



Coating Inspector Program

Level 1

Student Manual

December 2007
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**Your CIP Level 1
Instructors are:**

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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



CIP Level 1 Manual Table of Contents

General Information

Course Outline

Chapter 1.1 Introduction, Welcome, Overview

Introduction.....	1
Objectives	1
Coating Inspector Program	2
CIP Level 1 – Mission Statement	3
CIP Level 2 – Mission Statement	4
Peer Review – Mission Statement	6
Level 1 – Objectives	6
NACE Policy – Use of Registration Number and Title	7
Update and Renewal Program	8
Level 1 – Overview.....	9
Lecture Sessions.....	9
Hands-On Practical Labs	10
Examinations.....	11
Introductions	13
Team Formation Exercise	13
Coating Inspector’s Job.....	16
The Inspector’s Role	17
Disclaimer	18

Chapter 1.2 Corrosion and Corrosion Control

Corrosion and Corrosion Control.....	1
Definition	1
Elements of a Corrosion Cell.....	3
Electrolyte	4
Anode	5



Metallic Pathway	5
Cathode	5
Corrosion on Steel Structures	6
Corrosion Products.....	6
Corrosion Cells	7
The Effects of Environmental Factors on Corrosion	8
Environments and Corrosion	9
The Effects of Corrosion.....	12
Safety	12
Cost	12
Appearance	13
Corrosion Control	13
Design	14
Inhibitors.....	14
Materials Selection.....	15
Cathodic Protection.....	16
Protective Coatings	17
Alteration of the Environment	18

Chapter 1.3 Coatings

Coatings Introduction.....	1
Liquid-Applied Coatings	1
Coating Terms.....	1
Coating Definition	1
Classification of Coatings	2
Coating Components.....	2
Pigment	2
Vehicle	3
Functions of Pigments	3
Pigment Shapes.....	4
Composition of Vehicle	6
Binder Resin.....	6
Solvents.....	7
Characteristics of Solvents.....	9
Evaporation Rate.....	9
Aliphatic Hydrocarbon Solvents.....	11
Aromatic Hydrocarbon Solvents.....	11
Ketone Solvents	12
Ester Solvents.....	12
Alcohol Solvents.....	13
Alcohol Ethers/Glycol Ethers	14
Miscellaneous Solvents.....	15
Solution Kickout	15
United States Regulations on Volatile Organic Compounds (VOCs)	16

Solvent Safety	17
Fire Hazards – Flash Point.....	17
Health Hazards.....	17
Additives	18
Curing Mechanism.....	19
Introduction.....	19
Types of Cured Coatings	20

Chapter 1.4 Coating and the Inspector

Coatings and the Inspector.....	1
Inspection Issues	1
Surface Preparation.....	2
Mixing and Thinning	2
Coating Application.....	5
Inspection of Plural-component Coatings.....	6

Chapter 1.5 Coating Specification

The Coating Specification.....	1
Coating Specification Definition	1
The Coating Specification and the Coating Inspector	3
Elements of a Typical Coating Specification.....	4
Scope of Work	5
Inspector's Responsibilities Regarding the Job Site.....	6
Terms and Definitions.....	7
Reference Standards.....	8
Inspector's Responsibilities Regarding Standards and Codes	8
Safety	9
Inspector's Responsibility Regarding Safety.....	10
Safety Checklist	11
Pre-Job Conference	17
Inspector's Responsibilities Regarding Pre-Job Conference	18
Surface Preparation.....	18
Inspector's Responsibilities Regarding Surface Preparation.....	20
Coating Materials.....	21
Inspector's Responsibilities Regarding Coating Materials.....	22
Sampling Coatings	23
Inspector's Responsibilities Regarding Sampling of Coatings.....	23
Coating Schedule	24
Workmanship	24
Inspector's Responsibilities Regarding Workmanship.....	25
Application.....	25
Inspector's Responsibilities Regarding Application.....	26
Work Schedule.....	27
Inspector's Responsibilities Regarding Work Schedule.....	28



Repair and Remedial Coating Work	28
Inspector's Responsibilities Regarding Coating Repair and Remedial Work	29
Inspection	29
Inspector's Responsibilities Regarding Inspection	30
Documentation	31

Chapter 1.6 Teamwork and Subarctic Survival Exercise

Human Relations	1
Bad News	1
Defensive Behavior	2
Conflict	3
Improving Listening Skills	5
Subarctic Survival Situation	6
Effective Groups	7
Characteristics of Effective Groups	7
Achieving Consensus	8
Team Exercise	8
Expert Analysis	10
Team Evaluation vs. Expert Analysis	10
Summary	11

