profile or remove an excessive amount of concrete.

3.4 Concrete Defects

Concrete defects such as honeycombs and spalling shall be repaired. The procedures described in NACE Standard RP0390,[5] ICRI[(2)] 03730,[6] or ACI 301[7] may be used to ensure that the concrete surface is sound prior to surface preparation.

3.5 Physical Damage

3.5.1 Concrete should be tested for soundness by the qualitative methods described in NACE Publication 6G191[8] or Paragraph A1.4.3.

3.5.2 When qualitative results are indeterminate, or when a quantitative result is specified, concrete shall be tested for surface tensile strength using the methods described in Paragraph A1.6.

3.5.3 Concrete that has been damaged because of physical forces such as impact, abrasion, or corrosion of reinforcement shall be repaired prior to surface preparation if the damage would affect coating performance. Repairs should be made in accordance with ACI 301,[7] NACE Standard RP0390,[5] or Paragraph A1.4.

3.6 Chemical Damage

3.6.1 Concrete is attacked by a variety of chemicals, as detailed in ACI 515.1R[9] and PCA[(3)] IS001.[10]

(1) American Concrete Institute International (ACI), 38800 International Way, Country Club Drive, Farmington Hills, MI 48331.
(2) International Concrete Repair Institute (ICRI), 3166 S. River Road, Suite 132, Des Plaines, IL 60018.
(3) Portland Cement Association (PCA), 5420 Old Orchard Rd., Skokie, IL 60077.

3.6.2 All concrete surfaces that have been exposed to chemicals shall be tested and treated for contamination as described in Paragraph 3.7.

3.6.3 Concrete that has been exposed to chemicals shall be tested for soundness by the qualitative methods described in NACE Publication 6G191[8] or Paragraph A1.4.3.

3.7 Contamination

3.7.1 Contamination on concrete surfaces includes all materials that may affect the adhesion and performance of the coating to be applied. Examples include, but are not limited to, dirt, oil, grease, chemicals, and existing incompatible coatings.

3.7.2 Contamination may be detected by methods described in NACE Publication 6G191[8] and Paragraph A1.5. These methods include, but are not limited to, visual examination, water drop (contact angle) measurement, pH testing, petrographic examination, and various instrumental analytical methods. Core sampling may be required to determine the depth to which the contaminant has penetrated the concrete.

3.7.3 Concrete surfaces that are contaminated or that have existing coatings shall be tested by the method described in Paragraph A1.6.3 to determine whether the contamination or existing coating affects the adhesion and performance of the coating to be applied. Concrete surfaces that have existing coatings shall also be tested by the method described in Paragraph A1.6.3 to determine whether the existing coating is sufficiently bonded to the concrete.

3.7.4 In extreme cases of concrete damage or degradation, or thorough penetration by contaminants, complete removal and replacement of the concrete may be required.

3.8 Moisture

Moisture levels in the concrete may be determined by the methods described in Paragraph 5.6.

Section 4: Surface Preparation

4.1 Objectives

4.1.1 The objective of surface preparation is to produce a concrete surface that is suitable for application and adhesion of the specified protective coating system.

4.1.2 Protrusions such as from burrs, sharp edges, fins, and concrete spatter shall be removed during surface preparation.

4.1.3 Voids and other defects that are at or near the surface shall be exposed during surface preparation.

4.1.4 All concrete that is not sound shall be removed so that only sound concrete remains.

4.1.5 Concrete damaged by exposure to chemicals shall be removed so that only sound concrete remains.

4.1.6 All contamination, form-release agents, efflorescence, curing compounds, and existing coatings determined to be incompatible with the coating to be applied shall be removed.

4.1.7 The surface preparation method, or combination of methods, should be chosen based on the condition of the concrete and the requirements of the coating system to be applied.

4.1.8 All prepared concrete surfaces shall be repaired to the level required by the coating system in the intended service condition.

4.2 Surface Cleaning Methods

4.2.1 The surface cleaning methods described in Paragraphs 4.2.2 and 4.2.3 shall not be used as the sole surface preparation method of concrete to be coated as they do not remove laitance or contaminants or alter the surface profile of concrete. These methods shall be used as required, before and/or after the mechanical and chemical methods described in Paragraphs 4.3 and 4.4.

4.2.2 Vacuum cleaning, air blast cleaning, and water cleaning as described in ASTM[(4)] D 4258[11] may be used to remove dirt, loose material, and/or dust from concrete.

4.2.3 Detergent water cleaning and steam cleaning as described in ASTM D 4258[11] may be used to remove oils and grease from concrete.

4.3 Mechanical Surface Preparation Methods

4.3.1 Dry abrasive blasting, wet abrasive blasting, vacuum-assisted abrasive blasting, and centrifugal shot blasting, as described in ASTM D 4259,[12] may be used to remove contaminants, laitance, and weak concrete,

[(4)] ASTM International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

to expose subsurface voids, and to produce a sound concrete surface with adequate profile and surface porosity.

4.3.2 High-pressure water cleaning or waterjetting methods as described in NACE No. 5/SSPC-SP 12,[2] ASTM D 4259,[12] or "Recommended Practices for the Use of Manually Operated High Pressure Water Jetting Equipment,"[(5)13] may be used to remove contaminants, laitance, and weak concrete, to expose subsurface voids, and to produce a sound concrete surface with adequate profile and surface porosity.

4.3.3 Impact-tool methods may be used to remove existing coatings, laitance, and weak concrete. These methods include scarifying, planing, scabbling, and rotary peening, as described in ASTM D 4259.[12] Impact-tool methods may fracture concrete surfaces or cause microcracking and may need to be followed by one of the procedures in Paragraphs 4.3.1 or 4.3.2 to produce a sound concrete surface with adequate profile and surface porosity. The soundness of a concrete surface prepared using an impact method may be verified by one of the surface tensile strength tests described in Paragraph A1.6.

4.3.4 Power-tool methods, including circular grinding, sanding, and wire brushing as described in ASTM D 4259,[12] may be used to remove existing coatings, laitance, weak concrete, and protrusions in concrete. These methods may not produce the required surface profile and may require one of the procedures described in Paragraphs 4.3.1 or 4.3.2 to produce a concrete surface with adequate profile and surface porosity.

4.3.5 Surface preparation using the methods described in Paragraphs 4.3.1 through 4.3.4 shall be performed in a manner that provides a uniform, sound surface that is suitable for the specified protective coating system.

4.4 Chemical Surface Preparation

Acid etching, as described in ASTM D 4260[14] and NACE Standard RP0892,[15] may be used to remove laitance and weak concrete and to provide a surface profile on horizontal concrete surfaces. This method requires complete removal of all reaction products and pH testing to ensure neutralization of the acid. Acid etching is not recommended for vertical surfaces and areas where curing compounds or sealers have been used. Acid etching shall only be used where procedures for handling, containment, and disposal of the hazardous materials are in place. Acid etching with hydrochloric acid shall not be used where corrosion of metal in the concrete (rebar or metal fibers) is likely to occur.

4.5 Flame (Thermal) Cleaning and Blasting

4.5.1 Flame cleaning using a propane torch or other heat source may be used to extract organic contaminants from a concrete surface. To remove the extracted contaminants this type of cleaning may need to be followed by the cleaning methods described in ASTM D 4258.[11]

4.5.2 Flame cleaning and blasting using oxygen-acetylene flame blasting methods and proprietary delivery equipment may be used to remove existing coatings, contaminants, and laitance and/or create a surface profile on sound concrete.

4.5.3 The extent of removal when employing flame methods is affected by the rate of equipment advancement, the flame adjustment, and the distance between the flame and the concrete surface. Surface preparation using flame methods shall be performed in a manner that provides a uniform, sound surface that is suitable for the specified protective coating system.

4.5.4 High temperatures reduce the strength of or damage concrete; therefore, surfaces prepared using flame methods shall be tested for soundness and surface tensile strength. Concrete surfaces found to be unsound or low in tensile strength shall be repaired or prepared by other mechanical methods described in Paragraph 4.3.

4.6 Surface Cleanliness

After the concrete surface has been prepared to the required soundness and surface profile, surfaces may still need to be cleaned by one of the methods described in Paragraph 4.2 to remove the residue created by the surface preparation method or to remove spent media.

4.7 Moisture Content

If the moisture level in the concrete is higher than the specified limit tolerable by the coating, the concrete shall be dried or allowed to dry to the level specified in the procurement documents before inspection and application of the coating (see Paragraph 5.6).

4.8 Patching and Repairs

4.8.1 Prior to proceeding with patching and repairs, the prepared concrete surface shall be inspected according to Section 5. After the patching and repairs of the concrete surface are completed, the repaired areas shall be reinspected according to Section 5.

4.8.2 All gouges, surface air voids, and other surface anomalies shall be repaired to a level required by the coating system as specified in the procurement documents.

[(5)] WaterJet Technology Association, 917 Locust, Suite 1100, St. Louis, MO 63101-1419.

4.8.3 All repair materials, both cementitious and polymeric, should be approved or recommended by the coating manufacturer as being compatible with the coating to be applied. Repair materials not recommended or approved by the coating manufacturer shall be tested for compatibility prior to their application.

4.8.4 The repair material shall be cured according to the manufacturer's published instructions.

4.8.5 The repaired section may require additional surface preparation prior to coating application.

Section 5: Inspection and Classification of Prepared Concrete Surfaces

5.1 Surface Tensile Strength

5.1.1 All prepared concrete surfaces should be tested for surface tensile strength after cleaning and drying but prior to making repairs or applying the coating.

5.1.2 Surface tensile strength should be tested using a method agreed upon by all parties. (See Paragraph A1.6 for commentary on these methods.)

5.2 Coating Adhesion

5.2.1 If specified in the procurement documents and accepted by all parties, a test patch shall be applied to determine the compatibility of and adhesion between the prepared surface and the coating system. (See Paragraph A1.6.3 for commentary on this method.)

5.2.2 Coating adhesion should be tested using one of the methods agreed upon by all parties. (See Paragraph A1.6 for commentary on these methods.)

5.3 Surface Profile

5.3.1 If a specific surface profile is required for the performance of the coating system to be applied, the profile shall be specified in the procurement documents.

5.3.2 The surface profile of prepared concrete surfaces should be evaluated after cleaning and drying but prior to repairs or application of the coating.

5.3.3 The surface profile may be evaluated by comparing the profile of the prepared concrete surface with the profile of graded abrasive paper, as described in ANSI[(6)] B 74.18,[16] by comparing the profile with the ICRI Guideline No. 03732[17] (surface profile chips), or by another agreed-upon visual comparison.

5.4 Surface Cleanliness

5.4.1 All prepared concrete surfaces shall be inspected for surface cleanliness after cleaning and drying but prior to making repairs or applying the coating. If the concrete surfaces are repaired, they shall be reinspected for surface cleanliness prior to applying the coating.

5.4.2 Prepared concrete surfaces may be inspected for surface cleanliness by lightly rubbing the surface with a dark cloth or pressing a translucent adhesive tape on the surface. The test method and acceptable level of residual dust shall be agreed on by all parties.

5.4.3 The method used to verify compatibility of the coating to be applied over a contaminated surface or over contaminated surfaces that have been cleaned and prepared should be approved by the coating manufacturer and specified in the procurement documents.

5.5 pH

5.5.1 If a specific pH range is required for proper performance of the coating system to be applied, the pH of the concrete shall be specified in the procurement documents.

5.5.2 The pH of concrete surfaces prepared by acid etching should be tested after etching and rinsing but before the prepared surface has dried.

5.5.3 ASTM D 4262[18] should be used to determine pH.

5.6 Moisture Content

5.6.1 If a specific moisture content is required for proper performance of the coating system to be applied, the moisture content of the concrete shall be specified in the procurement documents.

5.6.2 Prepared concrete surfaces should be tested for residual moisture after cleaning and drying but prior to the application of the coating.

5.6.3 ASTM D 4263,[19] ASTM F 1869,[20] or ASTM F 2170[21] should be used to determine the residual moisture content in concrete.

5.6.4 If required or accepted by all parties, any of the methods described in Paragraph A1.8.4 may be used to determine the moisture content of the concrete surface.

[(6)] American National Standards Institute (ANSI), 1819 L Street NW, Washington, DC 20036.

Section 6: Acceptance Criteria

6.1 The acceptance criteria for prepared concrete surfaces shall be specified in the procurement documents.

6.2 The procurement documents may refer to the specifications in Table 1.

Table 1:
Suggested Acceptance Criteria for Concrete Surfaces After Surface Preparation

Property	Test Method	Light Service[A]	Severe Service[B]
Surface tensile strength	See Paragraph A1.6	1.4 MPa (200 psi) min.	2.1 MPa (300 psi) min.
Surface profile	Visual comparison[16]	Fine (150) abrasive paper min.	Coarse (60) abrasive paper min.
Surface cleanliness	Visible dust[11]	No significant dust	No significant dust
Residual contaminants	Water drop[15,22]	0° contact angle	0° contact angle
pH	ASTM D 4262[18]	(pH of rinse water) -1, +2[C]	(pH of rinse water) -1, +2[C]
Moisture content[D]	ASTM D 4263[19]	No visible moisture	No visible moisture
Moisture content[D]	ASTM F 1869[20]	15 g/24 hr/m^2 (3 lb/24 hr/1,000 ft^2) max.	15 g/24 hr/m^2 (3 lb/24 hr/1,000 ft^2) max.
Moisture content[D]	ASTM F 2170[21]	80% max.	80% max.

[A] Light service refers to surfaces and coatings that have minimal exposure to traffic, chemicals, and changes in temperature.
[B] Severe service refers to surfaces and coatings that have significant exposure to traffic, chemicals, and/or changes in temperature.
[C] The acceptance criterion for ASTM D 4262 is as follows: The pH readings following the final rinse shall not be more than 1.0 lower or 2.0 higher than the pH of the rinse water (tested at the beginning and end of the final rinse cycle) unless otherwise specified.
[D] Any one of these three moisture content test methods is acceptable.

Section 7: Safety and Environmental Requirements

7.1 Disposal of contaminants, old coatings, acid from etching, and contaminated water and blasting media shall comply with all applicable facility, local, state, and federal regulations.

7.2 Handling of hazardous materials, machinery operations, worker protection, and control of airborne dust and fumes shall comply with all applicable facility, local, state, and federal health and safety regulations.

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3. NACE No. 5/SSPC-SP 12, “Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

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Appendix A: Comments
(This section does not contain any mandatory requirements.)

A1.1 General[23,24,25,26]

A1.1.1 This standard does not recommend surface preparation methods or differentiate levels of surface preparation that are specifically required for various protective system designs, types, thicknesses, and end-use requirements. These specifications should be decided and agreed upon by all parties (the specifier, facility owner, coating manufacturer, and contractor).

A1.1.2 Concrete and its surfaces are not homogeneous or consistent and, unlike steel, cannot be discretely defined. Therefore, visual examination of a concrete surface is somewhat subjective. The acceptance or rejection of a prepared concrete surface should be based on the results of specific tests, including, but not limited to, tests for surface tensile strength, contamination, and moisture.

A1.1.3 Joints, cracks, and curing shrinkage of concrete should be considered in the design of the protective coating system; however, these topics are beyond the scope of this standard. See NACE Standard RP0892,[15] ACI 515.1R,[9] and NACE 6G197/SSPC-TU 2[27] for more information.

A1.1.4 When a significant amount of weak, deteriorated, or contaminated concrete is removed during the course of surface preparation to achieve a sound surface, the profile of the remaining concrete is often too rough for the intended coating system. In these cases, and where form voids and surface air voids must be filled, patching or grouting materials are specified to repair or level the concrete surface. See NACE Standard RP0892,[15] ACI 515.1R,[9] NACE Standard RP0390,[5] NACE 6G197/SSPC-TU 2,[27] and Paragraph A1.4.4 for more information about patching materials.

A1.2 Concrete Finishing and Surface Characteristics[23]

A1.2.1 The method used to finish concrete surfaces affects the concrete's surface profile, composition, porosity, and density. These surface properties affect the adhesion and performance of concrete coatings. Typical surface properties obtained using the most common finishing methods are given in Table A1. These properties are evaluated prior to surface preparation.

A1.2.2 No preferred method of finishing concrete to accept coatings has been established by the concrete coating industry. The surface cure, surface preparation method, and type of coating system to be applied are all factors in determining the suitability of any specific concrete finishing method. For example, broom finishing is sometimes used because it gives a profile for the coating; however, most of the profile may be removed during surface preparation if the surface is not properly cured, negating this inherent advantage of the broom finish. When sacking is used to fill voids in formed concrete surfaces, subsurface voids are created, and the added cement is usually removed during surface preparation due to improper cure of the added cement paste.

Table A1:
Typical Surface Properties of Finished Concrete

Method	Profile[A]	Porosity[A]	Strength[A]	Problems
Formed concrete	Smooth to medium	Low to medium	Medium	Voids, protrusions, release agents
Wood float	Medium	Medium	Medium	
Metal trowel	Smooth	Low	High	
Power trowel	Smooth	Very low	High	Very dense
Broom finish	Coarse to very coarse	Medium	Medium	
Sacking	Smooth	Low to medium	Low to high[B]	Weak layer if not properly cured
Stoning	Smooth to medium	Low to medium	Low to high[B]	Weak layer if not properly cured
Concrete block	Coarse to very coarse	Very high	Medium	Pinholes
Shotcrete[C]	Very coarse	Medium	Medium	Too rough for thin coatings

[A] These surface properties are based on similar concrete mix, placement, and vibration and prior to surface preparation.
[B] Strength depends on application and cure.
[C] Shotcrete may be refinished after placement, which would change the surface properties given in this table.

A1.2.3 Use of a metal trowel is gaining acceptance as the preferred finishing method for horizontal surfaces to be coated, provided the surface is not excessively trowelled, the concrete is cured properly, and the laitance is removed prior to coating.

A1.2.4 Photographic examples of concrete finishes are shown in ASTM PCN:03-401079-14.[28]

A1.3 Concrete Cure[29]

A1.3.1 Maintaining sufficient moisture and proper temperature in concrete in the early stages of cure is important to ensure development of the designed strength. Keeping the surface moist until sufficient strength has developed at the surface is important to ensure formation of sufficient surface strength, to reduce curling, and to reduce surface cracking.

A1.3.2 ACI 308[4] recommends seven days of moist curing for Type I portland cement concrete and three days for Type III portland cement concrete, if the temperature is above 10°C (50°F). ACI 308 also recommends numerous methods to properly cure concrete, including the use of sealing materials and other methods to keep concrete moist.

A1.3.3 ACI 308[4] also gives recommendations on the use of curing compounds, which are commonly used immediately after placement and finishing of concrete surfaces to reduce moisture loss and improve surface cure. The curing compound should either be compatible with the coating or be removed during surface preparation.

A1.4 Identification and Repair of Surface Defects and Damage[30]

A1.4.1 Physical and Chemical Damage

A1.4.1.1 Existing concrete structures that have been subjected to mechanical damage (caused by impact or abrasion), chemical attack, or rebar corrosion are restored to provide a uniform, sound substrate prior to coating application.

A1.4.1.2 In order to best receive and hold the patching material all deteriorated concrete should be removed and the surrounding sound concrete cut using the procedures described in ICRI 03730.[6] Some contaminants have a detrimental effect on the rebar or the applied coating if they are not completely removed.

A1.4.1.3 A number of polymeric grouts and patching materials can be used, especially when the coating is to be applied immediately. These materials should be compatible with the coating to be applied.

A1.4.2 Other Defects and Imperfections

A1.4.2.1 Defects such as honeycombs, scaling, and spalling do not provide a sound, uniform substrate for the coating. These defects are repaired by removing all unsound concrete and then patching the concrete prior to surface preparation. NACE Standard RP0390[5] and ICRI 03730[6] describe removal and repair procedures for concrete

that is spalled because of rebar corrosion.

A1.4.2.2 Surface air voids, pinholes, or excessive porosity may affect the application or performance of the coating. The maximum substrate void size or surface porosity that can be tolerated depends on the coating system under consideration. If voids are not filled before the coating is applied, the trapped air vapor expands and contracts and may affect the performance of the coating. For liquid-rich coatings, excess porosity at the surface may result in pinholes in the coating. Voids are usually filled after surface preparation and prior to coating application.

A1.4.2.3 Protrusions such as form lines, fins, sharp edges, and spatter may cause holidays or thin sections in the coating if they are not removed. Protrusions and rough edges are usually removed during surface preparation.

A1.4.3 Testing for Surface Soundness

A1.4.3.1 NACE Publication 6G191[8] describes the following commonly used methods for determining surface soundness:

A screwdriver, file, or pocket knife is lightly scratched across the concrete surface. If the metal object rides over the surface without loosening any particles and leaves no more than a shiny mark, the surface is sound. If this process gouges the surface, the surface is not sound.

The concrete surface is lightly struck with the edge of a hammer head. If the hammer rebounds sharply with no more than a small fracture at the impact area, the surface is sound. If it lands with a dull thud and leaves powdered dusts in the indentation, the surface is not sound.

A chain is dragged across horizontal concrete surfaces. Differences in sound indicate unsound concrete and holes or pockets within the concrete.

A1.4.4 Patching of Concrete Surface Imperfections

A1.4.4.1 Materials such as grouts, putties, and sealers are used to repair, patch, smooth, or seal the concrete surface to provide a substrate that is suitable for the coating system to be applied. These materials are applied after surface preparation and require the following characteristics:

(1) good adhesion;

(2) adequate strength;

(3) low volumetric and linear shrinkage;

(4) compatibility with the coating to be applied; and

(5) proper consistency for the application.

In addition, the patching material is often required to cure sufficiently, be traffic bearing, and be ready to recoat in a short time frame (usually within 24 hours).

A1.4.4.2 Shrinkage of the patching material may reduce the adhesion of that material to the concrete substrate. Differences in thermal expansion between the concrete, patching material, and coating system cause stresses during thermally induced movement that may reduce adhesion between these layers.

A1.4.4.3 The most common types of patching materials are cementitious, polymer-modified cementitious (usually acrylic), and polymeric (usually epoxy). Cementitious materials are lower in cost than polymeric materials, but polymeric materials generally cure faster and have higher strengths, better adhesion, and increased chemical resistance.

A1.4.4.4 Patching materials are available in a range of consistencies for application to vertical or horizontal surfaces by a variety of methods. The amount of filler also varies. For example, grouts for deep patching are typically highly filled, while porosity sealers may be minimally filled or unfilled. Numerous proprietary materials are low-shrinking, nonshrinking, or expanding.

A1.4.4.5 Additional surface preparation may need to be performed on cured patching materials to ensure that the laitance is removed and/or that the patched surface meets the profile requirements of the coating system.

A1.4.4.6 Photographic examples of patched concrete surfaces are shown in ASTM PCN:03-401079-14.[31]

A1.5 Identification and Removal of Contaminants[22,32,33,34]

A1.5.1 Hydrophobic Materials

A1.5.1.1 Hydrophobic materials such as form-release agents, curing compounds, sealers, existing coatings, oil, wax, grease, resins, and silicone may be detected by a simple water drop test. Analytical techniques such as infrared analysis or gas chromatography may also be used to detect and identify these contaminants.

A1.5.1.2 Oils and greases can be removed by steam cleaning, flame blasting, baking soda blasting, or using degreasers and absorbents.

A1.5.1.3 If they are incompatible with the coating to be applied, existing curing compounds, sealers, form-release agents, and coatings should be removed by the least destructive, most practical, economical, and safe method that is successful. Methods such as grinding, abrasive blasting, wet abrasive blasting, waterjetting, scarifying, flame blasting, or paint stripping may be used.

A1.5.2 Salts and Reactive Materials

A1.5.2.1 Salts and reactive materials such as laitance, efflorescence, acids, alkalis, and by-products of chemical attack of concrete can sometimes be detected by pH testing, soundness testing using the screwdriver test, or visual examination (see PCA IS214).[35] When these methods are not successful, chemical analysis techniques are required.