Chapter 1.7 Self-Study Questions

Self-Study Questions	1
----------------------------	---

Practical Math Assignment

Practical Math Assignment	1
English/Metric Conversion	1
Sample conversion:	2
Calculating Percentages	3
Averaging	6
Calculating WFT from DFT	10
Spreading Rate or Coverage	14
Answers	18

Chapter 2.1 Environmental Test Instruments

Environmental Testing	1
Environmental Conditions Affecting the Coating Job	1
Test Instruments	1
Surface Temperature	2
Ambient Conditions	4
Sling Psychrometer	5
Electronic Hygrometers	7
Psychrometric Tables	7
Ambient Conditions - Wind Effects	9

Airborne Contaminants	10
Sample Collection	14
Testing Liquid Samples	15
Soluble Salts in Specifications	17

Chapter 2.2 Inspection Procedures

Inspection Procedures	1
Sample Inspection	1
Inspection Procedures Summary	4
Inspection Procedure Checklist	5

Chapter 2.3 Practice Piece Specification

Coating Specification ARC-CS2	1
1.0 General scope	1
2.0 Terms and definitions	2
3.0 Reference standards	2
4.0 Safety	3
5.0 Pre-job conference	4
6.0 Coating materials	4
7.0 Surface preparation	4
8.0 Coating application	5
9.0 Sampling coatings	6
10.0 Workmanship	6
11.0 Work schedule	6
12.0 Repair and remedial coating work	7
13.0 Documentation	7
14.0 Inspection and reporting	7
Environmental Conditions	8
Surface	8
Coating	8
Equipment and Air Supply	8
Abrasive	8
Inspection Procedure	8

Chapter 2.4 Documentation

Inspection Documentation	1
Inspector's Logbook or Daily Report	2
Daily Reports	3
Other Routine Reports	4
Materials Inventory Reports	5
Instrument Calibration History Reports	5
Weekly Reports	5
Report Formats	6
Coating Inspector's Logbook	7

Basic Principles.....	7
Specification Review	8
Pre-Job Meeting Minutes.....	8
Technical Facts of the Project Specification.....	9
Scope of Work	10
Safety Data.....	10
Coating Inspector's Checklist	10
Inspection Details.....	11
Ambient Conditions	11
Pre-Cleaning	11
Initial Preparation.....	12
Surface Preparation.....	12
Measurement of Anchor Profile.....	12
Coating Application.....	12
Dry-Film Thickness Measurements.....	13
Holiday Detection	13
Final Inspection.....	13
Nonconformance Report.....	13
Daily Report Form (sample, typical)	15
International Maritime Organization (IMO) Forms for Ballast Tank Inspection.....	16

Chapter 2.5 Pre-Job Conference

Pre-Job Conference.....	1
Working with the Team	4

Chapter 2.6 Surface Preparation

Surface Preparation Overview	1
Design Defects	3
Steel Surface Defects	11
Fabrication Defects	13
Imperfect Welds.....	14
Conditions of Steel Surfaces.....	18
Surface Preparation Methods.....	20
Surface Preparation Standards	20
Metal Surfaces for Painting	21
New or Unpainted Steel Surfaces	22
Mill Scale	22
Corroded Steel Surfaces.....	23
Corroded Galvanized or Zinc-Coated Surfaces	23
Corroded Aluminum Surfaces	24
Coatings Selection	25
Solvent Cleaning.....	25
Manual or Hand Tool Cleaning	29
Power Tool Cleaning	32

Rotary Wire Brushes	33
Impact Tools	33
Rotary Scalers	36
Grinders and Sanders	36
Disc Sanders.....	37
Vacuum Connections	37
Power Tool Cleaning to Bare Metal SSPC-SP 11	38

Chapter 2.7 Case Study 1-A

Case Study I-A Ethics.....	1
----------------------------	---

Chapter 2.8 Environmental Instruments Practice Lab

Environmental Test Instruments (Practice Lab)	1
Measuring Humidity and Determining Dew Point	2
Procedure	2
Environmental Instrument Test Lab Data.....	4
Station 1: Environmental Test Equipment.....	5