A1.5.2.2 Residual acids and alkalis are first neutralized and then removed by high-pressure water cleaning. Salts and efflorescence can be removed by abrasive blasting, high-pressure water cleaning, or applying a weak acid or alkali solution and then high-pressure water cleaning.

A1.5.3 Microorganisms

A1.5.3.1 Microorganisms such as fungus, moss, mildew, algae, decomposing foods, and other organic growths can sometimes be detected by visual examination (see PCA IS214).[35]

A1.5.3.2 Microorganisms are removed by washing with sodium hypochlorite (household bleach) and rinsing with water. High-pressure water cleaning or abrasive blasting may also be used.

A1.6 Adhesion Testing[36]

The two commonly used methods for testing adhesion of coatings to concrete substrates are ASTM D 4541[37] (modified for concrete substrates as discussed in Paragraph A1.6.1) and ACI 503R.[38] Testing for surface tensile strength consists of scoring (core drilling) the concrete surface, bonding a test fixture with an adhesive, pulling the fixture with an adhesion tester, and noting the pull-off strength or adhesion value. Testing for coating adhesion is performed using the same procedure, noting the adhesion value, and noting the adhesion failure mode (see Paragraph A1.6.4).

A1.6.1 The procedure described in ASTM D 4541[37] may be used to determine pull-off strength or coating adhesion strength using a portable adhesion tester, typically either a manual tester with a 20-mm (0.78-in.)-diameter loading fixture (test dolly) or a pneumatic adhesion tester with a 13-mm (0.5-in.) loading fixture. ASTM D 4541 states that "Scoring around the fixture violates the fundamental in situ criterion that an unaltered coating be tested," but it also states that scoring should be noted in the results when employed.[37] The procedure in ASTM D 4541 should be modified for use on concrete substrates by scoring or core drilling prior to attaching the loading fixture. Scoring around the test fixture ensures that the pulling force is applied only to the area directly beneath the fixture. Without scoring, stress is transferred through the coating film beyond the area of the test fixture. This could result in significant error when testing thick or reinforced coatings. A water-lubricated diamond-tipped core bit should be used for scoring to reduce the possibility of microcracks in either the coating or the concrete substrate. The procedure may also be modified by using a larger (5-cm [2-in.] or more) loading fixture. A larger test fixture typically yields more accurate results than a smaller fixture because the greater surface area reduces the effect of inconsistencies, such as a piece of aggregate or a void, in the substrate.

A1.6.2 ACI 503R[38] discusses the process of applying a coating or adhesive coring to the substrate, bonding a 5-cm (2-in.) pipe cap to the coating, and applying tension with a mechanical testing device attached to a dynamometer. As with ASTM D 4541,[37] the tensile load and mode of failure are noted.

A1.6.3 A test patch involves applying the coating system to a small section (with the minimum size to be specified) of prepared concrete and testing for tensile strength and adhesion by either of the methods described in Paragraphs A1.6.1 and A1.6.2. The prepared concrete substrate—at least the portion to be patched—should meet the acceptance criteria as detailed in Section 6. The coating system should be applied in accordance with the coating manufacturer's published instructions. The last coat of the coating system serves as the adhesive for the loading fixture, or, when this is not recommended (e.g., for solvent-based topcoats), the loading fixture is attached to the coating system by an adhesive. If agreed by all parties, the primer alone may suffice as the test patch and the adhesive for the loading fixture.

A1.6.4 The acceptable adhesion strength and mode of failure may vary depending on the type of coating tested. The coating manufacturer should be consulted to determine the preferred test method, the suitability of that method, and acceptance criteria for the specified coating. When adhesion testing is performed, the mode of failure should be noted. The failure can be described using one or more of the following terms.

(1) Concrete (substrate) cohesive failure: This failure mode is defined as failure within the concrete, below the concrete/coating interface. This result, if the adhesion value is sufficient, is considered to be the most desirable for coatings applied to concrete. If concrete cohesive failure occurs but the adhesion value is low, the failure may be because of low concrete strength or microcracking from scoring. If only a thin layer of concrete is pulled with the fixture and the adhesion value is

low, it may be because of a weak concrete surface layer or laitance.

(2) Coating adhesive failure: This failure mode is defined as failure directly at the concrete/coating interface. For most coating systems, failure in this mode indicates a problem with surface preparation, residual contamination, or the coating.

(3) Coating cohesive failure or coating intercoat adhesion failure: This failure mode is defined as failure within the coating system, above the concrete/coating interface. This mode of failure indicates a problem with the coating material or with the coating application.

(4) Fixture adhesive failure: This failure mode is defined as failure within the fixture adhesive or at the fixture adhesive/coating interface. When this failure mode is encountered, the test should be repeated.

A1.7 Surface Profile

A1.7.1 In addition to removing laitance, weak concrete, and contamination at the concrete surface, surface preparation usually opens the pores and/or creates a profile on the concrete surface. Profile increases the surface area available for bonding between the concrete and the coating, enhances adhesion at the concrete/coating interface, and helps the coating resist peeling and shear forces.

A1.7.2 The depth of surface profile required depends on:

(1) tensile and shear strength of the concrete and the coating system;

(2) adhesion of the coating system to the concrete;

(3) internal stresses in the coating system created during application (e.g., from shrinkage);

(4) difference in the coefficient of thermal expansion between the coating and the concrete;

(5) modulus or stress-relaxation properties of the coating system;

(6) thermal and chemical exposure environment; and

(7) coating thickness.

A1.7.3 At this time, no recognized testing equipment or method is used to quantify the surface profile of concrete that is analogous to the replica tape method used on steel. The profile can be subjectively compared to the standard classification for coated abrasive paper as described in ANSI B74.18,[16] or by comparing the profile with the ICRI Guideline No. 03732[17] (surface profile chips). For extremely coarse prepared concrete surfaces (assuming that the coating system can cover and perform over such a substrate), the profile may be estimated as an average distance between peaks and valleys on the concrete surface and quantified in mm (mils).

A1.8 Moisture in Concrete[39,40,41,42]

A1.8.1 The movement of moisture in concrete during the curing process and after application of the coating is important to consider in the design of the concrete structure. Concrete is normally placed with water levels in excess of that required to completely hydrate the cement. Excess free water in the concrete can adversely affect the application and cure of many coatings. Pressure caused by excess moisture in the concrete or from ground water may be substantial and, in some instances, may be sufficient to disbond barrier coating systems that appear to be well bonded. These pressures are commonly referred to as hydrostatic, capillary, and osmotic pressures.

A1.8.2 Concrete has traditionally been coated no sooner than 28 days after concrete placement (see Paragraph A1.10). In addition to allowing the concrete to sufficiently cure (see Paragraph A1.3), this waiting period allows excess moisture to evaporate prior to applying a barrier coating system. The waiting period is especially important if a vapor barrier (or positive-side waterproofing) is installed, which prevents moisture from exiting into the ground.

A1.8.3 The drying rate of concrete is a function of the concrete temperature, thickness, porosity, and initial free-water content. The drying rate is also a function of the velocity and dew point of the drying air. Excess free water can be removed by dehumidifiers, surface air movers, or surface heaters provided that (1) the forced drying does not begin until sufficient concrete strength is developed and (2) it does not adversely affect the concrete properties. Dehumidifiers lower the air dew point, can increase the air temperature, and perform best when the area is enclosed. Surface air movers direct low-dew point air across the concrete surface at high velocities, but they should be periodically repositioned to ensure uniform drying over the entire surface. Surface heaters increase the mobility of free water; they work best if the heat penetrates the concrete and if they do not raise the dew point of the drying air.

A1.8.4 Moisture Test Methods[40,41]

The following are some of the common methods used to identify or quantify the free moisture in concrete prior to the application of coatings.

ASTM D 4263, Plastic sheet method[19]

ASTM F 1869, Calcium chloride test[20]

ASTM F 2170, Relative humidity test[21]

ASTM E 1907, Conductivity test[43]

ASTM E 1907, Calcium carbide method[43]

ASTM E 1907, Capacitance-impedance method[43]

A1.8.5 Use and Interpretation of Moisture Test Methods

A1.8.5.1 The plastic sheet method[19] and the calcium chloride test are commonly used and accepted in the United States. The hygrometer and conductivity tests are cited in numerous British standards and are accepted in the United Kingdom, while the carbide method is accepted in other parts of Europe.

A1.8.5.2 All of these methods are quantitative except the plastic sheet method.[19] The plastic sheet, calcium chloride, and capacitance-impedance methods are nondestructive, while the hygrometer, conductivity, and calcium carbide methods involve drilling into the concrete.

A1.8.5.3 Testing duration is 16+ hours for the plastic sheet method[19] and 72 hours for the calcium chloride and relative humidity tests. The other methods give results immediately if the testing equipment has been calibrated.

A1.8.5.4 The plastic sheet method may indicate whether excess moisture is present at the time of the test. However, because the method depends on a moisture differential—a higher relative humidity in the concrete than in the air above the concrete surface—during the test span, potential problems are not always evident at the time the test is performed.

A1.8.5.5 Information on the tolerance of a specific coating system for free water or moisture migration should be provided by the coating manufacturer. A free water content of less than 5% by weight is acceptable for most coatings. Alternatively, concrete with a relative humidity of less than 80% or a moisture transmission rate of less than 15 g/24 hr/m^2 (3 lb/24 hr/1,000 ft^2) has proved acceptable for most coatings.

A1.8.5.6. Occasionally, despite moisture testing, a problem is not identified until after a low-permeability coating is applied.

A1.9 Surface Preparation Methods[17,32,44,45,46]

The surface preparation methods described in this standard are listed in Table A2 with their intended use, profile created, typical problems encountered when using each method, and solutions to those problems.

A1.9.1 Photographic examples of prepared concrete surfaces are shown in ASTM PCN:03-401079-14.[47]

A1.10 The 28-Day Waiting Period[48,49]

A1.10.1 The traditional 28-day waiting period after concrete placement and prior to coating installation is a controversial topic that involves all parties. Although the waiting period is not usually required for surface preparation, it affects the timing of surface preparation because many coatings are applied within 24 hours after surface preparation.

A1.10.2 The 28-day waiting period originated from the structural benchmark to test concrete strength at 28 days after placement to verify that the tested strength met the design strength. The 28-day benchmark became the industry standard to identify the point in time when the concrete was considered fully cured. The 28-day waiting period was adopted by the coating industry because it usually allows sufficient time for concrete surface strength to develop and for excess moisture to evaporate.

A1.10.3 Many factors can reduce or increase the time required for strength and moisture levels to be acceptable. In addition, many construction schedules do not allow for a 28-day waiting period. For these reasons, quantifying surface requirements as in Paragraph A1.12 are preferred over the traditional 28-day waiting period.

A1.10.4 NACE Standard RP0892[15] and ACI 515.1R[9] do not recommend a specific cure period but do address surface dryness, surface strength requirements, and other surface quality issues.

A1.11 Temperature Considerations

The temperature of the surface at the time of the coating application and the temperature progression during the application are both important. Rising concrete temperatures during the application of the coating systems may cause blistering and pinhole problems in the coating caused by out-gassing from the concrete. Coating application during periods of falling temperatures may be required to prevent this problem. Although controlling the ambient temperature in outdoor installations is difficult, concrete is often shaded from direct sunlight during coating application. In addition to potential problems from moisture in the concrete as described in Paragraphs A1.8.1 and A1.8.2, monitoring the dew point during periods of changing weather is often recommended to ensure that coatings are not applied over moisture that has condensed on the concrete surface.

Table A2:
Surface Preparation Methods

Preparation Method	When Used	Profile Created[A]	Problems	Solutions
Dry abrasive blasting	Removal, profile, cleaning	Fine (150) to extra coarse (40)	-Dust on surface -Airborne dust -Noise	-Vacuum cleaning -Vacuum attachments -None
Wet abrasive blasting	Removal, profile, cleaning	Fine (150) to extra coarse (40)	-Wets concrete -Creates sludge	-Let concrete dry -Cleaning
High-pressure water cleaning	Removal, cleaning	Fine (150) to extra coarse (40)	-Wets concrete -Creates sludge	-Let concrete dry -Cleaning
Waterjetting (with or without abrasive)	Removal	Rougher than extra coarse	-Creates sludge -Wets concrete -Coarse profile	-Cleaning -Let concrete dry -None[B]
Impact tools	Removal, profile, cleaning	Rougher than extra coarse	-Airborne dust -Fracturing -Coarse profile	-Vacuum attachments -Other methods -None[B]
Power tools	Removal	Smooth (no grit equivalent)	-Airborne dust -Fine profile	-Vacuum attachments -Other methods
Flame blasting	Removal, profile, cleaning	Rougher than extra coarse	-Excess removal -Damages concrete	-Experience[B] -Remove damaged concrete
Acid etching	Profile, cleaning	Fine (150) to coarse (60)	-Hazardous -Not for vertical or overhead surfaces -Neutralization -Wets concrete -Curing membrane	-Other acids -Other methods -pH testing -Let concrete dry -Other methods

[A] Profile is described using graded abrasive paper sizes. These are typical surface profile values only. Results may vary significantly because of concrete properties and surface preparation practices.
[B] For coating systems that do not perform over a coarse profile, refinishing the concrete or an underlayment may be required.

A1.12 Recommendations for Procurement Documents (Project Specifications) for Concrete Surface Preparation

Because of the wide range of concrete types, existing concrete conditions, ambient conditions, types of protective coatings to be applied, and project scheduling, producing a comprehensive standard that can be used as a project specification is not possible. Therefore, the following is a checklist of items that should be included in a comprehensive procurement document.

A1.12.1 NACE No. 6/SSPC-SP 13

A1.12.2 Contaminants

A1.12.2.1 Types anticipated

A1.12.2.2 Detection methods

A1.12.2.3 Preferred removal method

A1.12.2.4 Other acceptable removal methods

A1.12.3 Surface Preparation

A1.12.3.1 Preferred method

A1.12.3.2 Other acceptable methods

A1.12.4 Surface Tensile Strength

A1.12.4.1 Minimum allowable

A1.12.4.2 Test method and mode of failure

A1.12.5 Surface Profile

A1.12.5.1 Minimum and maximum allowable

A1.12.5.2 Test method or visual comparison

A1.12.6 Surface Uniformity

A1.12.6.1 Maximum allowable void size

A1.12.7 Repairs and Patching

A1.12.7.1 Preferred materials

A1.12.7.2 Other acceptable materials

A1.12.8 Cleanliness

A1.12.8.1 Maximum allowable residual dust level

A1.12.8.2 Test method or visual comparison

A1.12.9 Moisture Content

A1.12.9.1 Maximum allowable

A1.12.9.2 Test method and when to test (e.g., before or after surface preparation, or immediately before coating)

A1.12.10 Surface Flatness and Levelness

A1.12.10.1 Minimum and maximum slope allowed

A1.12.10.2 Minimum flatness allowed

A1.12.10.3 Test method or visual comparison

Item No. 21088

Joint Surface Preparation Standard

NACE No. 8/SSPC-SP 14
Industrial Blast Cleaning

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Foreword

This joint standard covers the use of blast cleaning abrasives to achieve a defined degree of cleaning of steel surfaces prior to the application of a protective coating or lining system. This standard is intended for use by coating or lining specifiers, applicators, inspectors, or others who may be responsible for defining a standard degree of surface cleanliness.

The focus of this standard is industrial blast cleaning. White metal blast cleaning, near-white metal blast cleaning, commercial blast cleaning, and brush-off blast cleaning are addressed in separate standards.

Industrial blast cleaning provides a greater degree of cleaning than brush-off blast cleaning (NACE No. 4/SSPC-SP 7[1]) but less than commercial blast cleaning (NACE No. 3/SSPC SP-6[2]).

Industrial blast cleaning is used when the objective is to remove most of the coating, mill scale, and rust, while the extra effort required to remove every trace of these is determined to be unwarranted.

The difference between an industrial blast cleaning and a brush-off blast cleaning is that the objective of a brush-off blast cleaning is to allow as much of an existing adherent coating to remain as possible, while the purpose of the industrial blast cleaning is to remove most of the existing coating.

A commercial blast cleaned surface is free of mill scale, rust, and coatings, and allows only random staining on less than 33 percent of each unit area of surface. The industrial blast cleaned surface allows defined mill scale, coating, and rust to remain on less than 10 percent of each unit area of surface and allows defined stains to remain on all surfaces.

This joint standard was originally prepared in 1998 by the SSPC/NACE Task Group (TG) A on Surface Preparation by Abrasive Blast Cleaning. This joint TG includes members of both the SSPC Surface Preparation Committee and the NACE Unit Committee T-6G on Surface Preparation. It was reaffirmed in 2006 by NACE Specific Technology Group (STG) 04, Protective Coatings and Linings: Surface Preparation, and the SSPC Surface Preparation Committee.

In NACE/SSPC standards, the terms *shall, must, should,* and *may* are used in accordance with Paragraph 2.2.1.8 of the Agreement Between NACE International and SSPC: The Society for Protective Coatings. The terms *shall* and *must* are used to state mandatory requirements. The term *should* is used to state something considered good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

Joint Surface Preparation Standard

NACE No. 8/SSPC-SP 14
Industrial Blast Cleaning

Contents

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Section 1: General

1.1 This joint standard covers the requirements for industrial blast cleaning of uncoated or coated steel surfaces by the use of abrasives. These requirements include the end condition of the surface and materials and procedures necessary to achieve and verify the end condition.

1.2 The mandatory requirements are described in Sections 1 to 9. Section 10, "Comments," and Appendix A, "Explanatory Notes," are not mandatory requirements of this standard.

1.3 Information about the function of industrial blast cleaning is in Paragraph A1 of Appendix A.

1.4 Information about use of this standard in maintenance coating work is in Paragraph A2 of Appendix A.

Section 2: Definitions

2.1 **Industrial Blast Cleaned Surface:** An industrial blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, and dirt. Traces of tightly adherent mill scale, rust, and coating residues are permitted to remain on 10 percent of each unit area of the surface (approximately 5,800 mm^2 [9.0 $in.^2$]) (i.e., a square 76 mm x 76 mm [3.0 in. x 3.0 in.]) if they are evenly distributed. The traces of mill scale, rust, and coating are considered to be tightly adherent if they cannot be lifted with a dull putty knife. Shadows, streaks, and discolorations caused by stains of rust, stains of mill scale, and stains of previously applied coating may be present on the remainder of the surface.

2.1.1 The shape, configuration, and design of structures can lead to areas of limited accessibility for blast cleaning. Examples include crevices around rivets or fasteners, and behind or between tightly configured back-to-back angles. Because of the limited accessibility, these areas are exempt from the 10 percent restrictions established in Paragraph 2.1. However, all surfaces in limited-access areas shall be subjected to the abrasive blast, and on completion, old coating, rust, and mill scale are permitted to remain provided they are well-adherent as determined using a dull putty knife.

2.1.2 Acceptable variations in appearance that do not affect surface cleanliness as defined in Paragraph 2.1 include variations caused by type of steel, original surface condition, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat-affected zones, blasting abrasives, and differences because of blasting technique.

2.1.3 SSPC-VIS 1[3], ISO[(1)] 8501-1[4] (Condition B Sa 2), or other reference photographs or comparators may be used to supplement the written definition. Condition B Sa 2 of ISO 8501-1 does not depict the influence that previously applied coating may have on the appearance of the cleaned surface. It is based on cleaning of a previously uncoated steel surface covered with rust and flaking mill scale. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 3: Associated Documents

3.1 The latest issue, revision, or amendment of the documents listed in Paragraph 3.3 in effect on the date of invitation to bid shall govern unless otherwise specified.

3.2 If there is a conflict between the requirements of any of the documents listed in Paragraph 3.3 and this standard, the requirements of this standard shall prevail.

3.3 Documents cited in the mandatory sections of this standard include:

[(1)] International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland.

Document	Title
SSPC-AB 1[5]	Mineral and Slag Abrasives
SSPC-AB 2[6]	Cleanliness of Recycled Ferrous Metallic Abrasives
SSPC-AB 3[7]	Ferrous Metallic Abrasives
SSPC-SP 1[8]	Solvent Cleaning
SSPC-VIS 1	Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning
ISO 8501-1	Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness

Section 4: Procedures Before Cleaning

4.1 Before blast cleaning, visible deposits of oil, grease, or other contaminants shall be removed in accordance with SSPC-SP 1 or other agreed-upon methods.

4.2 Before blast cleaning, surface imperfections such as sharp fins, sharp edges, weld spatter, or burning slag should be removed from the surface to the extent required by the procurement documents (project specification). Additional information on surface imperfections is in Paragraph A4 of Appendix A.

4.3 If reference photographs or comparators are specified to supplement the written standard, the condition of the steel prior to blast cleaning should be determined before the blasting commences. Additional information on reference photographs and comparators is in Paragraph A3 of Appendix A.

Section 5: Blast Cleaning Methods and Operation

5.1 Clean, dry compressed air shall be used for nozzle blasting. Moisture separators, oil separators, traps, or other equipment may be necessary to achieve this requirement.

5.2 Any of the following methods of surface preparation may be used to achieve an industrial blast cleaned surface:

5.2.1 Dry abrasive blasting using compressed air, blast nozzles, and abrasive.

5.2.2 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with compressed air, blast nozzle, and abrasive, with or without vacuum for dust and abrasive recovery.

5.2.3 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with centrifugal wheels and abrasive.

5.3 Other methods of surface preparation (such as wet abrasive blast cleaning) may be used to achieve an industrial blast cleaned surface by mutual agreement between those responsible for establishing the requirements and those responsible for performing the work. Information on the use of inhibitors to prevent the formation of rust immediately after wet abrasive blast cleaning is in Paragraph A5 of Appendix A.

Section 6: Blast Cleaning Abrasives

6.1 The selection of abrasive size and type shall be based on the type, grade, and surface condition of the steel to be cleaned, the type of blast cleaning system used, the finished surface to be produced (cleanliness and surface profile [roughness]), and whether the abrasive will be recycled.

6.2 The cleanliness and size of recycled abrasives shall be maintained to ensure compliance with this standard.

6.3 The blast cleaning abrasive shall be dry and free of oil, grease, and other contaminants as determined by the test methods found in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

6.4 Any limitations on the use of specific abrasives, the quantity of contaminants, or the degree of allowable embedment shall be included in the procurement documents (project specification) covering the work,

because abrasive embedment and abrasives containing contaminants may not be acceptable for some service requirements. Additional information on abrasive selection is in Paragraph A6 of Appendix A.

6.5 When a coating is specified, the cleaned surface shall be roughened to a degree suitable for the specified coating system. Additional information on surface profile and the film thickness of coating applied over the surface profile is in Paragraphs A7 and A8 of Appendix A.

Section 7: Procedures Following Blast Cleaning and Immediately Prior to Coating

7.1 Visible deposits of oil, grease, or other contaminants shall be removed according to SSPC-SP 1 or another method agreed upon by those parties responsible for establishing the requirements and those responsible for performing the work.

7.2 Dust and loose residues shall be removed from prepared surfaces by brushing; blowing off with clean, dry air; vacuum cleaning; or other methods agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

7.2.1 The presence of toxic metals in the abrasives or coating being removed may place restrictions on the methods of cleaning permitted. The chosen method shall comply with all applicable regulations.

7.2.2 Moisture separators, oil separators, traps, or other equipment may be necessary to achieve clean, dry air.

7.3 After blast cleaning, any remaining surface imperfections (e.g., sharp fins, sharp edges, weld spatter, burning slag, scabs, slivers) shall be removed to the extent required by the procurement documents (project specification). Any damage to the surface profile resulting from the removal of surface imperfections shall be corrected to meet the requirements of Paragraph 6.5. Additional information on surface imperfections is in Paragraph A4 of Appendix A.

7.4 Immediately prior to coating application, the entire surface shall comply with the degree of cleaning specified in this standard. Any visible rust that forms on the surface of the steel after blast cleaning shall be removed by recleaning the rusted areas before coating. Information on chemical contamination, rust-back (rerusting), and the effect of dew point (surface condensation) is in Paragraphs A9, A10, and A11 of Appendix A.

Section 8: Inspection

8.1 Work performed and materials supplied under this standard are subject to inspection by a representative of those responsible for establishing the requirements. Materials and work areas shall be accessible to the inspector. The procedures and times of inspection shall be as agreed upon by those responsible for establishing the requirements and those responsible for performing the work.

8.2 Conditions not complying with this standard shall be corrected. In the case of a dispute, an arbitration or settlement procedure established in the procurement documents (project specification) shall be followed. If no arbitration or settlement procedure is established, a procedure mutually agreeable to purchaser and supplier shall be used.

8.3 The procurement documents (project specification) should establish the responsibility for inspection and for any required affidavit certifying compliance with the specification.

Section 9: Safety and Environmental Requirements

9.1 Because abrasive blast cleaning is a hazardous operation, all work shall be conducted in compliance with applicable occupational and environmental health and safety rules and regulations.

Section 10: Comments (Nonmandatory)

10.1 Additional information and data relative to this standard are in Appendix A. Detailed information and data are presented in a separate document, SSPC-SP COM.[9] The recommendations in Appendix A and SSPC-SP COM are believed to represent good practice, but are not to beconsidered requirements of the standard. The sections

of SSPC-SP COM that discuss subjects related to industrial blast cleaning are listed below.

Subject	Commentary Section
Abrasive Selection	6
Film Thickness	10
Maintenance Repainting	4.2
Reference Photographs	11
Rust-Back (Rerusting)	8.3
Surface Profile	6.2
Weld Spatter	4.4.1
Wet Abrasive Blast Cleaning	8.2

References

1. NACE No. 4/SSPC-SP 7 (latest revision), “Brush-Off Blast Cleaning” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

2. NACE No. 3/SSPC-SP 6 (latest revision), “Commercial Blast Cleaning” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

3. SSPC-VIS 1 (latest revision), “Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning” (Pittsburgh, PA: SSPC).

4. ISO 8501-1 (latest revision), “Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness – Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings” (Geneva, Switzerland: ISO)

5. SSPC-AB 1 (latest revision), “Mineral and Slag Abrasives” (Pittsburgh, PA: SSPC).

6. SSPC-AB 2 (latest revision), “Cleanliness of Recycled Ferrous Metallic Abrasives” (Pittsburgh, PA: SSPC).

7. SSPC-AB 3 (latest revision), “Ferrous Metallic Abrasives” (Pittsburgh, PA: SSPC).

8. SSPC-SP 1 (latest revision), “Solvent Cleaning” (Pittsburgh, PA: SSPC).

9. SSPC-SP COM (latest revision), “Surface Preparation Commentary for Steel and Concrete Substrates” (Pittsburgh, PA: SSPC).

10. SSPC-PA Guide 4 (latest revision), “Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems” (Pittsburgh, PA: SSPC).

11. NACE SP0178 (formerly RP0178-2003) (latest revision), “Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service” (Houston, TX: NACE).

12. NACE Standard RP0287 (latest revision), “Field Measurement of Surface Profile of Abrasive Blast-Cleaned Steel Surfaces Using a Replica Tape” (Houston, TX: NACE).

13. ASTM[(2)] D 4417 (latest revision), “Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel” (West Conshohocken, PA: ASTM).

14. SSPC-PA 2 (latest revision), “Measurement of Dry Coating Thickness with Magnetic Gages” (Pittsburgh, PA: SSPC).

15. NACE No. 5/SSPC-SP 12 (latest revision), “Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating” (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

16. SSPC-Guide 15 (latest revision), “Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates” (Pittsburgh, PA: SSPC).

[(2)] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

Appendix A: Explanatory Notes (Nonmandatory)

A1 FUNCTION: Industrial blast cleaning (NACE No. 8/SSPC-SP 14) provides a greater degree of cleaning than brush-off blast cleaning (NACE No. 4/ SSPC-SP 7) but less than commercial blast cleaning (NACE No. 3/SSPC-SP 6). It should be specified only when a compatible coating will be applied. The primary functions of blast cleaning before coating are: (a) to remove material from the surface that can cause early failure of the coating and (b) to obtain a suitable surface profile (roughness) to enhance the adhesion of the new coating system. The hierarchy of blasting standards is as follows: white metal blast cleaning, near-white metal blast cleaning, commercial blast cleaning, industrial blast cleaning, and brush-off blast cleaning.

A2 MAINTENANCE COATING WORK: When this standard is used in maintenance coating work, specific instructions should be provided on the extent of surface to be blast cleaned or spot blast cleaned to this degree of cleanliness. In these cases, this degree of cleaning applies to the entire specified area. For example, if all weld seams are to be cleaned in a maintenance operation, this degree of cleaning applies to 100 percent of all weld seams. If the entire structure is to be cleaned, this degree of cleaning applies to 100 percent of the entire structure. SSPC-PA Guide 4[10] provides a description of accepted practices for retaining old sound coating, removing unsound coating, feathering, and spot cleaning.

A3 REFERENCE PHOTOGRAPHS AND COMPARATORS: SSPC-VIS 1 provides color photographs for the various grades of surface cleaning as a function of the initial condition of the steel. The photographs G_1 SP 14, G_2 SP 14, and G_3 SP 14 depict previously coated surfaces cleaned to industrial blast grade. ISO 8501-1, Photograph B Sa 2, depicts the appearance of a surface that is consistent with the definition of an industrial blast cleaned surface. Other available reference photographs and comparators are described in Section 11 of SSPC-SP COM.

A4 SURFACE IMPERFECTIONS: Surface imperfections can cause premature coating failure when the service is severe. Coatings tend to pull away from sharp edges and projections, leaving little or no coating to protect the underlying steel. Other features that are difficult to cover and protect properly include crevices, weld porosities, laminations, etc. The high cost of the methods to remedy surface imperfections (such as edge rounding and weld spatter removal) should be weighed against the costs of a potential coating failure.

Poorly adhering contaminants, such as weld slag residues, loose weld spatter, and some minor surface laminations, may be removed during the blast cleaning operation. Other surface defects (steel laminations, weld porosities, or deep corrosion pits) may not be evident until the surface cleaning has been completed. Repair of such surface defects should be planned properly because the timing of the repairs may occur before, during, or after the blast cleaning operation. Section 4 of SSPC-SP COM and NACE SP0178[11] contain additional information on surface imperfections.

A5 WET ABRASIVE BLAST CLEANING: Steel that is wet abrasive blast cleaned may rust rapidly. Clean water should be used for rinsing. It may be necessary to add inhibitors to the water or apply them to the surface immediately after blast cleaning to temporarily prevent rust formation. The use of inhibitors or the application of coating over slight discoloration should be in accordance with the requirements of the coating manufacturer. CAUTION: Some inhibitive treatments may interfere with the performance of certain coating systems.

A6 ABRASIVE SELECTION: Types of metallic and nonmetallic abrasives are discussed in SSPC-SP COM. Blasting abrasives may become embedded in, or leave residues on, the surface of the steel during cleaning. While such embedment or residues are normally not detrimental, care should be taken to ensure that the abrasive is free from detrimental amounts of water-soluble, solvent-soluble, acid-soluble, or other soluble contaminants (particularly if the cleaned steel is to be used in an immersion environment). Criteria for selecting and evaluating abrasives are in SSPC-AB 1, SSPC-AB 2, and SSPC-AB 3.

A7 SURFACE PROFILE: Surface profile is the roughness of the surface that results from abrasive blast cleaning. The profile height is dependent on the size, shape, type, and hardness of the abrasive, particle velocity and angle of impact, hardness of the surface, amount of abrasive recycling, and the proper maintenance of working mixtures of grit and/or shot.

The allowable minimum/maximum height of profile is usually dependent on the thickness of the coating to be applied. Large particle-sized abrasives (particularly metallic) can produce a surface profile that may be too high to be adequately covered by a single thin-film coat. Accordingly, the use of larger abrasives should be avoided in these cases. However, larger abrasives may be needed for thick-film coatings or to facilitate removal of thick coatings, heavy mill scale, or rust. If control of surface profile (minimum/maximum) is deemed to be significant to coating performance, it should be addressed in the procurement documents (project specification). Typical surface profile heights achieved with commercial abrasive media are shown in Table 6 of SSPC-SP COM. Surface profile should be measured in accordance with NACE Standard RP0287[12] or ASTM D 4417.[13]

A8 FILM THICKNESS: It is essential that ample coating be applied after blast cleaning to adequately cover the peaks of the surface profile. The dry-film thickness of the coating above the peaks of the profile should equal the thickness known to be needed for the desired protection. If the dry-film thickness over the peaks is inadequate, premature rust-through or coating failure will occur. To ensure that coating thicknesses are properly measured, the procedures in SSPC-PA 2[14] should be used.

A9 CHEMICAL CONTAMINATION: Steel contaminated with soluble salts (e.g., chlorides and sulfates) develops rust-back rapidly at intermediate and high levels of humidity. These soluble salts can be present on the steel surface prior to blast cleaning as a result of atmospheric contamination. In addition, contaminants can be deposited on the steel surface during blast cleaning if the abrasive is contaminated. Therefore, rust-back can be minimized by removing these salts from the steel surface and eliminating sources of recontamination during and after blast cleaning. Wet methods of removal are described in NACE No. 5/SSPC-SP 12.[15] Identification of the contaminants along with their concentrations may be obtained from laboratory and field tests as described in SSPC-Guide 15.[16]

A10 RUST-BACK: Rust-back (rerusting) occurs when freshly cleaned steel is exposed to moisture, contamination, or a corrosive atmosphere. The time interval between blast cleaning and rust-back varies greatly from one environment to another. Under mild ambient conditions, if chemical contamination (see Paragraph A9) is not present, it is best to blast clean and coat a surface on the same day. Severe conditions may require a more expeditious coating application to avoid contamination from fallout. Chemical contamination should be removed prior to coating.

A11 DEW POINT: Moisture condenses on any surface that is colder than the dew point of the surrounding air. It is therefore recommended that the temperature of the steel surface be at least 3°C (5°F) above the dew point during dry blast cleaning operations. It is advisable to visually inspect for moisture and periodically check the surface temperature and dew point during blast cleaning operations and to avoid the application of coating over a damp surface.

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Chapter 24: Safety

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Surface preparation safety
- Spray application safety
- Confined space safety
- Lock out/tag out
- Job-specific safety and security
- Working at heights
- Scaffolding
- Personal responsibility

Disclaimer

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It is the responsibility of each person to be aware of current local, state, and federal regulations. This course is not intended to provide comprehensive coverage of regulations.

24.1 Introduction

The purpose of this chapter is to discuss safety in coating operations. Regardless of the specific types of equipment used, it is essential to be aware of the safety issues associated with each process during the operation.

24.2 Surface Preparation Safety

All participants in surface preparation including coating inspectors, should use common sense to recognize potential hazards. Report any lighting, scaffolding, or equipment malfunctions that are possible safety hazards to the appropriate person. Workers who are knowledgeable and responsible always ensure the safety of staging, spiders (powered drum hoist), and/or swing scaffolding before use.

24.2.1 Abrasive Blasting Safety

Abrasive blast cleaning at high pressures is a dangerous operation. Operator safety is a top priority on any job where this is done. Moreover, it is essential that all other site personnel are well protected and safety is always the first priority. Coating inspectors need to know what to look for to ensure the operator is working safely. That scrutiny may preserve the lives of those on the jobsite.

Never get in the path of an abrasive blast.

The abrasive particles can travel as fast as 450 mph (724 kph), with the same effect as a shotgun blast.

While abrasive blasting is in progress:

- Allow only the blast operator within the vicinity of the blasting
- Display prominent warning signs
- Ensure a look-out (or pot-man) is on the alert
- Test all equipment to ensure it operates properly and safely

All on-site personnel, including the coating inspector, **must** follow the safety and health

rules established by either the safety engineer or the person designated in the contract.

The coating inspector should be familiar with and, when appropriate, use the following protective equipment:

- Hood
- Respirator
- Heavy protective clothing and gloves
- Eye and hearing protection

Since blast operators are usually required to ground their equipment, coating inspectors need to know how to properly ground equipment in order to verify that the equipment ***is*** properly grounded.

Site safety must conform to applicable worker protection rules and regulations. In the United States, Occupational Safety and Health Administration (OSHA) establishes the governing regulations. In other countries, similar governmental bodies have regulations that must be observed.

24.2.2 Blasting Operator Safety

Other than the personal protective equipment (PPE) an abrasive blasting operator wears the *Deadman's Handle* (Deadman's Valve). It is perhaps the most important safety feature of the equipment (Figure 24.1). It is a handle attached to the nozzle. When it is depressed by the hand holding the nozzle, it allows the equipment to operate. Releasing the handle immediately stops operation of the blasting equipment. Inspectors need to ensure it is operable and in use during blast operations.

Figure 24.1 Dead-man Valve (note hand position)

The other essential safety components for blasting operators are their PPE. See Figure 24.2. Typically these include:

- Safety boots (with steel insert toe caps)
- Coveralls
- Strong leather gloves
- Air-fed blasting helmet, incorporating a replaceable visor and leather cap
- Hearing protection

Figure 24.2 Operator Safety PPE

It is also critical that the operator has a good supply of clean, fresh air to breathe. Two common ways to provide this are:

- Air delivery at low pressure from the blast pot via a filter. The disadvantage is the air is the same used for blasting (often poor quality).
- Air delivery, at relatively low pressure, from a remote air-driven pump located well away from contaminated or dust-laden air.

24.3 Spray Application Safety

Coating inspectors, supervisors, and workers are usually well aware of typical worksite hazards (mechanical equipment, cranes, ladders, staging, etc). **However, they may not realize the extent of the toxic and fire/ explosion hazards inherent when spray applying coatings.**

When coating application is being done, all personnel on site must be aware of the tremendous damage that can result from a small quantity of a vaporized volatile substance (it is both **a health and explosion hazard**). Personnel need to be aware of the hazards to health inherent in solvent fumes, toxic fumes, finely atomized metals, vapor mists, and dust dispersed in the air. **These are all both health and explosion hazards.**

Workers have been killed by explosions while painting in confined places. One accident occurred when the workers, because of a toxic hazard, were properly breathing fresh air through masks. They were killed suddenly by an explosion. The concentration of toxic vapor in the air was in the explosive range, so when an extension light bulb broke the vapor ignited killing several men.

Flash point indicates the fire or explosion hazard of a flammable substance. Coatings and their solvents are sometimes categorized according to their flash-point temperature. Low flash point solvents are those with flash points below typical storage temperatures, 73ºF (23ºC) and are the most hazardous to store and/or use. When concentrations of these volatile vapors are sufficient, even hot surfaces can ignite them.

Adequate ventilation is essential to keep the solvent content of the air below the lower explosive limit (LEL), with the additional benefit of facilitating coating cure.

Static electricity discharges may also ignite solvent vapors. To reduce this hazard, ground the spray equipment and ensure connections are electrically continuous.

Spray finishing also creates a certain amount of overspray, hazardous vapors, and toxic fumes. This is true even under ideal conditions and there is no way to avoid it entirely. Mitigate hazards to personnel by ensuring they use respirators appropriate for the specific vapors and fumes.

Even if the concentration of flammable gas or vapors in the air is below the LEL, ***it may still be far above the safe limit for breathing*.** Workers should not exceed the **maximum allowable concentration** (MAC) of hazard exposure during an eight-hour workday. The MAC applies to vapors, gases, mists, and solids. MAC data are published annually in the US in the *Archives of Industrial Hygiene.* These same MACs are often adopted in other countries.

In general, **aromatic solvents**, such as xylene and toluene, are more hazardous than aliphatic solvents, such as mineral spirits. Unfortunately, mineral spirits are rarely used in high-performance coatings, but relatively hazardous solvents are still widely used. Aromatic solvents are used almost exclusively in some synthetic paints, such as lacquer and vinyls, and to a greater or lesser

degree in oleoresinous paints, such as phenolic varnish and some alkyds.

Allowable concentrations for the **aliphatic solvents** are greater than for the aromatic solvents, **but in every case the MAC for breathing is far less than the LEL**. This means that while an airspace may be considered safe from fire or explosion, it can still be extremely dangerous to personnel. Supply exposed workers with fresh air masks that connect to a source of clean, cool, filtered air.

The common use of low flash point solvents such as methyl ethyl ketone (MEK) or acetone as ***universal thinners*** can be extremely hazardous, particularly in enclosed spaces.

Protect both spray and brush painters against breathing dangerous concentrations of coatings containing lead or chromates. In addition to adequate ventilation, spray removal, respirators, and air filters, ensure workers clean themselves thoroughly before eating and before leaving the job. Workers must thoroughly clean contaminated clothing before reuse.

24.3.1 Respirators

A respirator is a mask worn over the mouth and nose to prevent the inhalation of overspray fumes and vapor. Respirators are necessary for two reasons:

- Inhaling paint overspray and solvent fumes is not healthy.
- Use of respiratory protection is dictated by governing regulatory agencies such as OSHA and NIOSH.

It is critical to ensure that **air-supplied respirators** deliver fresh and pure air. The common practice of using plant air (air taken from a factory supply) is dangerous if the air is contaminated by a compressor or operations elsewhere in the plant. Always ensure filters and warning monitors are fitted in line before use by the sprayer or brush painter.

There are four primary types of protective respirators available:

- Air-supplied helmets or hoods
- Air-supplied masks
- Organic vapor (cartridge) respirators
- Filtering face-piece respirators (“paper” or “dust” masks)

Air-Supplied Helmet / Hood Respirators cover the entire head and neck area and supply the wearer with clean, dry air at low pressure through a filtered air supply. These respirators provide the most complete means of protection because they protect the wearer from heavy concentrations of vapor, fumes, dust, and dirt that can harm respiratory organs, eyes, ears, and skin.

They are used where other types of respirators are either impractical or do not provide sufficient protection. The continuous supply of dry fresh air ensures mist or fog do not form inside the hood or helmet.

These respirators are commonly required when coating work takes place in confined spaces, such as tanks, and may be mandatory when certain coatings (e.g., those containing isocyanates) are spray applied.

Air-supplied mask respirators operate from an external air supply and may cover the nose and mouth only or may cover the full face. They do not provide the degree of protection against splashes, etc., that a helmet/hood respirator does. If a full-face respirator is not used, workers must wear eye protection, such as goggles.

Organic-vapor respirators cover the nose and mouth and incorporate cartridges designed to remove organic vapors by chemical absorption. Use the correct cartridges and install replacement cartridges as needed.

Some organic-vapor respirators are designed to remove solid particles from the air *before* the air passes through the chemical cartridge. They are usually used in finishing operations that use standard materials, but are not recommended for use in commercial coating operations.

For organic-vapor respirators to be effective, ensure there is a complete seal between the mask and the face. Workers should wear separate safety goggles or other eye protection as required. Because the cartridges have a limited life and must be replaced, maintain records of respirator/cartridge use.

Sprayers or helpers may use **dust respirators**, but in most coating applications they are not effective and are probably illegal. The cartridges of these respirators remove only solid particles from the air (i.e., contaminants produced from surface preparation operations like sanding, grinding, or buffing) and are not designed to remove vapors. Workers should wear separate safety goggles or other eye protection when required.

Safety recommendations for proper PPE are usually on the coating manufacturer's MSDS. Workers should always wear the clothing specified (i.e., gloves, masks, and long-sleeve shirts).

Airless spray equipment safety precautions are essentially the same as conventional air spray equipment, with one very important addition. *Airless spray operates on the principle of forcing materials at very high pressure through a very small opening*. The atomization of the material is so effective that liquids can pass through a membrane (e.g., human skin) without breaking it. This is exactly the same principle the high-pressure devices the military uses, instead of hypodermic needles, to give military personnel medical shots. The hazard of accidentally injecting coating materials into the body is a **very real** danger.

Injection of solvents or other fluids through the skin damages local tissue and can get into the blood stream. Localized swelling occurs and continues to occur until the pressure is relieved. Proper treatment involves cutting open the skin of the affected area to release the pressure and the toxic chemicals. The resulting wound may be very significant. If accidental injection is not treated immediately, it can result in the loss of a limb, or may even be fatal.

An accidental injection is highly unlikely **if all safety precautions are observed**. However, remember to take anyone accidentally injected to a doctor **immediately,** even if the injury seems minor. Delay may cause loss of a finger, arm, or leg, or even death.

When working with or near airless spray equipment, treat an airless spray gun as if it is a loaded gun. Safety authorities in the US recognize the danger and require that airless spray guns: (1) carry a safety warning, and (2) have a safety spacer at the tip of the nozzle. The spacer reduces the possibility of coating injection (Figure 24.3).

Figure 24.3 Airless Spray Gun with Spacer

Use all equipment in accordance with OSHA or Health and Safety at Work Act, or the governing standards for the specific country where the jobsite is located.

Some additional rules for airless spray safety are:

- Never leave a pressurized unit unattended. Shut off the unit, relieve the pressure, make sure the spray gun's trigger safety is engaged, and the power shut off.
- Ensure all fluid connections are high-pressure-rated airless spray fittings, and are securely tightened and checked before each use.
- Ensure the fluid hose is electrically grounded to reduce the hazard of static electricity sparking.
- Ensure the coating and solvent manufacturers' safety precautions and warnings are followed.
- Report any unsafe condition or practice to the safety supervisor immediately.

24.4 Confined Space Safety

Confined spaces that require permits to enter have inherent hazards that all personnel involved in coating operations need to know and understand. Most owner/operators require workers to attend a detailed class for confined spaces safety. Those who need permit-required confined space training are:

- Permit issuer or company area supervisor
- Quality assurance manager
- Permit recipient or on-site supervisor
- Authorized on-site attendant or standby
- Authorized on-site linkman (as needed for communication)
- Authorized on-site entrants
- Authorized alternates (as needed)

24.4.1 Confined Spaces Terminology

The following are **terms related to permit-required confined spaces** that inspectors need to know and understand to ensure safety is enhanced and observation of all regulations:

- **The designated authority** is the senior person in charge (or appointed representative, possibly the inspector) of the coating operation.
- **Confined space** is any space that is not routinely or continuously occupied, is enclosed or can be sealed thereby limiting ventilation; has a restricted entry or exit; and could contain or produce dangerous concentrations of airborne contaminants or asphyxiants.
- **Explosive atmosphere** is any atmosphere that contains a concentration of flammable or combustible material that could explode when exposed to a source of ignition.
- **Flammable material** is any material that will ignite when there is a proper mixture of gases, vapors, and air.
- **Oxygen deficiency** is any atmosphere that has an oxygen concentration of 19.5% or less.