Chapter 2.9 Surface Preparation

Surface Preparation.....	1
Blast Cleaning	1
Blast Cleaning Equipment	3
Direct-Pressure Unit.....	3
Vacuum Unit.....	4
Suction Unit	4
Jet-Feed System	4
Blast Cleaning Cabinets.....	5
Centrifugal Blast	6
Manual Blasting Technique	7
Hoses.....	8
Air Supply Hose.....	8
Blast Abrasive Hose.....	8
Couplings	9
Blast Pot Care and Safety	10
Air Compressors and Equipment Used for Surface Preparation	11
Essential Compressor Accessories.....	14
Blotter Test.....	15
Blast Cleaning Nozzles and Nozzle Pressure	16
Air and Abrasive Hoses	21
Productivity	22
Abrasives.....	24
Chilled Iron Grit or Shot	25
Crushed Slags.....	26
Ceramic Grit (Aluminum Oxides and Silicon Carbides).....	27

Shot	28
Abrasives Checks.....	28
Abrasive Sieve Analysis	30
Types of Abrasives	32
Other Abrasives	36
Abrasive Selection	37
Abrasive Recycling.....	37
Abrasive Test Summary.....	38
Safety	43
Blast Pot and Accessories	44
Safety Summary.....	46
Surface Profile	47
Surface Cleanliness	53
Surface Cleanliness Standards	54
Effect of Environment on Abrasive Blasting Operations	55
Dehumidifiers	57
Inspection of Surface Cleanliness	59
Water Blast Cleaning	62
Waterjetting and Water Blasting.....	63
Inhibitors	64
Waterjetting.....	65
Low-Pressure Water Cleaning	66
High-Pressure Water Cleaning	67
High-Pressure Waterjetting.....	67
Ultrahigh-Pressure Waterjetting	67
Grit Blast with Water Shroud	69
Sand-Injected Water Blast	70
Slurry Blasting with Water/Abrasive Mix	71
Moisture-Tolerant Coatings.....	71
Waterjetting Summary	71

Chapter 2.10 Self-Study Questions

Self-Study Questions	1
----------------------------	---

Chapter 3.1 Coating Application by Brush, Roller, and Mitt

Coating Application by Brush, Roller, and Mitt.....	1
Application Methods.....	1
Brush Application	3
Paint Mitts	7
Roller Application.....	8
Finish Coat Appearance.....	10

Chapter 3.2 Coating Application by Conventional Spray

Coating Application by Conventional Spray	1
Conventional Air Spray	2
Airless Spray	3
Spray Safety Overview	4
Conventional Spray Equipment	9
Conventional Air Spray - Air Control Equipment	9
Conventional Air Spray Equipment Overview	12
Internal vs. External Mix	23
Paint Application Problems	27

Chapter 3.3 Coating Application by Airless Spray

Coating Application by Airless Spray	1
Airless Spray Safety	4
Airless Spray Equipment	6
Airless Spray Guns	9
Spray Techniques	16
Paint Mixing	19
Applying the Coating	21
Paint Application: Quality Control	24
Spray Application: The Coating Inspector's Task	32

Chapter 3.4 Nondestructive Test Instruments

Destructive Test Instruments	1
Nondestructive Test Instruments	2
Wet-Film Thickness Gauge	2
Magnetic Pull-Off DFT Gauge	12
Pencil Pull-Off (SSPC-PA 2 Type 1B)	15
Constant-Pressure Probe DFT Gauge	15
Calibration	16
Calibration Procedure Using NIST Standards	16
NIST Calibration Standards	17
Calibration Using Nonmagnetic Shims	18
Pinhole and Holiday Detection	20
Low-Voltage (Wet-Sponge) Holiday Detector	21
High-Voltage Pulse-Type DC Holiday Detector	24
High-Voltage AC Holiday Detector	27

Chapter 3.5 Instrument Practice Lab

Instrument Practice Lab	1
Station 2: Anchor Pattern Comparators and Replica Tape	3
Station 3: High-Voltage DC Holiday Detector	5
Station 4: Coating Thickness-Magnetic Pull-Off Gauge (Type 1)	6
Station 5: Wet-Sponge Low-Voltage Holiday Detector	7



Station 6: Coating Thickness—Electromagnetic Gauge.....	8
Station 7: Surface Cleanliness	9
Station 8: Wet-Film Thickness Gauge.....	10

Chapter 4.1 Field Practice Lab

Field Practice Lab	1
Lab Safety Orientation.....	1
Pre-Job Conference.....	3
Coating Schedule	3
Pre-Inspection	3
Pre-Cleaning	3
Cleaning	3
Application.....	3
Materials	4
Inspection and Documentation	4
Lab Site Work Sequence and Procedures	4
Lab Site Work Sequence.....	5