- **Oxygen enriched atmosphere** is any atmosphere having 22% or more oxygen content.
- **Hazardous/toxic atmosphere** is any substance or atmosphere that has the capacity to produce personal injury, illness or death to humans through ingestion, inhalation, or body-surface absorption.
- **Acceptable environmental condition** is a confined space workplace where uncontrolled hazardous atmospheres and/or physical hazardous conditions are not present.
- **Entry/work permits** are part of the system that controls all work performed in and around permit-required confined spaces. **All work** in these spaces must be approved by the responsible operations person. **Pre-entry job site "check list" system** is a part of the procedures by which the on-site job supervisor conducts a pre-entry on-site job assignment orientation meeting to include contents of entry and work permits, personnel and work assignments, safety check results, and emergency rescue procedures.
- **Safe Clearance procedure** is a process that secures potential physical hazards.
- **Blanking and blinding** is the absolute closure of a pipeline, or duct, by fastening a solid plate or cap across the bore (opening), completely covering it.
- **Double block and bleed** is the closure of a line, duct, or pipe by locking and tagging any drain or vent that is open to the atmosphere and located in the line between two locked-closed valves. Lock out/tag out (LOTO) is covered later in the chapter.
- **Standoff Blind** is used to isolate an enclosed space. The blind is used to cap the side of the system that must be sealed off, but leaves the other side of the system open to the atmosphere.
- **Hot tap** is any connection made to a pipeline, tank, or other equipment, that contains flammable material that has not been cleared and prepared for cutting using conventional construction methods.
- **Emergency** is any occurrence (including failure of hazard control or monitoring equipment) or event(s) internal or external to the confined space, that could endanger entrants.
- **Engulfment** is when a person is surrounded and effectively captured by a liquid or finely divided solid substance.
- **Permit issuer** is the person responsible for issuing confined space entry- or work-permits.
- **Permit recipient** is an on-site supervisor (possibly the inspector) who receives the permit for the group performing the work.
- **Standby/attendant** is the person responsible for protecting others and their equipment from hazards associated with the confined space entry and associated works such as "hot work" (work generating a flame or spark, such as welding or grinding). The attendant is stationed outside the space. This person monitors the authorized entrants specifically listed on the confined space entry permit.
- **Linkman** is the alternate person assigned responsibility for the communication link between the standby and the workers inside the permit-required confined space.
- **Entrant** is the person(s) authorized to enter the permit-required confined space to do the assigned work. **Alternates** must be trained in the permit-required confined space entry regulations and be ready to act as stand-ins for other workers.
- **Operating area** is any area under the supervision of operations personnel, including, but not limited to, loading docks, tank farms, offshore platforms, separators, vapor recovery units, or fire foam houses, etc.
- **Personal entry** is when any part of a person's body passes through the boundary of

an enclosed space, including ensuing work in that space.

- **Rescue teams** are the contractor's pre-approved and pre-arranged personnel responsible for rescuing people inside the permit-required confined space in an emergency.

Permit-required confined spaces can become unsafe as a result of:

- Atmospheric contamination by toxic or flammable vapors, oxygen deficiency, or excess oxygen
- Physical hazards, such as agitators or moving parts located inside the space
- The inadvertent admission of liquids, gases, or solids during occupancy
- An event or occurrence that isolates the occupants from help in case of need or rescue.

24.4.2 Types of Confined Spaces

The four types of confined spaces include:

Class A: a measured/tested confined space that has conditions immediately dangerous to life or health (IDLH). These conditions include, but are not limited to:

- Oxygen deficiency of 19.5% or less
- Oxygen enrichment of 23.5% or greater
- Explosive or flammable atmospheres, 10% or greater of LEL
- Acute IDLH concentrations of toxic substances.

This space requires full life support equipment and standby personnel.

Class B: a measured/tested dangerous confined space that is not immediately life threatening. Its conditions include:

- The potential to cause injury and illness if preventive and/or control measures such as isolation, ventilation, and/or respirators are not taken
- The oxygen level is 16.1% to 19.4%
- A 10% to 19% LEL
- Less than a IDLH level of toxicity

This space requires full life support or cartridge respirators and standby personnel.

Class C: a measured/tested confined space with potential hazards from work procedures, but one that does not require any special modification of the work procedures and/or atmosphere. Authorized or unauthorized entrants could cause a hazard to arise through their actions, such as welding while in the confined space. The conditions are:

- Oxygen level is 19.5% to 21.8%
- Has a 10% LEL or less
- The toxicity level is less than contamination levels
- If a ladder is used as a means of access to the scaffold, it shall be securely attached and shall comply with the section on ladders.

This space does not require full life support or a cartridge respirator, but does require standby personnel.

Class D: a documented low-hazard confined space that can be entered without the need for life support or an attendant. Entrants can perform repetitive entries but not any process or procedure which may cause a hazard, i.e. hot work, without obtaining a new or amended work or entry permit.

Inspectors need to know the pre-job checklist for permit-required confined spaces. These are some of the items that should be on the checklist:

- Know the job-site assignments, the on-site supervisor, the standby person, the linkman (if needed), the entrants, and the alternates

- Know the location of personnel assignments
- Know the length of work assignments, working hours, and job
- Know if the work is hot work
- Know the proper place to park personal vehicles
- Know what restrooms, water fountains, and break facilities are for the workers
- Know the emergency phone numbers, wash stations, rescue team, etc.
- Know the terminal location
- Know the contractor's personnel
- Inspect the contractor's equipment
- Know all on-site personnel's responsibilities
- Confirm that the on-site supervisor's daily report is filled out and accurately documents the work to be performed
- Confirm that the on-site supervisor witnesses required vapor/atmosphere testing and that the official work permit is issued and signed
- Go over the on-site safety guidelines and facility-specific requirements for personnel, testing, and safety equipment
- Ensure any authorized outside contractor adheres to requirements for permit-required confined space entry
- Discuss the work to be performed, the procedures, and the specifications
- Discuss any restrictions at the job-site
- Discuss the emergency procedures, rescue plan, terminals list of phone numbers, local and terminal fire departments numbers, hospital and ambulance services, etc.

24.4.3 Hazards in a Confined Work Space

Conditions in and around permit-required confined spaces vary greatly depending on the classification of the confined space, its configurations, and the hazards of the materials used and processes of the work to be done. Two common hazards are:

- Flammable atmospheres
- Toxic substances

The term "**flammable atmosphere**" refers to the fuel to air ratio which can ignite only when components in the atmosphere are within certain limits. Facts about a flammable atmosphere follow:

- It cannot ignite when the ratio of oxygen to combustible material in the air is neither too rich nor too lean for combustion to occur.
- It cannot ignite when the (LEL) is the minimum concentration of flammable vapors in the air below which propagation of flame does not occur.
- The upper explosive limit (UEL) is the maximum concentration of flammable vapors in air above which fire does not occur on contact with an ignition source, often referred to as "too rich to burn."
- The LEL and UEL explosive limits for most petroleum products are between 1% and 10% hydrocarbon vapors by air volume.
- Combustible gases or vapors accumulate when there is inadequate ventilation in confined spaces.
- Flammable gases (such as acetylene, butane, propane, hydrogen, methane, natural or manufactured gases, or vapors from liquid hydrocarbons) can be trapped in confined spaces; since many gases are heavier than air, they seek lower levels in storage tanks and various other vessels.
- In a closed-top tank, lighter-than-air gases can rise and develop a flammable concentration if trapped above the opening.

Toxic substances may be present in permit-required confined spaces; these are classified as:

- Irritants
- Corrosives (either acutely toxic or chronically toxic)

Irritants are substances that cause minor or transient, and possibly painful, injuries that heal without scars and produce no known after effects.

Corrosives are substances that destroy tissue and leave permanent scars. Examples of corrosive substances are hydrofluoric acid, sulfuric acid, and caustics such as lye. *Acutely toxic* (primary) substances, with a only a single dose or short-term exposure, can cause symptoms ranging from a simple headache or nausea, to disablement or death. Examples of acutely toxic substances are:

- Chlorine
- Ozone
- Hydrochloric acid
- Hydrofluoric acid
- Sulfuric acid
- Nitrogen dioxide
- Ammonia
- Sulfur dioxide
- Hydrogen sulfide

Chronically toxic (secondary) substances are those that can produce physiological impairment with long latency, such as cancer, or with gradual progression, such as pulmonary obstructive disease. In some cases, these substances can adversely affect reproductive organs. Some examples of *chronically toxic* substances are:

- Benzene
- Carbon tetrachloride
- Ethyl chloride
- Trichloroethane
- Trichloroethylene
- Chloropropene
- Chloride

24.5 Lock Out/Tag Out

Before anyone enters a permit-required confined space, it is necessary to complete a lock out/tag out isolation procedure and ensure an on-site supervisor approves the process. The Lock out/Tag out Isolation process shall be determined for each type of confined space. Class A and Class B spaces shall be determined by the designated safety professional.

To completely isolate Class A and Class B spaces, the pipe should first be blanked at the flanges with valves locked or closed as appropriate. Blanks should be capable of withstanding the maximum working pressure or load of the line (following required safety factors). Each blank should have a gasket on the pressure side to ensure a leak proof seal. The gaskets should be made of a chemically non-reactive material.

In addition to blanking, pumps and compressors that serve the lines entering the confined space should be locked out to prevent accidental activation. Two types of isolation are needed:

- Electrical
- Mechanical

Electrical isolation prevents accidental activation of moving parts that could be hazardous. Ensure the circuit breakers and/or disconnects are locked in the open (off) position with a key-type padlock. The only key should remain with the person working

on the unit. If there is more than one worker, each person should place his/her own lock on the circuit breaker. In addition to the lockout system, there should be an accompanying tag that identifies the operation and prohibits activation of the system.

To mechanically isolate moving parts, such as linkage, drive belts, or chains, the controls or levers should be disconnected. Equipment with moving parts should be blocked to prevent accidental mechanical movement.

In summary, to prevent unexpected hazards from developing, make sure all electrical and mechanical operating systems that might endanger workers are locked out, blanked off, misaligned, and tagged out.

24.6 Job-Specific Safety and Security

Training is one of the most important elements of any safety and security program. Training helps workers learn to perform their jobs properly, introduces new ideas, and reinforces existing safety policies. Training is required for both supervisors and workers. Although the content of each safety meeting may vary, each session should focus on ensuring that:

- Each worker's immediate supervisor reviews the safe work procedures unique to that worker's job, and knows how these safe work procedures protect against risk and danger.
- Each worker knows when PEP is required or necessary, and how to use and maintain the equipment in good condition.
- Each worker knows what to do in case of emergencies on the jobsite.

Supervisors (inspectors) are key figures in successful job-site safety programs and have special duties concerning the safety of workers. The inspector may have the *primary responsibility* for the actual implementation of the job-site safety program, especially as it relates directly to the jobsite.

Supervisors (inspectors) are responsible for knowing:

- Safety and health hazards to which workers are exposed
- How to recognize the hazards
- Potential effects of the hazards
- Rules and procedures to maintain a safe workplace

Supervisors (inspectors) must convey this information to the workers on the jobsite, and investigate accidents according to the accident investigation policies stipulated by the specification.

The purpose of the safety meeting is to convey safety information and answer worker questions. Use the meetings to review, in language understandable to every worker, the content of the safety program, special work site hazards, serious concealed dangers, and MSDSs. Each day, the job-site supervisor (inspector), reviews a portion of the *contractors safe work practices* contained in the contractors safety manual or other safety related information. Whenever a new practice or procedure is introduced into the workplace, thoroughly review it for safety. Pass a sign-in sheet around each meeting, and distribute meeting notes afterwards.

Safety is a two-way street. Supervisors (inspectors) can preach safety, but only workers can practice safety. Safety education requires worker participation. Conduct a safety instruction meeting for all workers every day.

The workers can discuss how the safety program applies to their actual job assignments. Ask them to read and discuss a section of the manual and review how the general safety rules apply to specific situations. Remember, the **following general rules apply in all situations:**

- No one should undertake a job that appears to be unsafe
- No one is expected to undertake a job until he/she has received adequate safety instructions, and is authorized to perform the task
- No one should use chemicals without fully understanding their toxic properties and without the knowledge required to work safely with these chemicals
- Mechanical safeguards must be kept in place
- Workers must report any unsafe conditions to the job site supervisor
- Any work-related injury or illness must be reported to management at once
- PEO must be used when and where required. All such equipment must be properly maintained

It is extremely important to communicate to workers the commitment to safety and make sure they are familiar with the elements of the safety. If inspectors see a supervisor or someone in management do something unsafe, please tell that person. Do not forget that actions speak louder than words.

24.7 Working at Heights

If a person is truly afraid of heights, that person should not be on a tank, bridge, or tower. Respecting heights, however, is different. ***Respect*** of the height does not mean a person is afraid, it means that person is a great deal more careful. In this industry, working heights can range from a few feet (meters) to several hundred feet (meters) above the ground or water. If workers are uncomfortable, their concentration will be diverted and they will be a hazard to themselves and others. There are three important safety factors when working at heights:

- Attitude
- Alertness
- Common sense

Inspectors on the job are responsible for their own safety, including:

- Recognition of own physical limitations
- Knowledge of the rules and requirements for the job
- The safety of fellow workers
- The duty to report any unsafe act or accident

An inspector's job requires work on scaffolding, platforms, and/or lifts. Falls are the leading cause of death in the construction industry, so **proper fall protection** and **fall prevention are critical issues**. The employer is responsible for fall protection (i.e., safety harnesses). The contractor is required to provide safe access for inspection. The access is usually defined by the laws of the country or locale where the work is performed.

24.8 Scaffolding

The following section is a basic summary of industry guidelines, including US CFR, ANSI, and other accepted governing bodies.

Scaffolds shall be provided for all work that cannot be done safely by workers standing on permanent or solid construction at least 20 inches wide, except such work that can be safely done from ladders.

There are two exceptions to this rule:

- Work of a limited nature and of short duration when the permanent or solid construction is less than 20 inches in width and the fall distance does not exceed 15 feet in height and provided adequate risk control is recognized and maintained under competent supervision.
- Work of a short duration from joists or similar members at 2 feet or closer centers, planks resting on these members forming a plank platform 12 inches wide or equivalent protection.

Scaffolds must be constructed of wood or other suitable materials such as steel or aluminum members of known strength characteristics. Where materials other than wood are used, or where scaffold designs differ from those specified, the scaffold and its parts must provide a degree of strength, rigidity and safety equivalent to that provided by the described scaffold it replaces.

Anchorage and bracing shall be such that scaffolds and false-work will be prevented from swaying, tipping, or collapsing. Scaffold lumber, except for planks, used on suspended or ladder-jack scaffolds, shall be the equivalent of "selected lumber," free from damage that will affect its strength.

Extension planking of the finger type shall be made with at least 5 fingers on each side. These fingers shall be at least 1-inch by 2 1/8-inch selected straight-grained Douglas fir or material of equal strength. All metal fittings shall be adequate to maintain the structural qualities of the device.

The length of the extended planking shall not exceed 12 feet 6 inches, and the actual mechanical overlap between the 2 halves shall be not less than 1/8 of the length of the extended planking. A substantial stop shall be provided to maintain this overlap.

Not more than one employee shall be permitted at one time on any extension planking that is more than 3 feet in height. Extension planking shall not be used as a platform on ladder-jack, suspended, or other unstable scaffolds.

The erection and dismantling of scaffolds or false-work shall be performed under the supervision and direction of a qualified person.

NOTE: In addition to persons meeting the requirements of "qualified persons" or person(s) possessing a certification of competence in scaffold erection, dismantling and use issued by trade associations, state-approved apprenticeship or training programs or other similar training programs shall be considered a "qualified person(s)."

Erection and dismantling of scaffolds shall be performed in accordance with good engineering practice. Where engineering design is required by these orders, the engineering drawings shall be made available at the job site during erection or upon request by the division.

All required ties to the structure shall be installed as soon as the scaffold has been completed to the tie-in area during erection. Ties shall only be removed during dismantling as the work progresses downward unless other methods are used to prevent the scaffold from falling over.

No structural members shall be removed from scaffolds during dismantling operations below the level being dismantled. Where work platforms are proposed, guardrails shall be installed before other work not

directly related to scaffold erection is permitted to begin.

Scaffolds or false-work installations shall not be altered by removing uprights, braces, or supports unless other members providing equivalent strength are substituted. Scaffolds shall not be overloaded. Material shall not be allowed to accumulate to the extent that a scaffold is subjected to loading it is not designed to support.

A safe and unobstructed means of access, such as a walkway, stair, or ladder shall be provided to all scaffold platforms. Climbing ladders or stairways on scaffolds used for access and egress shall be affixed or built into the scaffold by proper design and engineering, and shall be so located that their use will not disturb the stability of the scaffold.

If a ladder is used as a means of access to the scaffold, it shall be securely attached and shall comply with the section on ladders. Permanent stairways shall comply with the applicable provisions of the General Industry Safety Orders. Prefabricated scaffold steps or stairs shall comply with the design, manufacture and installation requirements of ANSI A10.8-1988, Scaffolding-Safety Requirements.

Horizontal members of end frames may be designed and used as a climbing device provided that the steps are:

- Reasonably parallel and level.
- Continuous climb as required in this chapter under the Metal Scaffolds Section (a)(8), using frames of the like configuration.
- Provided with sufficient clearance to provide a good handhold and foot space.

Platforms shall not be sloped more than 2 feet vertically to 10 feet horizontally and shall be positively secured against slipping from supports. No worker shall be permitted to work on a scaffold platform where slippery conditions exist unless such conditions are a necessary part of the work.

Workers on scaffolds who are exposed to overhead hazards shall be provided with overhead protection or other means that will effectively eliminate the hazard. Bolts used in the construction of scaffolds shall be of a size and in sufficient numbers at each connection to develop the designed strength of the scaffold. Where materials are line-hoisted onto a scaffold, a tag line shall be used where necessary to control the load.

When a scaffold materially changes its direction, the platform planks shall be laid to prevent tipping. The planks that meet the corner ledger at an angle shall be laid first, extending over the diagonally placed ledger far enough to have a good safe bearing, but not far enough to involve any danger from tipping. The planking running in the opposite direction at an angle shall be laid so as to extend over and rest on the first layer of planking.

Do **NOT** get on a scaffold until you know it is safe!!

24.9 Personal Responsibility

Every person on a jobsite has a personal responsibility to prevent accidents. This is a responsibility to each person's family, fellow workers, and employer. Each individual is expected to observe safe practice rules and instructions relating to the efficient handling of the work. Personal responsibilities include the following:

- Incorporate safety into every job procedure.

- No job is done efficiently unless it has been done safely.
- Know and obey safe practice rules.
- Know that disciplinary action may result from a violation of the safety rules.
- Report all injuries immediately, no matter how slight the injury may be.
- Caution fellow workers when they perform unsafe acts.
- Do not take chances.
- Ask questions when there is any doubt concerning safety.
- Do not tamper with anything not understood.
- Report all unsafe conditions or equipment to the supervisor immediately.

Follow all safety and health rules and regulations. Some general safety rules to always observe are:

- Observe all smoking and fire prevention regulations.
- Workers with long hair, regardless of gender, must maintain their hair in such a way that it does not become a safety hazard.
- Work clothing must not present a safety hazard.
- Wear work boots or shoes. Safety toe shoes are highly recommended.
- Wear protective head gear (hard hats), hearing protection, eye protection and other PEP in designated areas.
- Do not operate equipment until safety guards are in place.
- Do not remove lock out tags or locks unless authorization to remove them is given.
- Do not adjust or remove safety devices unless authorization is given.
- Observe safety signs.
- Report industrial injuries to the supervisor immediately.
- Orderly and clean work places are everyone's responsibility.
- Turn in fire extinguishers that have been used or that have a broken seal to the supervisor.
- Use fire hoses for fires only.

Each person's cooperation is necessary to protect themselves and everyone else. It is important to follow safety rules, to use the safeguards and the safety equipment provided, and to make safety part of the job. Everyone is expected to cooperate fully to maintain compliance, including immediately notifying supervisors of any known or concealed dangers in the work area. If anyone feels uncomfortable or unsafe in any work situation please let a supervisor know immediately that assistance is needed. Do not perform any task or duty unless properly equipped or trained to do the work.

REMEMBER — SAFETY IS YOUR RESPONSIBILITY!

Chapter 25: The Coating Inspector's Job

Objectives

When this module is complete, the training candidate will have knowledge and understanding of:

- Specification
- Pre-Job conference
- Standards
- Materials
- Surface preparation
- Mixing and thinning
- Application
- Documentation

Prerequisites

Prior to class, be sure to:

- Complete the previous chapters
- Read through the chapter

25.1 Introduction

The role of the coatings inspector has changed over the past few years. While NACE International's Coating Inspectors Program (CIP) defines the inspector's role as a "quality control technician," it is very uncommon to find a coatings inspector on any job site working in this sole capacity. The distinction between inspection and consulting has not changed'.

Inspectors must not only read and understand the project specifications, but also understand that expectations of inspector's responsibilities varies from job to job, *even when working for the same client*. The true definition of the job title "coatings inspector" is subject to dispute, but it is now quite evident is that coatings inspectors must seek education to become qualified/certified in all fields that relate to the hugely varied work expectations performed on a daily basis. Examples of duties include: scaffold inspection, containment, basic safety inspection, and waste management. To further complicate matters, application contractors have their own expectations of what a coatings inspector should do.

Many owners today require additional documented training/certifications in addition to the primary qualification, *Certified Coatings Inspector.* The good news is that most experienced inspectors noted the trend, recognized the need to obtain additional training, and did it!

There is, however, a troubling trend developing in which some coatings inspectors seem to now think of themselves as corrosion engineers and project managers, without having the necessary training, experience, or qualifications. Even more troubling is that some assume management roles and become part of the decision making process by default. Usually, this goes unnoticed by the owner until something goes wrong, and questions begin. Coatings inspectors should stay within their area of expertise to avoid and/or reduce liabilities to their employers.

During previous discussions in this course on the pre-job conference, emphasis was put on the need for inspectors to clarify their

authority and responsibilities. **Please remember:** once the coating inspector's authority and responsibility are defined and clarified, **do not step outside those boundaries**. That is the best way to avoid problems.

25.2 Inspector's Job

Based on NACE International's definition of an inspector's job as quality control technician, the following list identifies what an inspector's job may entail:

- Specification
- Pre-job conference whenever possible
- Standards
- Materials
- Surface preparation
- Mixing and thinning
- Application
- Final inspection
- Documentation

25.3 Specification

Earlier in the course, the project specification was covered in detail (Figure 25.1). **Inspectors must understand the specification**. Coating inspectors have this responsibility because it is very likely that any interpretation of the specification after the pre-job conference is most likely *going to be left up to them*. It is not uncommon for the foreman and/or supervisors to change during a project. Often projects will have several supervisors over the duration of a project.

This generates many challenges that the coatings inspector must deal with on a case-by-case basis. Expect to explain and clarify the requirements of the specification to new supervisors and crew members many times. The key to success in the midst of such change is tolerance, coupled with the knowledge that contractors and supervisors with a good grasp of the requirements go a long way to create a more harmonious and more stress free project.

Figure 25.1 Site Walk Through with Contractor

Most specifications make reference to standards from various organizations (NACE, ISO, ASTM, etc.). *Take responsibility **to ensure*** that those standards pertaining to the work being performed *are physically on site* for easy reference as needed. **Do not** rely on contractors to furnish copies of the standards unless it is their contractual requirement. Work closely with contractors to review and ensure a mutual understanding of the standards.

Another important document that inspectors are required to keep are the product data sheets for all specified products. These are very handy during the application process since most specifications do not always contain some of the specific information found on product data sheets. Also, it is not uncommon for a specified product's formulation to change or modify between the time the specification is written and the project begins. Examine the product data sheets and

notify the owner/specifier and contractor immediately about any changes.

25.4 Pre-job Conference

This subject has been addressed previously. Inspectors should have a good understanding of the purpose and objectives of a pre-job conference. An important reminder: it is not uncommon for owners, and supervisors of inspectors attending a pre-job conference to find the inspector absent. Make every effort to attend the pre-job conference. It is vitally important because there is no information better than first-hand information. As mentioned before, attend the meeting to meet the team and to ask questions about issues that might not otherwise be discussed. **Attend the pre-job conference**. **It is a valuable and critical part of a coating inspector's job**.

25.5 Standards

By now it is clear that standards have an important role to ensure team members perform the same task, in the same manner, to achieve the same or similar results (Figure 25.2). Therefore, as stated in the previous section, whenever a standard is referenced in a specification, ensure those standards are available for reference on the job site. Experience has proven that even the most commonly used surface preparation standards have different meanings to different people in this industry.

In many cases, crew members have never seen a standard but rather were only told about it and what it means. Supervisors may know the standards and requirements, but unfortunately, most of the *correct* information gets lost when communicated to the work crew. Inspectors need to explain the requirements of a standard to crews to keep work consistent and avoid so much rework. Therefore, it is critical for inspectors to acquire and have the standards available on site.