Chapter 4.2 Case Study 1-B

Case Study 1-B DFT Measurements.....	1
Discussion Question.....	3

Chapter 4.3 Self-Study Questions

Self-Study Questions	1
----------------------------	---

Chapter 5.1 Surface Preparation

Surface Preparation Standards	1
General Conditions of Steel Surfaces	3
SSPC-Vis 1	3
ISO 8501-1.....	4
Joint Surface Preparation Standards (NACE/SSPC) for Abrasive Blast Cleaning.....	5
Section 2: Definition	6
Section 3: Reference Documents	11
Section 4: Procedure before Blast Cleaning	11
Section 5: Blast Cleaning Methods and Operation	11
Section 6: Blast Cleaning Abrasives.....	12
Section 7: Procedure Following Blast Cleaning and Immediately Prior to Coating	13
Section 8: Inspection.....	13
Section 9: Safety and Environmental Requirements	14
Section 10: Comments (Non-Mandatory).....	14
Use of SSPC Visual Standards	14
SSPC-VIS 1	14
SSPC-Vis 3	17
ISO 8501-1 Visual Standards.....	23



Chapter 5.2 Material Safety Data Sheets & Technical Sheets

Material Safety Data Sheets (MSDS) and Technical Data Sheets.....	1
Understanding the Material Safety Data Sheet (MSDS)	2
ANSI Z400.1 MSDS Sections	2
HazComm	7
Product Technical Data Sheets	8

Chapter 5.3 Case Study 1-C

Case Study 1-C Theory or Practice?.....	1
---	---

Chapter 5.4 Panel Inspection

Panel Inspection	1
------------------------	---

Chapter 5.5 Coatings Technology

Coatings Technology	1
Nonconvertible (Solvent Evaporation Cure) Coatings	1
Coalescence/Evaporation Cure Coatings	3
Polymerization Cured Coatings	4
Types of Polymerization	5
Coating Systems.....	9
Single Coat Systems	10
Multiple Coat Systems	10
Types of Primers	11
Intermediate Coats (Mid-Coats)	13
Finish Coats	14
Coating Failures	16
Failures and Their Correction	17
Premature Coating Failure	18
Selection of the Wrong Coating.....	18
Responsibilities of the Specifier	19
Poor Design or Fabrication of the Structure	21
Coating Formulation	23
Chalking.....	24
Erosion	24
Checking	25
Alligatoring.....	26
Cracking.....	27
Wrinkling	27
Bacteriological Failure.....	28
Poor Formulation	29
Improper Surface Preparation	30
Bad Application Procedures and Poor Workmanship	31
Improper Thickness	32
Pinholes.....	33

Overspray.....	35
Holidays (Discontinuities)	35
Cratering (Fisheyes).....	36
Poor Workmanship	36
Mudcracking	37
Pinpoint Rusting (or Flash Rusting)	38
Application in Adverse Conditions.....	39
Substrate Related Problems	39
Types of Substrate.....	39
New Steel.....	39
Previously Used Steel	40
Galvanized or Zinc Coated Surfaces.....	40
Aluminum or Aluminum Coated Surfaces	41
Substrate Cleaning	41
Adhesion Related Problems.....	42
Blistering.....	42
Intercoat Delamination.....	45
Undercutting	46
Adhesion Related Problems.....	46
Lack of Inspection and Quality Control.....	47
Conclusion	47

Chapter 5.6 Self-Study Questions

Self-Study Questions	1
----------------------------	---

Chapter 6.1 Case Study 1-D

Case Study 1-D	1
Specification for Razorback Petroleum Channelside Refinery Storage Tanks	4
Maxicoat High-Build Coal Tar Epoxy Data Sheet	7
Maxicoat Epoxy Primer Data Sheet.....	8
Maxicoat High-Build Epoxy Data Sheet	9
Team Discussion Questions	10

Glossary

International Maritime Organization Resolution MSC.215(82)

Work Experience Documentation Forms

Instructions for Completing the ParSCORE™ Student Enrollment Sheet/Score Sheet

1. Use a Number 2 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**
 - ✓ LAST NAME: Your last name (surname)
 - ✓ FIRST NAME: Your first name (or name by which you are called)
 - ✓ 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.

ParSCORE™ STUDENT ENROLLMENT SHEET				PASSWORD	
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WEB INSTRUCTIONS FOR ACCESSING STUDENT GRADES

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. The following are instructions for this process:

To access grades on the NACE Web site go to: www.nace.org

Choose: **Education**
Students Only
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

(Normally the last four digits of the telephone number entered on your exam form)

Click on **Search**

Prior to leaving the class, write down your course and student information in the spaces provided below:

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.