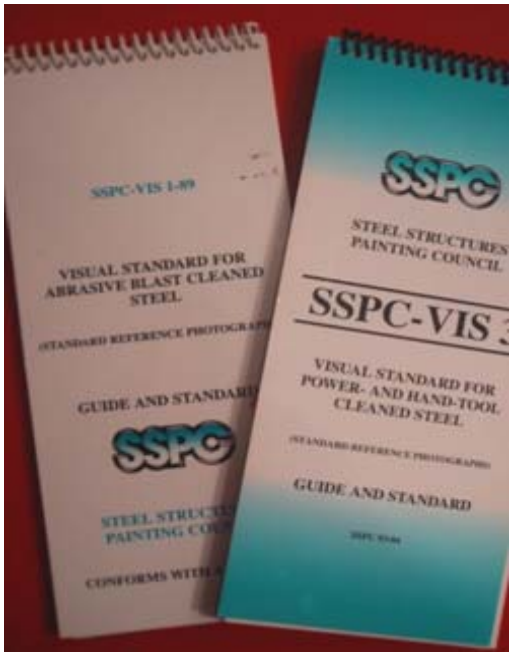

Figure 25.2 Standards

25.6 Materials

On rare occasions, particularly offshore, material acquisition for a project may be delegated to the inspector (Figure 25.3). However, an inspector's usual materials responsibilities are to receive the materials, check them in, and ensure they are stored properly, particularly coating and lining materials that have time- and temperature-related characteristics. This is critical because if there is a premature failure after application, the investigation **will** examine the storage conditions after the product left the manufacturer. While material storage always requires certain safety precautions, *always ensure the materials are stored* ***according to the manufacturer's recom-***

mendations. This information is on the Product Data Sheets. If clarification is needed, call the manufacturer.

Figure 25.3 Materials

25.7 Surface Preparation

The estimates for coating failures attributable to inadequate or poor surface preparation ranges between 75–90% (Figure 25.4). That single piece of data brings into razor-sharp focus the critical importance of a coatings inspector's responsibility to ensure **strict adherence** to the specified surface preparation, *and* to ensure that **any deviations from the specification are always authorized and documented in writing.** Most specifiers go to great lengths to ensure that surface preparation is specified correctly. Unfortunately, it is common for both inspectors and contractors to deviate from the specification without proper authorization. When this happens, the end result can be a costly failure where no one wins.

Figure 25.4 Surface Preparation

25.8 Mixing and Thinning

Another critical aspect of an inspector's job is to monitor the mixing and thinning of coatings (Figure 25.5). Most coatings come to the job site unassembled and require assembly before application. This is usually easy with single component coatings, but multi-component coatings can create serious problems, particularly if the crew is very inexperienced.

Ensure that coatings are mixed exactly to the manufacturer's guidelines. When solvents are added, ensure that the right solvent is used **and** in the correct quantity.

Figure 25.5 Mixing and Thinning

25.9 Application

Do not fall in the trap of some inspectors who seem to believe that once application begins, their work comes to an end (Figure 25.6).S This philosophy and practice is troubling. Coatings inspectors must work to change these attitudes. Most applicators want to do a good job, but many factors influence the quality of their work. Application supervisors tend to put extreme pressures on the applicators, who then respond by rushing the process, thus resulting in inferior work.

An astute inspector can avert mistakes during application such as:

- Insufficient WFT that leads to low DFT readings
- Lapping
- Incorrect wet edge time
- Runs and sags
- Excessive overspray and dry spray
- Holidays

Figure 25.6 Application

Final Inspection

A well written specification should have a section dedicated to the final inspection process (Figure 25.7).S This should include an outline of acceptance and rejection criteria, particularly when specialty coatings are being applied. The final inspection section should also detail what equipment to use and which standards to follow during the process. Ensure the application and inspection are done correctly.

The fact is, a good visual inspection can yield valuable clues to the overall condition of the applied protective coatings. A certificate of completion signed by the inspector and applicator is sometimes required, so once the inspection and recommended repairs are complete, ensure the certificate of completion is signed by both parties and is part of the final project documentation.

Figure 25.7 Final Inspection

25.10 Documentation

As discussed previously, a coatings inspection job is not complete until the project documentation is delivered to the owner. Deliver the documentation as soon as possible after the acceptance of the work. While most inspectors do not keep copies of their reports for future reference, it is wiser to keep them. Keep copies of all records, unless prevented by contractual clauses or otherwise. It is a wiser course of action.

25.11 Case Study

James Ward is a NACE Certified Level 3 Inspector with extensive experience in the protective coatings industry. Before starting work as a full time third-party coatings inspector with ProCoat© Inspections, he was a sales representative with Hurricane Moisture Control, a well established provider of dehumidification services.

Because of his background in dehumidification, he was chosen as the coatings inspector for a tank lining project in Bigfoot, Texas, which required dehumidification. It was critical for the project to go well and complete on time to avoid costly settlements related to loss of use. During the pre-job conference, the owner made it clear that all the equipment had been properly sized by his technical services staff and it was the contractor's responsibility to ensure that he had the right equipment for the job. He also stated that Mr. Ward's sole responsibility was to observe, document, and report the process.

The project began as planned and surface preparation for the entire tank floor was completed on schedule. Before application could begin, Mr. Ward took environmental readings inside the tank and noticed that humidity readings were in the region of 65%, which was much higher than the acceptable (45%) in the specification. He approached the applicator foreman and advised him of the findings. Kim Johnson was the applicator foreman with over 20 years of experience and was quite concerned. He took his own readings, which confirmed what Mr. Ward had indicated.

Knowing the possible repercussions if the situation was not addressed, he asked Mr. Ward for some guidance on how to proceed.

Being so proud of his dehumidification background, Mr. Ward made a few calls (or so he claimed), then told Mr. Johnson that he must call Hurricane Moisture control and get the equipment that Mr. Ward had just ordered as a replacements. Mr. Johnson felt obligated and did just what Mr. Ward had ordered. The equipment arrived later that day and the switch out was done personally by Mr. Ward.

The following morning, both men were on the job site and noticed that the DH unit was not working. They went into the tank and noticed that there was flash rusting all over the tank's floor.

Mr. Johnson advised Mr. Ward that he would need a change order to reblast the floor since Mr. Ward was the one who brought in the new DH unit that had stopped working overnight, causing the surface condition to deteriorate and thus fail to meet the requirements of NACE No. 1. Mr. Ward refused, saying that his duty on this project was only to observe, document and report. This created an impasse and after 2 days of argument, the owner, applicator, and inspection company had to call a meeting to settle the issue.

25.11.1 Assignment

1. Read and understand the case study, then get into teams for discussion.
2. As a team, determine what went wrong (not with the DH unit itself) and who should be held accountable for the current impasse?
3. Did Inspector Ward overstep his area of responsibility and authority?
4. What is the best way to proceed?

Study Guide Answers

Chapter 2 - Corrosion

1. Define corrosion.
   The deterioration of a substance, usually a metal from a reaction with its environment.

2. What is passivation?
   A layer of oxides formed on the surface of a metal that provides corrosion protection. Stainless Steel for example.

3. What are the elements of a corrosion cell?
   Anode
   Cathode
   Metallic Pathway
   Electrolyte.

4. Describe what happens at the anode.
   The metal dissolves into the electrolyte.

5. What is the function of the electrolyte?
   Allows the passage of ions to connect the corrosion cell.

6. What is the function of the metallic pathway?
   Allows the flow of electrons to connect the corrosion cell

7. What is the galvanic series?
   A listing of metals in order of reactivity (more or less noble) in seawater at 25°C.

8. The general rules of galvanic corrosion are:
   The less noble (or more reactive) metal when connected to a more noble (or less reactive metal) will corrode preferentially.

9. Name five important factors that affect the rate of corrosion.
   Humidity
   Oxygen
   Chemical Salts
   Pollutants
   Gases
   Temperature

10. General corrosion is:
    - *Results in a relatively uniform loss of material over the entire surface*
    - *Results in a general thinning of the affected surface*
    - *Relatively easy to inspect*
    - *Does not cause catastrophic failures*

11. Localized corrosion is:
    Typically Pitting and Crevice Corrosion. It is typically of the most concern as damage is concentrated and loss of integrity or structural failure can result.

12. List some of the common tools/methods used for corrosion control.
    - Design
    - Inhibitors
    - Material Selection
    - Cathodic Protection
    - Protective Coatings
    - Splash Zone Systems
    - Alteration of the Environment

Chapter 4 – The Role of the Inspector

1. How does NACE define the inspector's role?
   *The inspector's role is that of a **quality control technician** responsible for observing and reporting conformance or deviation from the project specification.*

2. What is the inspector's responsibility when it comes to safety on the project?
   Safety enforcement is not the responsibility of the inspector; however, it is his/her responsibility to report any issues that may affect the project.

3. Name some tests that may need to be conducted during surface preparation and coating operations.
   Temperature, Relative Humidity, Dew Point, Anchor Profile, Surface Cleanliness

4. Name some of the documentation/reports that may be required to be maintained on a coatings project.
   Daily, Weekly Summary, Materials Usage Report, Manpower and Equipment, Non-Conformance, and Conformance.

5. What are the most important characteristics of a good report?
   Objective, Accurate, and Detailed.

6. What is the inspector's primary responsibility and what should the inspector not do as it pertains to the specification.
   *The Inspector's primary responsibility as the inspector is to **"enforce"** the specification. The inspector is **NOT** to make changes to the specification for any reason.*

7. What type of information could you expect to find on a Product Data Sheet?
   Surface preparation and application information such as recommended level of surface cleanliness, recommended application methods and equipment such as tip sizes. Environmental parameters for application such as max and min temperatures, curing times, recoat windows.

8. What type of information could you expect to find on a Material Safety Data Sheet?
Health, Safety and Environmental. The PPE required. Physical characteristics.. Emergency responder information.

9. Explain the difference between Quality Assurance (QA) and Quality Control (QC).
***Quality Assurance** - Any systematic process of checking to see whether a product or service being developed is meeting specified requirements.*

***Quality Control** - A procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements of the client or customer*

Chapter 5 – Environmental Testing

1. Identify some of the defects that can be caused by incorrect application temperatures.
•*Failure to cure*
•*Too rapid solvent evaporation*
•*Poor film formation*

2. Describe relative humidity.
The amount of moisture in the air compared to saturation level

3. What is the dew point temperature?
The temperature at which moisture will begin to form on a steel surface.

4. Name some of the effects wind may have on a coatings project.
•*blowing abrasives*
•*causing excessive drift or overspray*
•*accelerating solvent evaporation*
•*contributing to the formation of dry spray*

5. What are some of the common errors when using an electronic hygrometer?
Failure to acclimate the instrument to the environment with adequate time.

6. Explain the process for use of the sling psychrometer.
•*Make sure the wick is wet and clean*
•*Continue to "sling" until 3 consecutive readings are achieved*

Chapter 7 – Coating Fundamentals

1. List three (3) desirable properties of a coating?
Chemical Resistance
Water Resistance
Ease of Application
Adhesion to Substrate
Cohesive Strength
Flexibility and Elongation

Impact Resistance
Abrasion Resistance
Temperature Resistance
Dielectric Strength

2. Two broad classifications of a coating are:

Organic	Convertible	Thermosetting
Inorganic	Non-Convertible	Thermoplastic

3. What are the two (2) primary components of a liquid applied coating?
   Pigment
   Vehicle (Resin or Binder and Solvent)

4. What are the three methods by which a coating provides corrosion control?
   Barrier
   Inhibitive
   Sacrificial

5. What are the three different ways a coating can adhere to the surface?
   Chemical
   Mechanical
   Polar
   A combination of all three

Chapter 8 – Coating Types and Curing Mechanisms

1. The two broad classification for curing mechanisms are:
   Convertible
   Non-Convertible

2. List two (2) Non-convertible coating types.
   Chlorinated Rubber
   Vinyl

3. List three (3) convertible coating curing mechanisms.
   Oxidation
   Co-reaction (polymerization)
   Hydration
   Fusion

4. List two (2) characteristics of oxidation cure coatings.
   Not suitable for immersion service
   Not suitable for use over alkaline substrates
   Limited dry film thickness per coat

5. List three (3) coating types that cure by polymerization.
   Epoxies
   Polyurethanes
   Polyureas
   Polyaspartics
   Polysiloxanies

6. Induction time is ***the time required by the product data sheet (coatings manufacturer) between mixing the coating and the start of application.***

7. What is a main requirement for a hydration coating to cure?
   Moisture

8. Industrial and marine coatings are commonly referred to by ***generic resin type.***

9. Oil based coatings applied over alkaline surfaces may result in ***Saponification.***

Chapter 9 – Coating Project Specification

1. List five (5) of the formal sections usually contained in a good specification.
   Scope of work
   Terms and definitions
   Reference standards and codes
   Safety
   Pre-job conference
   Surface preparation
   Coating materials (includes the coating schedule)
   Sampling coatings
   Workmanship
   Application
   Work schedule (sequence of work to be done)
   Repairs and remedial coating work
   Inspection
   Documentation

2. What are two of the inspector's responsibilities as it relates to the specification?
   Enforce the specification.
   Do NOT to make changes to the specification.

Chapter 10 – Surface Preparation

1. During surface preparation, surface cleanliness should be inspected (as a minimum) the following three (3) times:
   Before any surface preparation activities
   After surface preparation, before coating begins
   Between each application of coating in a multi-coat system

2. Factors during surface preparation that may effect service life include:
   Residues of oil, grease, and soil
   Residues of (non-visible) chemical salts
   Rust on the surface
   Loose or broken mill scale
   Rust scale
   Anchor pattern
   Defects mechanical cleaning equipment
   Surface condensation
   Old coatings that may have poor adhesion or may be too deteriorated for recoating
   Existing coatings that may be incompatible

3. Common design defects include:
   - Hard-to-reach or inaccessible areas
   - Rivets, bolts, or other connectors
   - Welds
   - Gaps (particularly skip welds or surfaces close together)
   - Overlapping surfaces (e.g., roof plates in water tanks)
   - Angle iron badly oriented or in complex arrangements
   - Threaded areas
   - Dissimilar metals
   - Sharp edges, particularly on corners or rough cut plate
   - Construction aids

4. Common fabrication defects include:
   - Weld Spatter
   - Skip Welds
   - Rough Welds
   - Sharp Corners & Edges

5. Four (4) Typical SSPC SP1 pre-cleaning methods include:
   - Solvent wipe with cloth or rag
   - Immersion of the substrate in solvent
   - Solvent spray
   - Vapor degreasing
   - Steam cleaning
   - Emulsion cleaning
   - Chemical paint stripping
   - Use of alkaline cleaners

6. One Standard for use with Power Tool Cleaning is: _____
   - ISO St2
   - ISO St3
   - SSPC SP-3
   - SSPC SP-11

7. Four (4) Examples of tools used for Power Tool Cleaning are:
   - Rotary Wire Brushes
   - Impact tools
   - Needle Scaler
   - Rotary Scalers
   - Piston Scalers
   - Grinders and sanders
   - Disc Sanders

8. Two (2) Abrasive Blasting methods include:
   - Centrifugal blasting
   - Sand-injected water blast
   - Slurry blast
   - Wet abrasive blast
   - Dry Grit Blast Cleaning (Air Blasting)

9. Visual Standards for abrasive blasting include:
   - SSPC-Vis 1
   - ISO 8501-1

10. SSPC SP 10/NACE 2 limits staining to **5%** per each unit area

11. SSPC SP 5/NACE 1 limits staining to **0%** per each unit area

12. SSPC SP 6/NACE 3 limits staining to **33%** per each unit area

13. The two (2) types of abrasive blasting nozzles include:
    - Straight
    - Venturi

14. The specified level of surface cleanliness must be achieved and maintained **immediately prior to coatings application**.

15. Advantages of centrifugal blast equipment include:
    - Dust and fines are contained
    - Abrasives are easily recycled
    - Blasting and priming can be an inline operation
    - General overall economy compared to air blasting
    - No compressors, piping, or air handling equipment needed for wheel blasting

16. The Inspector's checklist for surface preparation should include:
    - Ambient Conditions
    - Conditions of substrate
    - Pre-Blast surface cleanliness
    - Shot/Grit size selection
    - Shot/Grit Cleanliness
    - Abrasive Blasting Equipment
    - Surface Profile
    - Surface cleanliness after abrasive blasting
    - Operator qualifications
    - Safety

17. Abrasive media types include:
    - Shot & Grit (metallic)
    - Crushed Slag
    - Ceramic Grit
    - Silica Sand
    - Garnet
    - Agricultural Abrasives
    - Specialty Abrasives

18. Abrasive media typically used for recycling include:
    - Steel Shot
    - Steel Grit

19. List the pressure ranges that categorize:
    Low Pressure Water Cleaning: **<34 MPa (5,000 psi)**
    High-Pressure Water Cleaning: **34 to 70 MPa (5,000 to 10,000 psi)**
    High-Pressure Water Jetting: **70 to 210 MPa (10,000 to 30,000 psi)**
    Ultrahigh=Pressure Water Jetting: **>210 MPa (30,000 psi)**

20. Three (3) types of Water-Blasting include:
    Grit Blasting with a Shroud
    Sand Injected Water Blast
    Slurry Blast with Grit/Water Mix

21. The NACE-SSPC Waterjetting Standard is: **SSPC-VIS 4 and NACE-VIS 7**

22. Three (3) Test Methods for surface profile include:
    Comparator and coupons
    Replica tape
    Digital Surface Profile Gauge

Chapter 11 – Surface Preparation Instruments

1. Types of Soluble Salt Contamination include:
    Chlorides
    Sulfates
    Nitrates

2. If inspection is to be effective with regards to soluble salts, the specification should very clearly state:
    Limits to be accepted
    Specific salts to be limited
    Test method to be used
    Frequency of testing
    Locations in which tests should be administered

3. Test for soluble salts include:
    Bresle Patch
    Sleeve Test
    Soluble Salt Meters
    Conductivity Meters

4. Depth of surface profile can be evaluated by several methods:
    ISO Comparator
    Replica tape
    Digital Profile Gauge

5. The ISO Comparator grades may be recorded:
    Finer-than-Fine Grade
    Fine Grade
    Medium Grade
    Coarse Grade
    Coarser-than-Coarse Grade

6. The two types of replica tape are commonly used:
    Coarse—for 20 to 50 µm (0.8- to 2.0-mils)
    X-Coarse—for 37 to 112 µm (1.5- to 4.5-mils)

7. List the Standards for using the Replica tape:
    ASTM D 4417 Method C
    NACE SP 0287-2002

8. When using Replica tape common errors include:
    - Variation in point-to-point profile over the surface being tested
    - The presence of particles of dirt on either the replica tape or gauge
    - Gauge Accuracy
    - The rubbing or burnishing technique

Chapter 13 – Pre Job Conference

1. Goals of a Pre Job Conference include:
    - Discuss health, safety and environment (HES) Requirements
    - Address/ clarify emergency procedures
    - Review and discuss scope of work (SOW)
    - Review logistical support
    - Discuss line communications between parties
    - Review known critical hazards
    - Establish list of critical point of contacts (POCS)
    - Discuss and clarify inspector (s) responsibilities and authority
    - Clarify the chain of command (Reporting system)
    - Discuss and clarify areas of concern in the project specification (Omissions, clarifications, testing)
    - Agree on critical hold points for inspections
    - Conflict resolution between the inspector and applicator
    - Change orders

2. People may be required to attend a pre-job conference include:
    - Owner
    - Owners contract manager
    - Engineer
    - Specifying Engineer
    - Operations personnel
    - Specifier
    - Purchasing agents
    - Coatings manufacturer (Preferably tech. service representative)
    - Coatings Inspector (s)
    - Project safety personnel
    - Coatings applicator (Supervision personnel)

3. Before the start of the Pre Job Conference the inspector should obtain a copy of, read, and understand the:
    - Specification
    - Any standard / procedure referenced in the project specifications
    - Manufacturers product data sheets
    - Safety requirements of the MSDS

Chapter 14 – Documentation

1. Documentation may include:
    - Detailed written daily reports
    - Inspection logs
    - Routine reports
    - Reports for weekly progress meetings
    - Daily entries in a project log book
    - A daily inspection report using standardized forms
    - Routine reports
    - Monthly or quarterly reports

2. Inspection records show:
   - Environmental conditions
   - Pretreatment Details
   - Cleaning Details
   - Materials Details
   - Coating applications Details
   - Results of work and all tests

3. Good records allow management to:
   - Detect and tag design defects for future work
   - Evaluate coating performance
   - Determine annual cost data on each coating system
   - Develop ongoing maintenance program

4. Project inspection documentation provides:
   - Inspection (QC) records
   - Management information
   - Verification of work performed by the contractor
   - Details of non-conforming work

Chapter 15 – Coatings Application

1. One guides for an enclosures for coatings projects is:
   - SSPC Technology Guide No. 12
   - SSPC Technology Update No. 6 Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations

2. Low temperatures concerns during coatings application include:
   - Slow the curing of chemically curing coatings
   - Will increase the viscosity of material
   - Some coatings may use special cure

3. High temperatures concerns during coatings application include:
   - Can cause the solvent to evaporate too fast
   - Will reduce the pot life
   - Decrease the viscosity of many two-component materials

4. High humidity during coating application may:
   - Slows the evaporation of the solvent
   - Can leave moisture on the surface of the coating
   - May effect the gloss or color
   - May cause amine blush (must be removed prior to top coating)

5. Coatings may be applied by the following methods:
   - Roller
   - Brush
   - Airless spray (including plural component)
   - Conventional spray
   - High Volume Low Pressure (HVLP)
   - Air Assisted Airless

Chapter 18 – PDS & MSDS

1. Coatings Product Data Sheets (Paint Specs) provide users with the following:
   - Surface preparation
   - Storage
   - Mixing and thinning
   - Application procedure
   - DFT requirements

2. MSDS contain the following:
   - Provides workers and emergency personnel with critical information on composition, handling or working with the substance
   - Includes information such as melting point, boiling point, flash point, toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill handling procedures.
   - Provides information regarding the safety issues associated with any hazardous (or potentially hazardous) material.
   - Provides instructions for the correct action to take in the event of a spill, explosion, fire or hazardous exposure.

Chapter 20 – Coatings Defects

1. Non-drying films (failure to cure) may be caused by:
   - Not adding curing agent, wrong curing agent or incorrect amount of it
   - Problem with material from the manufacturer
   - Environmental issues(too cold, hot, or humid)
   - Wrong or contaminated thinner (Solvent)

2. Some of the problems that can be caused by amine blush are:
   - Surface tackiness or greasiness
   - Incomplete curing
   - Poor adhesion
   - Coating discoloration
   - Poor gloss retention

3. Runs, Sags, and wrinkles may be caused by:
   - Applying the coating too thick
   - Too much or the wrong thinner used
   - Surface too hot to apply the coating
   - Application of coating at the end of its pot life
   - Wrong thixotrope used in manufacturing

4. **Chalking** is a powdery, friable layer on the surface of a coating that is most common with epoxy coatings.

5. Cratering may be caused by:
   - Air trapped in the coating and forming a bubble which then bursts
   - Air trapped in the coating during mixing if the proper procedures are not followed

6. Vacules or voids are typically caused by:
   - Running the mixer too fast

7. Pinholes are:
   Very small holes in a coating typically caused by air or solvent trapped in porous film and escaping.