Any questions, please contact Carol Steele at carol.steele@nace.org or at 281-228-6244.

Paul Knobloch Scholarship Information

March 2007

Background

The Coating Inspector Program (CIP) Task Group of PDC voted to establish an annual honoree scholarship entitled "The Paul Knobloch Scholarship".

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.

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 or Peer Review) shall be the criterion for continuation of the scholarship. Failure to achieve a passing grade in any examination shall terminate the scholarship award.

Who May Nominate

Nominations must be submitted jointly 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 (this can include NACE CIP Instructors).

How to Obtain Nomination Forms

Forms may be obtained by the following methods:

Phone: Carmen Wisdom at +1-281-228-6233
Fax: Carmen Wisdom at +1-281-228-6333
E-mail: carmen.wisdom@nace.org



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: _____



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 e-mail to:
Join-coatings@nacecorrosionnetwork.com
2. **To Unsubscribe**, send a blank e-mail to:
Leave-coatings@nacecorrosionnetwork.com
3. You're done! You'll get an e-mail back telling you how to participate, but it's so easy that you'll figure it out without any help.

PARALLEL PATH TO CERTIFICATION FOR CORROSION TECHNOLOGIST AND SENIOR CORROSION TECHNOLOGIST

Traditionally, NACE certification has been awarded to candidates who have met work and educational requirements and have successfully completed an open book exam.

“Parallel Path” is an alternative route to achieving certification. Under the Parallel Path, NACE certification is achieved by earning credits through successful completion of specified NACE training courses.

The Parallel Path Menu has been included in the CIP Level 1 Notebook because successful completion of CIP Level 1 is one of the courses listed on the parallel path plan for Corrosion Technologist and Senior Corrosion Technologist certifications.

Technician	Technologist		Senior Corrosion Technologist		
	Option #1	Option #2	Option #1	Option #2	Option #3
Basic Corrosion	Basic Corrosion 1 from Menu A 1 from Menu B	Technician Cert 1 from Menu A 1 from Menu B	Basic Corrosion 1 from Menu A 1 from Menu B 1 additional course from Menu A or B Design for Corrosion Control Chemical Treatment Test	Technician Certification 1 from Menu A 1 from Menu B 1 additional course from Menu A or B Design for Corrosion Control Chemical Treatment Test	Technologist Certification 1 additional course from Menu A or B Design for Corrosion Control Chemical Treatment Test
					Note: You can not obtain multiple credit from a single course.

Menu A

- CP 1-Cathodic Protection Tester Class & Certification*
- CP 2-Cathodic Protection Technician Class & Certification*
- CP 3-Cathodic Protection Technologist Class & Certification
- CP 4-Cathodic Protection Specialist Class & Certification

* must meet work experience requirements

Menu B

- Basic Protective Coatings & Linings
- Advanced Protective Coatings & Linings
- Coating Inspector Program Level 1

CIP Level 1 Course Outline

DAY ONE	
Student Check-in	
Section 1.1	Introduction, Welcome, Overview
Section 1.2	Corrosion and Corrosion Control
Section 1.3	Coatings Introduction
Section 1.4	Coatings & the Inspector
Section 1.5	Coating Specification
Section 1.6	Teamwork & Subarctic Survival Exercise
Section 1.7	Self-Study Questions
Practical Math Assignment	
DAY TWO	
Section 2.1	Environmental Test Instruments
Section 2.2	Inspection Procedures
Section 2.3	Practice Piece Specification
Section 2.4	Documentation
Section 2.5	Pre-job Conference
Section 2.6	Surface Preparation Overview
Section 2.7	Case Study 1-A
Section 2.8	Environmental Instruments Practice Lab
Quiz 1	
Section 2.9	Surface Preparation
Section 2.10	Self-Study Questions
DAY THREE	
Section 3.1	Coating Application by Brush, Roller and Mitt
Section 3.2	Coating Application by Conventional Spray
Review Practical Math	
Quiz 2	



CIP Level 1 Course Outline

Section 3.3	Coating Application by Airless Spray
Section 3.4	Nondestructive Test Instruments
Section 3.5	Instrument Practice Lab
DAY FOUR	
Section 4.1	Field Practice Lab
Quiz 3	
Section 4.2	Case Study 1-B
Section 4.3	Self-Study Questions
DAY FIVE	
Section 5.1	Surface Preparation Lab
Section 5.2	Material Safety Data Sheets & Technical Data Sheets
Section 5.3	Case Study 1-C
Section 5.4	Panel Inspection
Section 5.5	Coatings Technology
Test Instrument Review	
Quiz 4	
Section 5.6	Self-Study Questions
DAY SIX	
Section 6.1	Case Study 1-D
Course Review and Exam Briefing	
FINAL WRITTEN EXAMINATION	
FINAL PRACTICAL EXAMINATION	





Level 1

Chapter 1.1

Introduction

Introduction

Hello! Welcome to the NACE International Coating Inspector Program, Level 1. By the end of today's session we will have accomplished several objectives.