8. A common cause of blistering is:
   Surface Contamination under the applied coating

9. Cracking of a coating is noted:
   When the crack extends to the substrate

10. Checking can be described as:
    Fine cracks in the surface of a coating that don't extend through to the substrate

11. Adhesion failures may be caused by:
    Contamination on the surface
    Wrong surface preparation specified
    Failure to inspect surface preparation
    Insufficient surface profile
    Exceeding the topcoat window
    Application of incompatible coatings

Chapter 21 – Low Voltage and High Voltage Holiday Detection

1. General types of holiday detectors include:
   Low-voltage DC
   High-voltage DC
   High-voltage AC

2. Low-voltage (wet-sponge) holiday detectors are powered by a battery with output voltages ranging **from 5 to 120 V DC**

3. Describe Low-voltage (wet-sponge) holiday detectors:
   Ground cable is attached directly to substrate
   Sponge saturated with a solution of tap water/wetting agent
   Maximum rate of 30 cm/s (1 linear ft/s) double stroke
   Used on coatings up to 500 µm (20 mils)
   May be used on concrete.

4. High Voltage DC Holiday detector types include:
   DC – Pulsed
   DC – Constant Current

5. Describe High Voltage DC Holiday Detectors:
   Ground connection must be made direct to metal substrate (preferred) or indirectly when necessary (e.g., to soil for pipeline measurement)
   Rule of thumb: 100V/mil (4V/µm)
   Electrode rate of 0.3 m/s (1 ft/s) in a single pass (according to NACE Standard SP0188)
   Voltage output range from 800 to 60,000 V

6. The type of High Voltage Holiday detector used for concrete is a:
   High Voltage DC Constant Current

Chapter 23 – Standards

1. What is a Standard?
   An established norm or requirement that is written by industry professionals
   A formal document that establishes uniform engineering or technical criteria, methods, processes and practices

2. What percentage of NACE Standards relate to coatings: **50%**

Practical Math Assignment

Briefing:

This section covers DFT/WFT, English/metric, and other practical math operations that a coating inspector may have to work with at one time or another. This is a homework section you should complete in the next 2 days, after which we will review the problems and answers.

Calculations similar to these must be made in both written and practical exams and are often made on site.

To do this assignment you may want to refer to Appendix A in the back of your student notebook. Also look at the other appendices, particularly the Glossary which contains terms we may be using this week that you may not be familiar with.

From time to time, coating inspectors may be required to perform a variety of practical math operations including:

- English/metric conversions
- Calculating percentages
- Averaging when taking dry film thickness measurements
- Converting dry-film thickness to wet-film thickness
- Calculating spreading rates (including loss factors) for various coatings

This section is designed to help you test yourself on your practical math skills and ability to apply them to coating inspection situations.

The answers to all the practice problems are given at the end of this section. We will review any difficulties you have with these problems in class.

English/Metric Conversion

The United States is one of the very few countries that continues to use the *English* system of measurement. Most other countries (including England) have adopted the metric system. The United States is currently, and slowly, in the process of converting to the metric system. The coating industry can be expected to follow suit.

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It is important for coating inspectors based in the United States to understand and, sooner or later, be able to use the metric system, particularly if they will be working outside the United States. At the same time, coating inspectors who are familiar with the metric system may be required to use American *English* units when using coating materials manufactured in the United States, or following specifications written in the United States.

One reason for the widespread adoption of the metric system is its simplicity. For this reason it has been used by scientists, even in the United States, for many years. Compare how the different units of measurement of length are expressed.

English	**Metric**
12 inches = 1 foot 3 feet = 1 yard 1,760 yards = 5,280 feet = 1 mile	1,000 µm = 1 millimeter (mm) 1,000 mm = 1 meter (m) 1,000 m = 1 kilometer (km)

As you can see, metric units increase in multiples of 10. For simplicity, we'll forget about intermediate units such as furlongs (English) and decameters (metric), since both are rarely used in industry.

Converting from English to metric, or vice versa, is not difficult. Five charts of English/Metric equivalents are included in Appendix A of this notebook.

Table 1: Liquid

Table 2: Length

Table 3: Area

Table 4: Pressure

Table 5: Weight

Sample conversion:

Question: 20 in. = ? mm

Turn to Table 2: Length. Look in the third column from the left, labeled *Inch* and then look down the table to the row where the number *1* is directly under *Inch*. Look across this row to the column under *mm*. You will see the number *25.4*. This shows that:

1 inch = 25.4 mm

Then multiply 20 inch by 25.4 mm and you get 508.0 mm; thus:

20 in. = 508.0 mm

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Test yourself on English/metric conversion by calculating the following conversions.

Problem 1. Length

100 in. = _____ cm

10 cm = _____ in.

20 m = _____ ft

20 m = _____ yd

Problem 2. Liquid (Note: gal., qt., etc are taken as U.S. units of volume)

3 gal = _____ L

6 L = _____ gal

6 L = _____ qt

15 L = _____ qt

Problem 3. Area

3 ft^2 = _____ m^2

6 m^2 = _____ ft^2

6 m^2 = _____ yd^2

100 ft^2 = _____ m^2

Calculating Percentages

In calculating percentages, one number is divided by another, then—to make it strictly correct—the product is multiplied by 100.

Examples:

80 is what percent of 100?

$$\frac{80}{100} \times 100 = 0.80 \times 100 = 80\%$$

100 is what percent of 80?

$$\frac{100}{80} \times 100 = 1.25 \times 100 = 125\%$$

15 is what percent of 60?

$$\frac{15}{60} \times 100 = 0.25 \times 100 = 25\%$$

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60 is what percent of 15?

$$\frac{60}{15} \times 100 = 4.0 \times 100 = 400\%$$

From time to time, the coating inspector may be required to calculate percentages for a variety of reasons, including:

- When performing sieve tests of abrasives
- When measuring coating DFT using SSPC-PA 2 as the standard

Following is an example and two practice problems for the former. The latter will be covered in the next section.

Example:

You have taken a 1,000 gm sample of abrasive and performed a sieve test. The amount of abrasive retained at each sieve is listed in column A. The percentage in column B is obtained by calculating the percentage (of 1,000) for each number in column A.

Sieve Size (NBS Screen #)	**A** **Grams Retained**	**B** **Percentage**
8	25	2.5
10	750	75.0
12	100	10.0
Passed through	125	12.5
Check sum	1000	100%

Note that these calculations are much easier in the metric system.

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Practice Problem 4		
You have taken two samples of abrasives, each weighing 500 gm, and sieve tested each sample. The amount of abrasives retained by each sieve is listed in column A, *Grams Retained*. Calculate what percentage of each sample is retained by each sieve.		
Sieve Size (NBS Screen #)	**A** **Grams Retained**	**B** **Percentage**
8	25	
10	40	
12	70	
14	325	
Passed through	40	
Checksum	500	

Practice Problem 5		
You have taken two samples of abrasives, each weighing 500 gm, and sieve tested each sample. The amount of abrasives retained by each sieve is listed in column A, *Grams Retained*. Calculate what percentage of each sample is retained by each sieve.		
Sieve Size (NBS Screen #)	**A** **Grams Retained**	**B** **Percentage**
8	20	
10	50	
12	65	
14	335	
Passed through	30	
Check sum	500	

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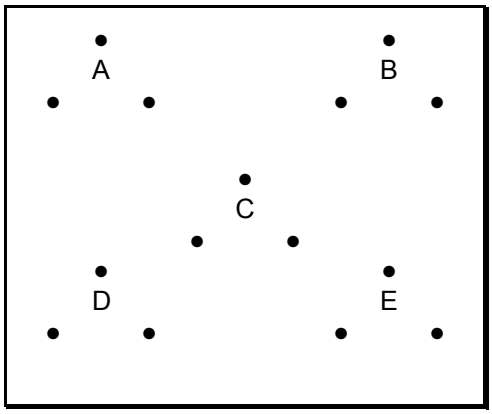
Averaging



One commonly used specification for measurement of dry-film thickness with magnetic gauges is SSPC-PA 2. To illustrate this specification, consider this square to be a 100 ft^2 area in which five separate spot measurements of three readings each have been made. Notice that a total of 15 individual readings have been made. Assume:

- This is the final inspection to determine the total thickness of the coating system.
- SSPC-PA2 is the specified procedure.
- The specification calls for a range of 12 to 15 mils DFT.
- The coating inspector has made measurements and compiled them into the following table:

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Measurement (mils)				Total*		
Area	**1**	**2**	**3**	**(1+2+3)**	***/ 3 = Average**	**Complies (Y/N)?**
A	10	12	12			
B	12	14	13			
C	15	14	14			
D	14	13	13			
E	12	13	12			
				Overall Average		

The coating inspector then performs the required calculations in the following steps.

Step 1: Add up the measurements for each area.

Measurement (mils)				Total*		
Area	**1**	**2**	**3**	**(1+2+3)**	***/ 3 = Average**	**Complies (Y/N)?**
A	10	12	12	34		
B	12	14	13	39		
C	15	14	14	43		
D	14	13	13	40		
E	12	13	12	37		
				Overall Average		

Step 2: Divide the total for each area by 3 (the number of measurements) to find the spot measurement for each area.

	Reading (mils)			Total*		
Area	**1**	**2**	**3**	**(1+2+3)**	***/ 3 = Average**	**Complies (Y/N)?**
A	10	12	12	34	11.3	
B	12	14	13	39	13.0	
C	15	14	14	43	14.3	
D	14	13	13	40	13.3	
E	12	13	12	37	12.3	
				Overall Average		

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Step 3: Calculate allowed spot measurements. Remember that any single spot measurement may be as low as 80% of the minimum DFT and as high as 120% of the maximum DFT, provided the overall average falls within the specified range.

Specified range = 12 to 15 mils DFT

80% of 12 mils = 9.6 mils, 120% of 15 mils = 18 mils

Any single spot measurement must be greater than 9.6 mils and less than 18 mils.

	Reading (mils)			Total*		
Area	**1**	**2**	**3**	**(1+2+3)**	***/ 3 = Average**	**Complies (Y/N)?**
A	10	12	12	34	11.3	Yes
B	12	14	13	39	13.0	Yes
C	15	14	14	43	14.3	Yes
D	14	13	13	40	13.3	Yes
E	12	13	12	37	12.3	Yes
Overall Average						

Step 4: Add the area averages, then divide by 5 (the number of areas) to obtain the average of the five spot measurements, which (if SSPC-PA 2 is the specified procedure) must not be less than the specified minimum thickness nor more than the specified maximum thickness.

Total of averages* 64.2

Divide by 5 . . . . . */5

Overall average of the five spot measurements . . 12.8 mils

	Reading (mils)			Total*		
Area	**1**	**2**	**3**	**(1+2+3)**	***/ 3 = Average**	**Complies (Y/N)?**
A	10	12	12	34	11.3	Yes
B	12	14	13	39	13.0	Yes
C	15	14	14	43	14.3	Yes
D	14	13	13	40	13.3	Yes
E	12	13	12	37	12.3	Yes
Overall Average					12.8 mils	Yes

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The coating inspector finds that the area falls within the specification because:

- All spot measurements are greater than 80% of the specified minimum.
- All spot measurements are less than 120% of the specified maximum.
- The average of the five spot measurements falls within the specified range.

Below are two more practice problems. In working these practice problems, assume:

- SSPC-PA2 is the specified measurement procedure.
- Five separate spot measurements of three readings each have been made in a 100 ft^2 area.
- This is the final inspection to determine the total thickness of the coating system.
- The specification calls for a range of 12 to 15 mils DFT.
- The coating inspector has taken readings and compiled them into the tables given.

Calculate:

- Spot measurements for each area (average of the three readings)
- Average of the five spot measurements; and
- State whether or not the area measured meets the specification.

Practice Problem 6.						
Area	**1**	**2**	**3**	**(1+2+3)***	***/3 = Average**	**Complies (Y/N)?**
A	9	10	10			
B	12	11	12			
C	13	14	13			
D	12	13	12			
E	15	13	14			
				Overall Average		

This area does _____ does not _____ meet the specification. (Check the correct answer.)

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Practice Problem 7						
Area	**1**	**2**	**3**	**(1+2+3)***	***/ 3 = Average**	**Complies (Y/N)?**
A	12	10	10			
B	13	14	13			
C	9	10	9			
D	14	15	15			
E	13	14	14			
				Overall Average		

This area does _____ does not _____ meet the specification. (Check the correct answer.)

Calculating WFT from DFT

Coating thickness can be measured during the application process, both while the film is wet and later in its dry state.

Dry-film thickness (DFT) is the usual specification criterion included in the coating contract. Wet-film thickness (WFT) measurements can serve as an aid in determining how much of a coating must be applied to reach the specified DFT. WFT measurements made as each coat is applied have the advantage of catching errors in thickness in time to correct them. However, wet-film thickness measurements generally serve as a guideline, with DFT being the defining measurement.

Knowing the wet-film thickness, then, is helpful only if the wet-film/dry-film relationship is understood. That is, given a range of DFT in the specification, what range of WFT values will produce a DFT that is within the specification?

The dry-film/wet-film ratio, is based on the percentage of solids by volume of the coating being used. Manufacturers' data sheets sometimes list solids by weight as well as solids by volume, but volume measurement must be used in this calculation. The basic formula is:

$$\frac{\text{DFT}}{\text{\% solids by volume}} = \text{WFT}$$

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The same formula works with both English and metric measurements.

$\frac{\text{DFT (mils)}}{\text{\% solids by volume}} = \text{WFT (mils)}$	$\frac{\text{DFT (µm)}}{\text{\% solids by volume}} = \text{WFT (µm)}$

Examples:

English	Metric
1. The coating specification calls for each application to have a DFT of 4 to 6 mils. The coating has 30% solids by volume. What range of wet-film thickness will probably dry down to the desired range of dry-film thickness? Since we have a low and high value for DFT, we calculate a low and high value for the desired WFT. $\frac{\text{4 mil DFT}}{\text{0.30 solids by volume}} = \text{13.3 mil WFT}$ $\frac{\text{6 mil DFT}}{\text{0.30 solids by volume}} = \text{20.0 mil WFT}$ Since WFT is not a very accurate indicator, we can say that if the applied WFT has a range of about 14 to 20 mil, the DFT will probably be within the specification.	2. The coating specification calls for each application to have a DFT of 100 to 125 µm. The coating has 35% solids by volume. What range of wet-film thickness will probably dry down to the desired range of dry-film thickness? Since we have a low and high value for DFT, we calculate a low and high value for the desired WFT. $\frac{\text{100 µm DFT}}{\text{0.35 solids by volume}} = \text{285.7 µm WFT}$ $\frac{\text{125 µm DFT}}{\text{0.35 solids by volume}} = \text{357.1 µm WFT}$ Since WFT is not a very accurate indicator, we can say that if the applied WFT has a range of about 285 to 350 µm, the DFT will probably be within the specification.

Practice Problem 8

For the DFT range and % solids by volume given, calculate the WFT range that will probably dry down to a DFT within the specification.

DFT Range	% Solids by Volume	WFT Range
2 to 3 mil	30	
4 to 6 mil	32	
5 to 7 mil	33	
100 to 150 µm	27	
50 to 75 µm	35	

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If the coating is thinned, this must be taken into account. Thinner increases the total volume without increasing the amount of solids. The formula to be used when thinner has been added is:

$$\frac{\text{DFT (1 + \% thinner by volume [TBV])}}{\text{\% solids by volume}} = \text{WFT}$$

If you are so fortunate as to be told by the contractor, *We're going to thin this coating by 25% by volume*, all you have to do is plug the 25% (0.25) figure into the formula. If, however, you are told, *We're going to add 1 pint of thinner to each gallon of coating*, you first have to calculate what percentage 1 pint is of 1 gal. A similar calculation will be required if the operator said *We're going to add half a liter of solvent to 5 liters of coating*.

To calculate the range of WFT that will probably result in Dots within the specification when thinner is added:

Step 1: Calculate % volume thinner

Step 2: Calculate WFT range

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Example:

English	Metric
The coating specification calls for a DFT of 3 to 4 mils. The coating has 35% solids by volume. The coating has been thinned by the addition of 1 pint of solvent per gallon of coating. What WFT range will probably result in DFTs within the specification? **Step 1: Calculate % volume thinner**. 8 pints = 1 gal 1 pint = 1/8 gal 1 pint - 0.125 gal So the number we will use for our % thinner by volume is 0.125 gal. **Step 2: Calculate WFT range.** Low WFT = 3 mil DFT x (1 + .125 TBV) (0.35 SBV) = 3 mil x 1.125 = 3.4 mil 0.35 0.35 = 9.6 mils High WFT = 4 mil DFT x (1 + .125 TBV) 0.35 solids by volume = 4 mil x 1.125 = 4.5 mil 0.35 0.35 = 12.9 mils	The coating specification calls for a DFT of 75 to 100 µm. The coating has 35% solids by volume. The coating has been thinned by the addition of 0.5 liters of solvent per 5 liters of coating. What WFT range will probably result in DFTs within the specification? **Step 1: Calculate % volume thinner**. 0.5 liters/5 liters = 1/10 = 10% So the number we will use for our % thinner by volume is 0.1 L. **Step 2: Calculate WFT range.** Low WFT = 75µm DFT x (1 + .10 TBV) (0.35 SBV) = 75 µm x 1.10 = 82.5 µm 0.35 0.35 = 236 µm High WFT = 100 µm DFT x (1 + .10 TBV) 0.35 solids by volume = 100 µm x 1.10 = 110 µm 0.35 0.35 = 314 µm

After rounding off to the nearest whole number, we find that the WFT range that will probably give us a range of DFT readings within the specification is 10 to 13 mils or 235 to 315 µm.

Given a specified range of acceptable DFT, the percent solids by volume of the coating, and the amount of thinner added per gallon, calculate the WFT range that will probably result in DFT values within the specification. (Round off to the nearest whole number.)

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Practice Problem 9			
DFT Range (mils)	% Solids by Volume	Thinner added Per gallon	WFT Range (mils)
3 to 5	33	1 pint	
2 to 4	25	2 pints	
4 to 6	35	1 pint	

Practice Problem 10			
DFT Range (µm)	% Solids by Volume	Thinner added per liter	WFT Range (µm)
100 to 125	33	100 mL	
150 to 200	25	100 mL	
125 to 175	35	200 mL	

Spreading Rate or Coverage

Inspectors should understand how to calculate wet and dry film thickness based on the previous formulas. It is equally important that inspectors can calculate the spreading rate of a material based on the DFT required and the percent solids by volume of the coating.

Spread rate, also known as coverage, is based on applying a coating to a smooth surface with no loss of material and therefore represents the theoretical spreading rate. Naturally, coating materials will be lost in application due to wastage during mixing, overspray, equipment cleaning, and other causes. The **practical spreading rate** must be calculated for practical purposes.

When calculating the spreading rate of a coating, the number 1,604 is often used since one U.S. gallon of liquid material will cover 1,604 ft^2 at a thickness of 0.001 inch or 1 mil (25.4 µm). In metric units, one liter of liquid coating material will cover 1,000 m^2 at a thickness of 1 µm.

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Example : Consider a coating that is 100% solids by volume.	
How many US gallons of material are required to coat an area of 1,000 ft^2 if the average DFT is 12 mils?	How many liters of material are required to coat an area of 100 m^2 if the average DFT is 300 µm?
1 gallon covers 1,604 ft^2 at a WFT of 1 mil. At a WFT of 12 mils, the area covered (by one gallon) is:	1 liter covers 1,000 m^2 at a WFT of 1 µm. At a WFT of 300 µm, the area covered (by one liter) is:
$\frac{1604}{12}$ = 133.7 ft^2.	$\frac{1,000}{300}$ = 3.3 m^2.
To cover 1,000 ft^2 at this same thickness, volume required is:	To cover 100 m^2 at this same thickness, volume required is:
$\frac{1,000}{133.7}$ = 7.48 gals.	$\frac{100}{3.3}$ = 30.3 liters

DFT is the same as WFT, since the coating is 100% solids by volume, so no further calculation is required. If, however, the paint is not 100% volume solids, the spreading rate is reduced.

The spreading rate at 1.0 mil DFT of a coating with less than 100% SBV is calculated by multiplying 1,604 by the actual percentage volume solids, **in decimal form**, of the coating being considered.

For example, if a coating has 60% SBV, the coverage (spread rate) will be:	
English	**Metric**
1,604 x 0.60 = 962 ft^2 at 1.0 mil dry	1000 x 0.60 = 600 m^2 @ 1 µm dry
If the applied DFT of the same coating was 6.0 mils, the spread rate would be:	If the applied DFT of the same coating was 150 µm, the spread rate would be:
$\frac{962\ ft^2 @ 1.0\ mil}{6.0\ mils}$ = 160.3(160) ft^2/gal	$\frac{600\ m^2 @ 1\ \mu m}{150\ \mu m}$ = 4 m^2/L

All calculations so far are based on the theoretical spreading rate. The practical coverage rate is equal to the theoretical spread rate minus the same spread rate multiplied by the estimated percentage loss of material.

The calculation based on the above data is as follows:

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Example: Assume a coating with a SBV of 60%, the DFT of 6.0 mils and an estimated 20% loss. Calculate the practical coverage rate (spread rate). 160 ft^2/gal - (160 x 0.20 loss) = 160 - 32 = 128 ft^2/gal	Example: Assume a coating with a SBV of 60%, the DFT of 150 µm and an estimated 20% loss. Calculate the practical coverage rate (spread rate). 4 m^2 /L - (4 x 0.20 loss) = 4-0.8 = 3.2 m^2/L

This same information is often expressed in the following formulas:

Theoretical Spreading Rate	
English	**Metric**
$\frac{1604\ (ft^2/gal)}{\%\ solids\ x\ DFT\ (mils)}$	$\frac{\%\ SBV\ x\ 1000\ (m^2/L)}{DFT\ (\mu m)}$

Practical Spreading Rate
Theoretical spreading rate – (theoretical spreading rate x %loss (decimal)) or Theoretical spreading rate (1 - % loss (decimal))

To calculate the quantity of coating material required, the area to be coated is divided by the practical spreading rate:

$$\text{Material Consumption} = \frac{\text{Area } (ft^2 \text{ or } m^2)}{\text{Practical Coverage (gal or L)}}$$

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Example	
English	**Metric**
The following data are presented for a given coating: Recommended DFT = 5 mils % Solids by volume = 45% The contractor must apply this coating to 5,000 square feet (465 meters) and anticipates a loss of 10%. How many gallons must the contractor order?	The following data are presented for a given coating: Recommended DFT = 125 µm % Solids by volume = 45% The contractor must apply this coating to 500 square meters and anticipates a loss of 10%. How many liters must the contractor order?
Theoretical spreading rate (ft^2/gal) = $\frac{0.45 \times 1{,}604}{5 \text{ mils}}$ = 144 ft^2/gal Practical spreading rate = 144 – (144 x 0.10) = 129.6 ft^2/gal Material to order = $\frac{5{,}000 \text{ } ft^2}{129.6 \text{ } (ft^2/gal)}$ …..= 38.58 gals Sensible order = 39 gallons	Theoretical spreading rate (m^2/L) = ……$\frac{0.45 \times 1{,}000}{125}$ = 3.6 m^2/L Practical spreading rate = 3.6 – (3.6 x 0.10) = 3.24 m^2/L Material to order = $\frac{500 \text{ } m^2}{3.24 \text{ } m^2/L}$ = 154.32 liters Sensible order = 155 liters

Practice Problem 11					
English			**Metric**		
Recommend DFT	=	6.0 mils	Recommend DFT	=	150 µm
% Solids by volume	=	54%	% Solids by volume	=	54%
thinner added	=	10%	thinner added	=	10%
a. The contractor must apply this coating to 7,000 square feet and anticipates a loss of 15%. How many gallons must the contractor buy?			a. The contractor must apply this coating to 650 square meters and anticipates a loss of 15%. How many liters must the contractor buy?		
b) What WFT must be applied to achieve the intended DFT?			b) What WFT must be applied to achieve the intended DFT?		

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Answers

Please Note: *Because of variances in calculators, rounding errors, etc., your answers may be slightly different from those given. If this is the case, check with your instructor.*

1. Length	**2. Liquid**	**3. Area**
100 in. = 254 cm	3.0 gal = 11.4 L	3.0 ft^2 = .3 m^2
10.0 cm = 3.9 in.	6.0 liters = 1.6 US gal	6.0 m^2 = 64.6 ft^2
20.0 m = 65.6 ft	6.0 liters = 6.3 qt	6.0 m^2 = 7.2 yd
20.0 m = 21.9 yd	15.0 liters = 15.9 qt	100 ft^2 = 9.3 m^2

4.

Sieve Size (NBS Screen#)	**A Grams Retained**	**B Percentage**
8	25	5
10	40	8
12	70	14
14	325	65
Passed through	40	8
Check sum	500 gm	100

5.

Sieve Size (NBS Screen #)	**A Grams Retained**	**B Percentage**
8	20	4
10	50	10
12	65	13
14	335	67
Passed through	30	6
Check sum	500 gm	100

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6.

Area	1	2	3	(1+2+3)*	*/ 3 = Average	Complies (Y/N)?
A	9	10	10	29	9.7	80.8 = yes
B	12	11	12	35	11.7	97.5 = yes
C	13	14	13	40	13.3	110.8 = yes
D	12	13	12	37	12.3	102.5 = yes
E	15	13	14	42	14.0	116.7 = yes
				Overall Average	12.2	Yes

This area does _X_ does not ___ meet the specification.

7.

Area	1	2	3	(1+2+3)*	*/ 3 = Average	Complies (Y/N)?
A	12	10	10	32	10.7	89.2 = yes
B	13	14	13	40	13.3	110.8 = yes
C	9	10	9	28	9.3	77.5 = no
D	14	15	15	44	14.7	122.5 = yes
E	13	14	14	41	13.7	114.2 = yes
				Overall Average	12.3	Yes

This area does ___ does not **_X_** meet the specification.

(Because the spot measurement for area C is less than 80% of the specified minimum, even though the average of the five spot measurements is within the specified range.)

8.

DFT Range	% Solids by Volume	WFT Range
2 to 3 mil	30	6 to 10
4 to 6 mil	32	13 to 19
5 to 7 mil	33	15 to 21
100 to 150 µm	27	370 to 556
50 to 75 µm	35	143 to 214

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9.

DFT Range (mils)	% Solids by Volume	Thinner added per gallon	WFT Range (mils)
3 to 5	33	1 pint	10 to 17
2 to 4	25	2 pints	10 to 20
4 to 6	35	1 pint	13 to 19

10.

DFT Range (µm)	% Solids by Volume	Thinner added per liter	WFT Range (µm)
100 to 125	33	100 mL	333 to 417
150 to 200	25	100 mL	660 to 880
125 to 175	35	200 mL	429 to 600

11.

	English	Metric
Theoretical Coverage	144 ft^2/gal	3.6 m^2/L
Practical Coverage	122 ft^2/gal	3.06 m^2/L
Consumption	57 gallons	213 liters
WFT required	12.2 mils	305 µm

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Spreading Rate or Coverage 14
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Conversion Tables

Table 1

Liquid Measurement

Gallon (gal)	Quart (qt)	Pint (pt)	Ounce (oz)	Liter (L)	Milliliter (mL)	Cubic Centimeter (cc)	Cu. in
1.0	4.0	8.0	128	3.785	3785	3785	231.0
.250	1.0	2.0	32	.946	946	946	57.75
.125	0.50	1.0	16	0.473	473	473	28.875
.0078	.031	.063	1.0	.0296	29.6	29.6	1.8
.264	1.057	2.114	33.81	1.0	1000	1000	61
.00026	.001	.002	.034	.001	1.0	1.0	.061
.0043	.0173	.035	.55	.016	16.39	16.39	1.0

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Table 2

Length

Yard (yd)	Foot (ft)	Inch (in)	Mil	Micron	Millimeter (mm)	Centimeter (cm)	Meter (m)
1	3	36	36,000	914,400	914.4	91.44	.9144
.333	1	12	12,000	304,800	304.8	30.48	.3048
.028	.083	1	1,000	25,400	25.4	2.54	.025
.00028	.00083	.001	1	25.4	.0254	.00254	.0000254
.0000011	.0000033	.000039	.0393	1	.001	.0001	.000001
.00109	.00328	.03937	39.37	1,000	1	.1	.001
.0109	.0328	.3937	393.7	10,000	10	1	.01
1.0936	3.280	39.37	39,370	1,000,000	1,000	100	1

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Table 3

Area

Square Yards ($yard^2$)	Square Foot ($foot^2$)	Square Inch ($inch^2$)	Square mm (mm^2)	Square cm (cm^2)	Square Meter (m^2)
1	9	1296	836,127.36	8,361.27	.83612
.1111	1	144	92,903.04	929.03	.0929
.00007716	.006944	1	645.16	6.4516	.0006452
.0000012	.0000108	.00155	1	.01	.000001
.0001196	.001076	.155	100	1	.0001
1.196	10.76	155.00	1,000,000	10,000	1

Table4

Pressure

Pounds per Square foot (lb/ft^2)	Pounds per Square inch (lb/in^2 or psi)	Kilograms per Square cm (kg/cm^2)	Kilograms Pascal (KPA)
1	.00694	.000488	.0479
144	1	.0703	6.895
2048	14.22	1	98.07
.0208	.000145	.0000102	1

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Table 5

Weight

Pounds (lb)	Ounces (oz)	Grams (gm)	Kilograms (kg)
1	16	453.6	.4536
.0625	1	28.34	.02834
.02206	.0353	1	.001
2.206	35.3	1000	1

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V.O.C. Calculation

The coating inspector must check the coating materials on site for compliance with allowable V.O.C. If any thinning is allowed and is done on site, the inspector must be able to determine maximum allowable thinning that is V.O.C. compliant

1. Must know:

- Allowable V.O.C. level
- of activated/mixed coating; and
- of thinner

2. To calculate ounces per gallon

$$\frac{\text{Allowable Coating (VOC lbs/gal)} - \text{Thinner (VOC lbs/gal)}}{\text{Allowable (VOC lbs/gal)}} \times 128 \text{ oz/gal} = \text{Allowable thinning in oz/gal.}$$

3. To calculate in grams per liter

$$\frac{\text{Allowable Coating (VOC gr/l)} - \text{Thinner (VOC gr/l)}}{\text{Allowable (VOC gr/l)}} \times \text{VOC thinner (gr/l)} = \text{Allowable thinning in gr/l.}$$

4. Example

	lbs/gal	**gr/l**
Allowable VOC	3.5	420
VOC coating	3.15	378
VOC thinner	6.85	822

A. $\frac{(3.5) - (3.15)}{(6.85) - (3.5)} \times 128 = \frac{(.35)}{(3.35)} \times 128 = (.104) \times 128 = 13.37$ oz/gal

B. $\frac{(420) - (378)}{(822) - (420)} \times 822 = \frac{(42)}{(402)} \times 822 = (.104) \times 1822 = 85.88$ gr/l

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Report of NACE Technical Unit Committee T—6D* on Application and Use of Coatings for Atmospheric Service. Prepared by Task Group T-6D-12** on Industrial Maintenance Painting Terminology.

Glossary of Terms used in Maintenance Painting

This glossary is a compilation of terms commonly used in the maintenance painting field, with generally accepted definitions of those terms. Although many of the terms used are generally understood, some are interpreted in several different ways: others are not commonly used because of lack of clear definitions. The purpose of this glossary is to eliminate misunderstanding resulting from conflicting interpretations of these terms and to improve communications between users, applicators, and manufacturers of industrial maintenance coatings.

The asterisks preceding some of the words in this glossary indicate the definition varies from the definition of the word as given by the Standard Definitions and Terminology Subcommittee of the NACE Publication Committee, published on pages 79-80 of this issue.

A

ASTM Cups—standard laboratory test cups for measuring viscosity.

abrasion resistance—resistance to mechanical wear.

abrasive *(see NACE Task Group T-6G-1k Report on "Surface Preparation Abrasives for Industrial Maintenance Painting"[1])*—the agent used for abrasive blast cleaning, for example, sand, grit, etc.

absorption—process of soaking up, or assimilation of one substance by another.

accelerator—catalyst; a material which accelerates the hardening of certain coatings.

acetone—dimethyl ketone: solvent.

acid number—a numerical index of free acid in an oil or resin.

acoustic paint—paint which absorbs or deadens sound.

acrylic resin—a clear resin polymerized from acrylic acid and methacrylic acid.

activator—catalyst or curing agent.

adaptors—connectors for joining parts of different sizes.

adduct curing agent—a curing agent combined with a portion of the resin.

adhesion—bonding strength; the attraction of a coating to the substrate.

adsorption—process of attraction to a sur face attachment, the retention of foreign molecules on the surface of a substance.

agglomeration—random attachment of single units to form groups; formation of masses of pigments, not dispersed.

aging—remaining undisturbed.

agitator—stirrer: mixer.

air adjusting valve—spray gun valve con trolling input air.

air bubble—dry bubble in paint film caused by entrapped air.

air cap *(or air nozzle)*—perforated housing for atomizing air at head of spray gun.

air drying—dries by oxidation or evaporative drying by simple exposure to air without heat or catalyst.

air entraining agents—natural wood resins, fats, inorganic materials, sulfonated compounds, and oils for air entrapment in concrete up to 10%.

air entrapment—inclusion of air bubbles in paint film.

air hose—hose of air supply quality, usually red.

airless spraying—spraying without atomizing air, using hydraulic pressure.

airjet *(sandblasting)*—a type of sand blasting gun in which the abrasive is conveyed to the gun by partial vacuum.

air manifold *(pig)*—common air supply for several lines.

air transformer—device for controlled reduction in air pressure.

air valve—control valve in air line system.

air volume—quantity of air in cubic feet (usually per minute) at normal (atmospheric) pressure.

alcohol—a flammable solvent, miscible with water: alcohols commonly used in painting are ethyl alcohol (ethanol) and methyl alcohol (methanol, wood alcohol)

aldehydes—chemical compounds containing R-CHO grouping.

aliphatic hydrocarbons—"straight chain" solvents of low solvent power, derived from petroleum.

alkali—caustic, inorganic compounds which release hydroxyl groups in aqueous media.

alkyd resins—resins prepared by reacting alcohols and acids.

alligatoring—surface imperfections of paint having the appearance of alligator hide.

allyl resins—resins prepared from allyl alcohol.

ambient temperature—room temperature or temperature of surroundings.

American gallon—231 cubic inches.

amides—compounds containing oxygen and amino (NH_2) groupings.

amine adduct—amine curing agent combined with a portion of the resin.

* C.W. Sisler, Monsanto Company, St. Louis, MO, chairman.

** P.E. Weaver, Dow Chemical Company, Houston, TX, chairman.

amines—organic substituted ammonia; organic compounds having an NH_2 group.

amino resins—those containing reactive NH_2 groups.

amyl phenol resins—particular group of organic film formers. See phenolic resins.

anchor pattern—profile, surface roughness.

angle blasting—blast cleaning at angles less than 90°.

angle or degree *(airless spray cap)*—orifice angle, controls width of spray pattern angle.

anhydride—compound not containing water.

anhydrous—dry; free of water in any form.

***anion**—negatively charged ion.

annular orifice—circular opening.

***anode**—the electrode at which corrosion (oxidation) occurs .

applicator—one who applies; tool for applying .

arcing—swinging spray gun away from perpendicular.

argillaceous—clay containing.

aromatic hydrocarbons—ring compounds; strong solvents.

asphalt—residue from distilling petroleum also a natural complex hydrocarbon find in Trinidad, the United States, and else where.

asphalt cut back—asphalt plus thinner, asphalt solution; asphalt coating formed by dissolving asphalt.

asphalt emulsion—asphalt dispersion, not a solution; a water emulsion of asphalt.

asphalt impregnated—containing absorbed asphalt.

atomize—break stream into small particles.

Aurand Scaler—proprietary cleaning tool using cutter wheel bundles.

B

baking finish—finish requiring heat cure.

banding—identifying with strips of tape.

barrier—shielding or blocking device.

base—substrate.

binder—resin, film former vehicle.

bitumen—product of asphalt or coal tar origin.

bituminous coating—coal tar or asphalt based coating.

blast angle—angle of nozzle with reference to surface, also angle of particle propelled from wheel with reference to surface.

blast cleaning—cleaning with propelled abrasives.

bleaching—removing color.

bleeder gun—a spray gun with no air valve; trigger controls fluid flow only.

bleeding—surface flotation of color from under coats.

blistering—bubbling in dry or partially dry paint film.

block coat *(barrier coat or transition primer)*—tie coat *(adhesive)* between non-compatible paints.

blooming—whitening; moisture; blush; blushing.

blow-back *(spray term)*—rebound.

blushing—whitening and loss of gloss due to moisture blooming.

body—viscosity; middle or under *(coat)*.

boilers *(solvent)*—solvents of particular evaporation rate.

Bonderizing—a five-step proprietary custom process for phosphatizing

bonding—adhesion.

boomerang *(Mikrotest Gauge)*—a single magnet Proprietary direct reading, dry film thickness gauge.

bounce-back—spray rebound.

boxing—mixing by pouring from one container to another.

bridging—forming a skin over a depression.

bright blast—white blast.

brittleness—degree of resistance to cracking or breaking by bending.

bronze tools—non-sparking tools.

bronzing—formation of metallic sheen on a paint film.

brushability—ease of brushing.

brush-off blast—see NACE No. 4 in this alphabetical listing.

bubbling—a term used to describe the appearance of bubbles on the surface while a coating is being applied.

bulking value—volume per unit weight, usually expressed as gallons per pound.

C

caking—hard settling of pigment from paint.

calcareous—lime containing.

calcimine—pigment used in white wash.

casein paint—water thinned paint with vehicle derived from milk.

catalyst—accelerator; curing agent, promoter.

cat-eye—hole or holiday shaped like a cat's eye; cratering.

***cathode**—the electrode at which corrosion (oxidation) usually does not occur.

***cathodic protection**—corrosion prevention by sacrificial anodes or impressed current.

***cation**—positively charged ion.

***cavitation**—undercutting, crevice forming may be caused by fluids at high velocities and by flashing from liquid to gaseous state.

cellulose resins—those prepared from cellulose derivatives.

cement finishes—coatings containing Portland cement.

centipoise—a metric unit of viscosity.

centrifuge—device for separating solids from liquids by centrifugal action.

***chalking**—powdering of surface.

champagne finish (effervesence)—rapid escape of solvent visible by bubbling.

check—shallow crack of short length.

checking—formation of checks.

chipping—(1) cleaning steel using special hammers. (2) type of paint failure.

chlorinated rubber—a particular film former used as a binder, made by chlorinating natural rubber.

cleaner—(1) detergent, alkali, acid or other cleaning material; usually water or steam borne. (2) solvent for cleaning paint equipment.

clean surface—one free of contamination.

coal tar—black residue remaining after coal is distilled.

coal tar epoxy paint—paint in which binder or vehicle is combination of coal tar with epoxy resin.

coal tar urethane paint—paint in which binder or vehicle is combi-

nation of coal tar with polyurethane resin.

coatings—surface coverings; paints: barriers.

coat of paint—one layer of dry paint, resulting from a single wet application.

cobwebbing—premature drying causing a spider web effect.

cohesion—property of holding self together.

cold-checking—checking caused by low temperature.

cold-cracking—cracking occuring at low temperature.

color dynamics—scientific use of action colors.

color-fast—non-fading.

color retention—ability to retain original color.

commercial blast—*see NACE No. 3 in this alphabetical listing.*

compatibility—ability to mix with or adhere properly to other components.

composition—analysis: makeup.

continuity—degree of being intact or pore free .

contrast ratio—the coefficient of reflection of the black surface area divided by the coefficient of reflection of the white area.

converter—that which causes change to different state catalyst: curing agent promoter.

copolymers—large molecules resulting by simultaneous polymerization of different monomers.

copper sulfate test *(for mill scale)*—copper color indicates absence of mill scale when steel swabbed with 5% to 10% solution .

***corrosion**—decay: oxidation; deterioration due to interaction with environment: eaten away by degrees.

***corrosion fatigue**—loss of strength caused by corrosion.

coumarone—indene resins, particular type of organic binder or resin, coal tar resins.

coverage—milage, usually in square feet per gallon for a given dry film thickness.

cracking—splitting: disintegration of paint by breaks through film.

cratering—formation of holes or deep depressions in paint film.

crawling—shrinking of paint to form uneven surface.

crazing—development of nonuniform surface appearance of myriad tiny scales or cracks.

creepage—see crawling.

cross-linking—a particular method by which chemicals unite to form films.

cross-spray—spraying first in one direction and second at right angles.

crystalline structure—a structure in which components have a regular pattern of planes.

curing—setting up; hardening.

curing agent—hardener; promoter.

curtaining—sagging.

curtains—sags having a draped effect.

cycling *(of pump)*—interval between strokes.

D

damp—wet not dry.

deadman valve—shut-off valve at blast nozzle, operated by remote control.

decorative painting—architectural painting; aesthetical painting.

degreaser—chemical solution (compound) for grease removal.

delamination—separation of layers.

density—weight per unit volume.

detergent—cleaning agent.

deterioration—decay.

dew point—temperature at which moisture condenses.

diluent—a liquid which lowers viscosity and increases the bulk but is not necessarily a solvent for the solid ingredients: a thinner.

discoloration—color change.

dispersion—suspension of one component in another.

distensibility—ability to be stretched.

distillation—purification or separation by volatilizing and condensing.

doctor blade—knife applicator.

dolomite—carbonate of calcium and magnesium.

double regulation—regulation of both pot and gun air pressure.

drier—chemical which promotes oxidation or drying of paint.

drift *(overspray)*—sprayloss.

drop *(scaffold)*—one vertical descent of the scaffold.

drop cloth—protective cover.

dry spray—overspray or bounce back, sand finish due to spray particle being partially dried before reaching the surface.

drying oil—an oil which hardens in air.

drying time—time interval between application and final cure.

dry to handle—time interval between application and ability to pick up without damage .

dry to recoat—time interval between application and ability to receive next coat satisfactorily.

dry to touch—time interval between application and tack—free time.

dulling—loss of gloss or sheen.

E

edging—striping.

efflorescence—deposit of soluble white salts on surface of brick and other masonry.

eggshell—semi-gloss, dull.

elasticity—degree of recovery from stretching.

Elcometer—a two-prong proprietary magnetic direct reading dry film thickness gauge.

***electrolysis**—decomposition by means of an electrical current.

***electrolyte**—a substance which disassociates into ions when in solution or a fused state and which will then conduct an electric current. Sodium chloride and sulfuric acid are common examples.

electrostatic spray—spraying in which electric charge attracts paint to surface.

elongation—stretch.

emulsion paint—water base paint with an emulsified resin vehicle.

enamel—pigmented varnish; any hard, glossy coating.

endothermic—a change or process which takes place with absorption of heat.

epoxy resins—film formers usually made from bisphenol and epichlorohydrin.

epoxy amine—amine cured epoxy resin.

epoxy adduct—epoxy resin having all of the required amine incorpo-

rated by requiring additional epoxy resin for curing.

epoxy ester—epoxy modified oil; single package epoxy.

erosion—wearing away of paint films; heavy chalking tends to accelerate erosion

ester—reaction product of alcohol and acid, an organic salt.

estimate—compute, calculated cost of a job.

etch—surface attack by chemical means.

evaporation rate—rate of solvent release.

evaporation rate, final—time interval for complete evaporation of all solvents.

evaporation rate, initial—time interval during which low boiling solvent evaporates completely.

exothermic—a change or process in which heat is given off.

explosion—cratering from release of solvent after surface is dry: also see blistering.

explosive limits—a range of the ratio of solvent vapor to air in which the mixture will explode if ignited. Below the lower or above the higher explosive limit the mixture is too lean or too rich to explode. The critical ratio runs from about one to seven percent of solvent vapor by volume at atmospheric pressure.

extender—filler; cheapener.

extension gun—pole gun.

external mix—spray equipment in which fluid and air join outside of aircap.

F

FDA—see Food & Drug Administration.

fadeometer—device for measuring color retention or fade resistance.

fading—reduction in brightness of color.

fallout *(spray)*—overspray.

false body—thixotropic.

fanning *(spray gun technique)*—arcing.

fan pattern—geometry of spray pattern.

fast drying—dry for recoat in less than two hours, quick hardening paint.

fat paint—too much oil.

fatty acid—a component of certain drying oils, vegetable oil derivative feather edge—tapered edge.

feathering—(1) flickering a gun at the end of each stroke (2) tapering edge.

federal specifications—government specifications for formulations, raw material components, or performance.

ferrous—iron containing.

field painting—painting at the job site.

filler—extender; bulking agent; inert pigment.

film build—dry thickness characteristics per coat.

film former—a substance which forms a skin or membrane when dried from a liquid state.

film integrity—degree of continuity of film.

film thickness gauge—device for measuring film thickness above substrate: dry or wet film thickness gauges are available.

filter—strainer; purifier.

fineness of grind—measure of particle size or roughness of liquid paint, degree of dispersion of pigment in the binder.

fingers *(airless)*—broken spray pattern; fingerlike.

fire retardant paint—a paint which will delay flaming or overheating of substrate.

fish eye—*see cratering.*

flaking—disintegration in small pieces or flakes.

flammability—measure of ease of catching fire, ability to burn.

flame cleaning—method of surface preparation of steel using flame.

flash point—the lowest temperature at which a given flammable material will flash if a flame or spark is present.

flat finish—dull finish, no gloss.

flatting agent—paint ingredient causing low gloss.

flexibility—ability to be bent without dam age.

floating—separation of pigment colors on surface.

flocculation—see agglomeration.

flocking—a coating process producing velvet—like surfaces.

flooding—see floating.

flow—a measure of self spreading ability; spread.

fluid adjusting screw—a screw on a spray gun which controls the amount of fluid entering the gun.

fluid flow—a measure of flow through a gun with atomizing air shut off.

fluid hose—specially designed hose for paint materials, usually black.

fluid nozzle—fluid tip or orifice; in a broader sense it connotes needle and tip combination.

fluid tip—orifice in gun into which needle is seated.

foaming—frothing.

fogging—misting.

Food & Drug Administration (FDA)—agency involved with linings for food or pharmaceutical service.

forced drying—acceleration of drying by increasing the temperature above ambient temperature accompanied by forced air circulation.

Ford Cup—a proprietary viscosity measuring device.

frothing—foaming.

fungicide—a substance poisonous to fungi; retards or prevents fungi growth.

fungus—any of a group of plants, such as molds, mildew, mush rooms, smuts, etc.

furane resins—dark chemical resistant resins made from furfuryl alcohol, furfural and phhenol.

furfural—a particular type of aldehyde used to make furane resins.

G

galvanic corrosion—corrosion of dissimilar metals in electrical contact.

galvanized steel—zinc plated steel applied in a molten bath of zinc.

gas checking—fine checking; wrinkling, frosting under certain drying conditions; said to be caused by rapid oxygen absorption or by impurities in the air.

gel—a jelly—like substance.

gelling *(gelation)*—conversion of a liquid to a gel state.

generic—belonging to a particular family.

Gilsonite—a special bitumen, an asphalt found in Utah, one of the purest of natural bitumens.

glazing *(paint term)*—application of transparent or translucent pigment on a painted surface to produce certain blended effects.

glazing *(puttying)*—setting glass.

gloss—sheen; ability to reflect; brightness; lustre.

gloss meter—device for measuring sheen or lustre.

gloss retention—ability to retain original sheen.

grain—surface appearance, usually of wood.

gray blast—commercial blast.

grind gauge *(Hegeman)*—proprietary instrument for measuring smoothness of liquid paint.

grit—an abrasive obtained from slag and various other materials.

ground wire *(airless)*—a wire attached to dissipate electrostatic charge.

grooving *(roofing term)*—formation of shallow channels.

guide coat—a coat similar to the finish or color coat but of a different color to as sure good coverage.

gun distance—space between tip of gun and work.

H

halide—a compound containing fluorine, bromine, chlorine or iodine.

halogen—bromide, chlorine, fluorine or iodine.

hardener—curing agent; promoter, catalyst.

hardness—the degree a material will with stand pressure without deformation or scratching.

hazing—clouding.

Hesiometer—proprietary device for measuring cohesion and adhesion.

heavy-centered pattern—spray pattern having most paint in center, less at edges.

hiding power—able to obscure substrate.

high-boiling solvent—a solvent with an initial boiling point above 302°F (150°C) .

high build—producing thick dry films per coat.

high flash naptha—an aliphatic solvent having a high flash point, (1131°, 45°C).

hold out—ability (or property) to prevent soaking into substrate.

holiday—pinhole, skip, discontinuity, voids.

holiday detector—device for detection of pinholes or holidays.

honeycombing—lack of vertical film integrity, formation of cell structure; voids.

hose cleaner—mechanical device promoting a beneficial swirling action to cleaning solvent.

hose restriction—impediment; reduced diameter.

hot spray—spraying material heated to reduce viscosity.

hot surface—above 120°F (48.9°C).

humidity—measure of moisture content; relative humidity is the ratio of the quantity of water vapor in the air to the greatest amount possible at the given temperature. Saturated air is said to have a humidity of 100.

hummocking *(roofing term)*—formation of raised islands.

hydraulic spraying *(see airless)*—spraying by hydraulic pressure.

hydrophilic—having an affinity for water; capable of uniting—with or dissolving in water.

hydrophobic—having an antagonism for water; not capable of uniting or mixing with water.

hydroxyl—chemical radical; OH; basic nature.

hygroscopic—having a tendency to absorb water .

I

impact resistance—a measure of resistance to a blow; ability to resist deformation from impact.

incompatibility—inability to mix with or adhere to another material.

indicator (pH) paper—a vegetable dyed paper indicating relative acidity or basicity.

inert—not reactive.

inert pigment—a non-reactive pigment; filler.

inflammability—measure of ease of catching fire: ability to burn: use of the word flammability is preferred to inflammability due to the possible misinterpretation of the prefix "in" as a negative.

inhibitive pigment—one which retards corrosion process.

***inhibitor**—an agent added to retard corrosion.

inorganic—containing no carbon.

inorganic coatings—those employing inorganic binders or vehicles.

insulation—thermal, electrical, or sound barrier material; a poor conductor.

intercoat contamination—presence of foreign matter between successive coats.

intermediate coat—middle coat, guide coat.

internal mix—a spray gun in which the fluid and air are combined before leaving the gun.

intumesce—to form a voluminous char on ignition; foaming or swelling when exposed to flame.

***ion**—an electrically charged atom or group of atoms.

iron phosphate coating—conversion coating; chemical deposit.

isocyanate resins—resins characterized by CNO grouping; polyurethane resins.

J

japan—dark colored glossy varnish.

japan drier—weak mixture of driers.

jeep test—continuity test using low voltage circuit.

K

KB Value—measure of solvent power.

KTA Panel—a proprietary paint test panel with unique configuration and markings.

KTA Rating System—10 for no failure, 0 for complete failure, proprietary method of measuring paint disintegration over KTA Panels.

kauri reduction—test for solvent power of petroleum solvents.

ketones—organic solvents containing CO grouping; commonly used ketones an acetone, dimethyl ketone;

MEK, methyl ethyl ketone; and MIBK, methyl isobutyl ketone.

kreb units—units of viscosity.

L

lacquers—coatings which dry by evaporation of solvent.

laitance—milky white deposit on new concrete; effloresence.

laminar scale—rust formation in heavy layers.

lap—see overlap.

latex—rubber like a common binder for emulsion *(water)* paints, there are natural and synthetic latexes.

leaching—the process of extraction of a soluble component from a mixture with an insoluble component by percolation of the mixture with a solvent, usually water.

leafing—orientation of pigment flakes in horizontal planes.

levelling—Rowing out to films of uniform thickness; loss of brush marks in paint.

lifting—softening and raisins of an under coat by application of a top coat.

linings—internal barriers; linings may be coated or sheet type.

livering—curds or gelling formation.

long oil—a resin having a large quantity of oil cooked per 100 pounds of resin *(25 gallons or more per 100 pounds of resin)*.

loose flake *(mill scale)*—thin, easily—removed scale.

low boiling solvent—a solvent with an initial boiling point below 302°F (150°C).

low pressure spraying—conventional air spraying.

M

MAC *(maximum allowable concentration)*—maximum allowable concentration in parts of solvent vapor to one million parts of air in which a worker can work not more than eight consecutive hours without an air fed mask; the lower the MAC number, the more toxic the solvent.

MEK—*see methyl ethyl ketone.*

MEK—*see methyl isobutyl ketone.*

MVT—*see moisture vapor transmission.*

maintenance painting—(1) repair painting any painting after the initial paint job in a broader sense it includes painting of items installed on maintenance; (2) all painting except that done solely for aesthetics.

maleic resins—a class of resins obtained from polymerization of maleic acid or maleic anhydride with alcohols; rosins; etc.

mandrel test—a physical bending test for adhesion and flexibility.

masking—covering areas not to be painted.

mass tone—base covering.

mastic—a heavy-bodied coating of high build.

melamine resins—synthetic resins which are condensate products of formaldehyde and melamine, they require baking.

metallizing—mechanical deposition of one metal on another.

methyl ethyl ketone *(MEK)*—a strong solvent.

methyl isobutyl ketone *(MIBK)*—a strong solvent.

Mikrotest Gauge—a proprietary single magnet dry film thickness gauge.

mil—one one-thousandth of an inch, .001".

milage—coverage rate; square feet per gallon at a given thickness.

mild steel—structural steel, SAE 1020.

mildew—fungus.

mildewcide—substance poisonous to mildew: prevents or retards growth of mildew.

***mill scale**—oxide layer formed on steel by hot rolling.

mill scale binder—gray oxide layer between mill scale and steel.

mill white—one-coat, high-hiding power interior paint.

mineral spirits—aliphatic solvent with solvency similar to turpentine.

miscible—capable of mixing or blending uniformly.

misses—holidays, skips, voids.

mist—coat-thin tack coat; thin adhesive coat.

moisture and oil separator—trap on air compressor or in air lines.

moisture vapor transmission *(MVT)*—moisture vapor transmission rate through a membrane: also see perm.

monomer—composed of simple molecules; a basic chemical used to make polymers.

mopping—swabbing, as with roofing asphalt.

mottling—speckling; an uneven color on paint.

mud-cracking—irregular cracking, dried mud puddle.

multicolor finishes—speckled finishes, paints containing flecks of colors different from the base color.

N

NACE No. 1 White Metal Blast Cleaned Surface Finish[2]—this finish is defined as a surface with a gray-white, uniform metallic color, slightly roughened to form a suitable anchor pattern for coatings: this surface shall be free of all oil, grease dirt, visible mill scale rust, corrosion products, oxides, paint or any other foreign matter; the surface shall have a color characteristic of the abrasive media used: photographic or other visual standards of surface preparation may be used to further define the surface.

NACE No. 2 Near White Blast Cleaned Surface Finish[2]—this finish is defined as one from which all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter have been removed from the surface except for very light shadows, very slight streaks or slight discolorations, at least 95% of the surface shall have the appearance of a surface blast cleaned to a white metal surface finish and the remainder shall be limited to the light discoloration mentioned above, photographic or other visual standards of surface preparation may be used to modify or further define the surface.

NACE No. 3 Commercial Blast Cleaned Surface Finish[2]—this finish is defined as one from which all oil, grease, dirt, rust scale, and foreign matter have been completely removed from the surface and all rust, mill scale, and old

paint have been completely removed except for slight shadows, streaks, or discolorations, if the surface is pitted, slight residues of rust or paint may be found in the bottom of pits, at least two—thirds of the surface area shall be free of all visible residues and the remainder shall be limited to light discoloration, slight staining or light residues mentioned above: photographic or other visual standards may be used to further define the surface.

NACE No. 4 Brush-Off Blast Cleaned Sur face Finish[2]—this finish is defined as one from which oil grease dirt rust scale loose mill scale, loose rust, and loose paint' or coatings are removed completely, but light mill scale and tightly adhered rust, paint and coatings are permitted to remain provided they have been exposed to the abrasive blast pattern sufficiently to expose numerous flecks of the underlying metal fairly uniformly distributed over the entire surface; photographic or other visual standards of surface preparation may be used to further define the surface.

Naphtha—an aliphatic solvent cut; hydro carbons of the $C_nH_{2n}+2$ series.

near-white blast cleaning—*see NACE No. 2 in this alphabetical listing.*

needle *(spray gun)*—fluid metering pin.

neoprene—a rubber-like film former; a type of elastomers based on polymers of 2 chloro-butadiene-l, 3.

nondrying oil—one which will not harden in air.

nonferrous—containing no iron.

nonflammable—incombustible.

nontoxic—not poisonous.

nonvolatile—solid: non-evaporating; the portion of a paint left after the solvent evaporates.

nozzle—orifice; sandblast nozzle; spray gun nozzle.

nylon resins—a particular group of film formers having recurring amide groups: CONH, as an integral part of the main polymer chain; polyamide resins.

O

oil absorption—a measure of the ability of pigments to absorb oil.

oil color—coloring *(pigment or dye)* dispersed in oil.

oil length—gallons of oil reacted with 100 pounds of resin.

oleoresinous—film former containing oil and resin.

opacity—hiding power.

orange peel—dimpled appearance of dried film: resembling orange peel.

organic—containing carbon.

organosol—film former containing resin plasticizer and solvent; colloidal dispersion of a resin in plasticizer containing more than 5% volatile content.

orifice—opening; hole.

osmosis—transfer of liquid through a paint film or other membrane.

osmotic blistering—formation of blisters containing liquid.

overatomize—dispersed too finely by use of excessive atomizing air pressure.

overcoat—second coat top coat.

overlap—portion *(width)* of fresh paint covered by next layer.

overspray—sprayed paint which did not hit target, waste.

***oxidation**—combination with oxygen; drying; burning; rusting.

oxide—chemical compound of an element, usually a metal, with oxygen.

P

PVA—see polyvinyl acetate.

PVC—see pigment volume concentration or polyvinyl chloride.

paint heater—device for lowering viscosity of paint by heating.

paint program—comprehensive painting plan. *(see NACE Task Group T-6D-3 Report "Industrial Maintenance Painting Program"[3]).*

paint project—single paint job.

paint system—the complete number and type of coats comprising a paint job. In a broader sense, surface preparation, pretreatments, dry film thickness, and manner of application are included in the definition of a paint system.

particle size distribution—percentages of particles of different screen sizes.

pass *(spray)*—motion of the spray gun in one direction only.

***passivation**—act of making inert or unreactive.

pattern length—spray pattern height.

pattern width—width of spray pattern at vertical center.

peeling—failure in which paint curls from substrate.

perm—a unit for expressing MVT rate; a perm-inch = 1 grain of water per hour per square foot per one inch thickness (except where otherwise noted) per one inch difference in mercury vapor pressure on each side of membrane.

permeability—quality or state of being permeable.

phenolic resins—particular group of film formers, phenol—formaldehyde type.

phosphatize—form a thin inert phosphate coating on surface usually by treatment with H_3PO_4 (phosphoric acid).

phthalic resins—a particular group of film formers, alkyds.

pH value—measure of acidity or alkalinity; pH 7 is neutral, the pH value of acids ranges from 1 to 7, and of alkalis (bases) from 7 to, and including, 14.

***pickling**—a dipping process for cleaning steel and other metals; the pickling agent is usually an acid.

pig—*see air manifold.*

pigment grind—dispersion of pigment in a liquid vehicle.

pigments—solid coloring agents.

pigment volume concentration *(pvc)*—percent by volume occupied by pigment in dried film.

pig tail—finger-like spray pattern.

***pitting**—formation of small, usually shallow depressions or cavities.

pin-holing—formation of small holes through the entire thickness of coating; see cratering.

plasticizer—a paint ingredient which imparts flexibility.

plastisol—film former containing resin and plasticizer with no solvents.

pock marks—pits: craters.

pole-gun—spray gun equipped with an extension tube.

polymerization—formation of large molecules from small ones.

polymer—the product of polymerization; large molecules.

polyvinyl acetate *(PVA)*—a synthetic resin used extensively in emulsion *(water)* paints; produced by the polymerization of vinyl acetate.

polyvinyl chloride *(PVC)*—a synthetic resin used in solvent type coatings and fluid bed coatings, produced by the polymerization of vinyl chloride, PVC is also used in emulsion *(water)* paints..

polyvinyl chloride acetate—a combination of PVA and PVC used in coatings.

porosity—hole; degree of integrity or continuity.

pot-life—time interval after mixing during which liquid material is usable with no difficulty.

precipitation—settling out of solid material.

pressure balance—in spray painting, relationship of pot pressure to atomizing air pressure.

pressure drop—loss in pressure due usually to length or size of line or hose.

pressure feed—fluid flow caused by application of air or hydraulic pressure on paint.

pressure feed paint tank *(pressure pot)*—fluid container in which fluid flow is caused by air pressure.

preventive maintenance painting—spot repair painting; touch up or full coats of paint before rusting starts.

prime coat—first coat.

primer—material used for prime coat.

production rate *(sq. ft./day)*—measurement of surface area cleaned or coated in one working day by one man.

profile—surface contour as viewed from edge.

profile depth—average distance between tops of peaks and bottom of valleys on the surface.

proprietary—available on open market under brand name.

protective life—interval of time during which a paint system protects substrate from deterioration.

pulsation—surging.

pump bypass—recirculating line which returns fluid to container.

pump ratio—multiplier of input pressure which indicates output pressure: ratio of air piston area to fluid piston area.

Q

quick release fittings—snap-lock fittings.

R

reaching *(spray gun)*—extending spray stroke too far.

rebound—paint spray deposit bounced back.

recoat time—time interval required between application of successive coats.

red label goods—flammable or explosive materials with flash points below 302°F (26.7°C).

reducer—a material which lowers viscosity but is not necessarily a solvent for the particular film former; thinner.

reflectance—degree of light reflection.

repainting—repetition of a complete painting operation including surface preparation.

resin—a material, natural or synthetic contained in varnishes, lacquers, and paints; the film former.

respirator—safety breathing mask.

reticulation—a surface defect of net-like appearance.

rise—height.

roller coating—the act of, or the material, applied with a roller.

round pattern—circular spray pattern.

runs—curtains, sags.

***rust**—corroded iron: red iron-oxide; also other metal oxides formed by corrosion.

rust bloom—discoloration indicating the beginning of rusting.

S

SSPC—Steel Structures Painting Council.

safety valve—pressure release valve preset to safe operating limit.

sags—runs.

salt spray—a salt fog test environment.

sandblast—blast cleaning using sand as an abrasive; for different grades of blast cleaning finishes *see NACE No. 1, NACE No. 2, NACE No. 3, and NACE No. 4 blast cleaned finishes in this alphabetical listing.*

sandy finish—a surface having the appearance of sandpaper overspray.

saturant—that substance, usually a liquid, which saturates something else.

saturated—holding the maximum amount of saturant it is capable of holding.

scale—laminar rust.

scaler—a hand cleaning chisel.

***scaling**—process of delamination.

sealer—a low viscosity (thin) liquid applied before priming wood or masonry.

seeding—formation of small agglomerates.

separation—division into components or layers by natural causes.

settling—caking; sediment.

shade—degree of gray tone in a color.

shelf life—maximum interval in which a material may be stored in usable condition.

shellac—a resin secreted by insects, a lacquer; resin in alcohol.

shielding—protecting; protective cover against mechanical damage.

shop coat *(prime, see NACE Task Group T-6D-3 report on "Industrial Maintenance Painting Program")*—first coat applied in fabricating shop.

short oil—a varnish prepared by cooking a relatively small quantity of oil with 100 pounds of resin, quick drying; brittle, less than 25 gallons of oil per 100 pounds of resin.

shot blasting—blast cleaning using steel shot as the abrasive.

shrinkage—decrease in volume on drying.

silicate paints—those employing silicates as binders.

silicone resins—a particular group of film formers; used in water proof and high temperature paints; organosiloxane polymers: semi-organic polymers containing silicon.

silking—a surface defect characterized by parallel hairlike striations in coated films.

skinning—formation of a solid membrane on top of a liquid.

skips—holidays ; misses; uncoated area; voids.

slow drying—requiring 24 hours or longer before recoating.

slug—surge of material; blob.

solid—non-volatile portion of paint.

solids volume—percentage of total volume occupied by non-volatiles.

solubility—degree to which a substance may be dissolved.

solution—a liquid in which a substance is dissolved.

solvency—measure of ability to act as solvent.

solvent—a liquid in which another substance may be dissolved.

solvent balance—ratio of amounts of different solvents in a mixture of solvents. solvent pop—blistering caused by entrapped solvent.

solvent power—see solvency.

solvent release—ability to permit solvents to evaporate.

solvent wash—cleaning with solvent.

***spalling**—the cracking, breaking or splintering of materials, usually due to heat.

spark testing—detection of holidays (flaws) using electric spark.

spark-proof tools—bronze beryllium tools.

specific gravity—ratio of weight of a given volume to weight of an equal volume of water at the same temperature.

specular gloss—mirror-like reflectance.

spewing—irregular or intermittent surging with liquid spillage.

Spider *(power staging)*—a proprietary mechanical boat swain's chair or platform.

spit—sputter.

spot repair—preventive maintenance; repainting of small areas.

spray cap—front enclosure of spray gun equipped with atomizing air holes.

spray head—combination of needle, tip and air cap.

spray pattern—configuration of spray, gun held steady.

spreading rate—coverage, milage, usually at specified dry thickness.

sputtering flow—spitting, surging.

squeegee—rigid bar applicator.

static wire—ground wire.

steam clean—a cleaning process using live steam.

strain—to filter.

streaks—a surface defect characterized by essentially parallel lines of different colors or shades.

striping—edge painting prior to priming.

stroke *(spray)*—a single pass in one direction.

styrene-butadiene—resin; copolymer of styrene and butadiene.

substrate—surface to be painted.

suction feed *(sandblaster)*—one in which the abrasive is siphoned to the nozzle.

suction feed *(spray gun)*—one in which the fluid Is siphoned to the spray head.

surface tension—cohesive force on liquid surface.

surfacer—a paint used to smooth the surface before finish coats are applied.

surge—see spewing; noncontinuous flow.

surge chamber *(airless spray)*—a device to eliminate uneven fluid flow.

sweating—condensing moisture on a surface.

swelling—increasing in volume.

swivel fitting—one capable of being moved in any direction.

swivel head—spray head adjustable to deliver spray in many directions.

synthetic—manufactured; not occuring naturally.

T

tack—degree of stickiness.

tail *(solvent evaporation)*—highest boiling solvent fraction.

tail line—short piece of blast hose smaller than the main hose to permit better maneuverability.

tails *(airless spray)*—finger-like spray pattern.

tank whites—good hiding, self cleaning white paints; usually alkyds.

tapered pattern—elliptical shaped spray pattern; a spray pattern with converging.

tape test—a particular type of adhesion tenacity—ability to stick together, cohesiveness; adhesiveness.

tensile strength—resistance to elongation the greatest longitudinal stress a sub stance can bear without rupture or remaining permanently elongated.

terpene resins—a particular group of film formers, prepared from isomeric hydrocarbons such as turpentine or similar oleoresins.

test pattern—spray pattern used in adjusting spray gun.

thermoplastic—mobile or softens under heat.

thermosetting—becomes rigid under heat and cannot be remelted.

thinners—volatile organic liquids for reducing viscosity; solvents.

thixotropic—false-bodied, a gel which liquefies with agitation but gels again on standing.

Tinsley Gauge—a proprietary pencil-like single magnet, dry film thickness gauge.

tint—degree of white in a color; a color produced by the mixture of white paint or pigment with a non-white colored paint or pigment.

toner—a color modifier.

tooth—profile; mechanical anchorage; sur face roughness.

top coating—finish coat.

touch-up painting—spot repair painting usually conducted a few months after initial painting.

toxic—poisonous.

toxicity—degree of poisonous or harmfulness.

transition primer *(block or barrier coat)*—coating compatible with primer and also with a finish coat which is not compatible with primer.

trigger—operating lever of spray gun.

triggering—intermittent squeezing and releasing of trigger.

tubercule—nodule; pimple.

two-component gun—one having two separate fluid sources leading to spray head.

U

underatomized—not dispersed or broken up fine enough.

unit cost—cost per given area.

urea resins—a particular group of film formers; (amino resins).

urea formaldehyde—a particular group of film formers; usually re-

quires baking; produced by reacting urea with formaldehyde.

urea melamine—see melamine.

urethane resins—a particular group of film formers; isocyanate resins.

V

VM&P naptha—varnish and paint manufacturers naptha, an aliphatic solvent.

vapor degreasing—a cleaning process utilizing condensing solvent as the cleaning agent.

vaporization—conversion from liquid or solid to a gaseous state, phase change

varnish—liquid composition of oil, resin; thinners and driers, which is converted to a transparent or translucent solid film after application as a thin layer or coat.

vehicle—liquid carrier; binder; anything dissolved in the liquid portion of a paint is a part of the vehicle.

veiling—curtaining, sagging.

venturi—a tube having a restriction to promote velocity increase.

vertical pattern—a spray pattern whose longest dimension is vertical.

vinyl acetate—a particular resin monomer: obtained by reaction of acetylene and acetic acid; see PVA, polyvinyl acetate.

vinyl choride—a particular resin monomer: obtained by reaction of acetylene and hydrochloric acid, cracking of ethylene dichloride, or reaction of ethylene dichloride and caustic soda; see PVC, polyvinyl chloride.

vinyl coating—one in which the major portion of binder is of the vinyl resin family.

vinyl copolymer—resins produced by copolymerizing vinyl acetate and vinyl chloride.

vinyl resins—a particular group of film formers, see PVA and PVC.

viscosity—a measure of fluidity.

viscosity cup—a device for measuring viscosity.

voids—holidays, holes, skips.

volatiles—fluids which evaporate rapidly.

volatile content—percentage of materials which evaporate.

W

washing—erosion of a paint film after rapid chalking.

wash primer—a thin inhibiting paint usually chromate pigmented with a polyvinyl butyrate binder.

water blasting—blast cleaning using high velocity water.

water spotting—a surface defect caused by water droplets.

weatherometer—a testing device intended to simulate atmospheric weathering.

weld joints—beads of weld joining two members.

weld slag—amorphous deposits formed during welding.

weld spatter—beads of metal left adjoining a weld.

weld splatter—see weld spatter.

wet edge—fluid boundary.

wet film gauge—device for measuring wet film thickness.

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

wet spray—spraying so that surface is covered with paint that has not started to dry.

wetting strength—the maximum distance or penetration the vehicle is capable of livering the paint or coating assembly in a vertical or horizontal direction on a specific substrate.

wetting time—the time required for a vehicle to reach the end point of distance and penetration on a metal.

whipping *(spray gun)*—arcing, waving.

whip blast—*see NACE No. 4 in this alphabetical listing.*

whip line—*see tail line.*

white blast—*see NACE No. 1 in this alphabetical listing.*

whiting—Paris white, gliders white, fine ground, naturally occurring calcium carbonate, $CaCO_3$, about 98% pure. Used as an inexpensive filler and extender.

wicking—absorption of liquid by capillary action.

wire brush—a hand cleaning tool comprised of bundles of wires; also the act of cleaning a surface with a wire brush including power brushes.

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

wrist action *(spraygun)*—swiveling of wrist without arcing forearm.

Y

yellowing—development of yellow color or cast, in whites, on aging.

zinc phosphate coating—a thin, inorganic deposit formed on zinc treated with phosphoric acid.

zinc silicate—inorganic zinc coating.

zinc yellow—zinc chromate.

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