Objectives

- Overview of certification program

We will present the NACE International Coating Inspector Program mission statement which will give you an idea of our overall objectives and what you can expect from this course.

- Overview of this week

We will review the outline of this week's activities.

- Introductions

We will ask each of you to introduce yourself and tell us about your job functions and your hobbies.

- Form teams

NACE believes the coating inspector's job is part of a team effort with others involved in the coating project. We will form teams reflecting a cross-section of the industries represented here today, and you will work in teams throughout the course.

- Discuss coating inspector's job

The inspector's specific job responsibilities may vary from job to job. We will identify the basic (general) duties of an inspector.

- Overview of corrosion

We will discuss *electrochemical*, or *galvanic*, corrosion and the ways that protective coatings can be used to control corrosion.

- Identify and demonstrate environmental test instruments

Ambient conditions affect coating jobs in a variety of ways. We will introduce and demonstrate instruments used to measure ambient conditions.

- Introduce protective coatings and curing mechanisms

In this review, we will define common coating terms, discuss coating components and curing mechanisms, describe the measurement of wet- and dry-film thickness, and define the inspector's tasks. We will defer a discussion of generic types of coatings and failure modes to Level 2, where we will have time to study these topics in more detail.

Let's get started with an overview of the Coating Inspector Training and Certification Program, which we will call CIP—the Coating Inspector Program.

Coating Inspector Program

The CIP is designed to accommodate the inexperienced candidate. No prior knowledge or experience is required to commence either of the two levels. A minimum of two year's work experience in coatings, whether gained prior to, during, or after attendance at the training sessions, is required before any candidate can register for the Peer Review examinations.

Upon successful completion of CIP Level 1, CIP Level 2 (which must be taken in sequence) and the Peer Review, the participant will be a ***NACE-Certified Coating Inspector—Level 3***.



Look in your student book at the NACE International CIP Mission Statements which outline in some detail what this program is all about and what you should expect to get out of the two levels.

CIP Level 1—Mission Statement

After attending CIP Level 1 participants enrolled in the NACE Coating Inspector Program (CIP) recognize the role of the independent coating inspector, and appreciate the need for quality control on coating application projects. They are able to perform the basic measurements needed to maintain quality control.

Upon successful completion of CIP Level 1, the inspector should be able to:

- Undertake simple coating inspection work on structural steel, on site, under direct supervision of a qualified (Level 3) inspector
- Read and understand a coating specification for surface preparation and coatings application
- Use inspection equipment for basic quality control, including but not limited to:
 - Sling psychrometer and weather tables (psychrometric charts)
 - Wet-film thickness (WFT) gauge
 - Hypodermic needle pressure gauge
 - Magnetic pull-off DFT (dry-film thickness) gauges
 - Electromagnetic DFT gauges
 - Low-voltage (wet-sponge) holiday detector
 - High-voltage DC holiday detector



- Understand and use surface preparation standards (NACE, SSPC, and ISO) to recognize specified surface cleanliness
- Recognize the inspector's job as part of a team effort
- Recognize the importance of pre-job meetings
- Recognize the need to determine the inspector responsibilities and authority
- Recognize the value of record keeping, and learn what information to record and how to fill out inspection reports

Upon successful completion of CIP Level 1, the inspector attains recognition as ***NACE Coating Inspector Level 1—Certified***.

[Note that recognition at the same level can be achieved by study of the CIP CD-ROM course (basic level) and successful completion of the short exam course that follows.]

CIP Level 2—Mission Statement

On completion of CIP Level 2, inspectors should be able to perform all those tasks listed for CIP Level 1 and:

- Undertake coating inspection work in a fixed coatings facility (shop)
- Use destructive coating inspection equipment, including
 - paint inspection gauge (Tooke gauge)
 - adhesion testers
 - impressor hardness tester
 - pencil hardness tester

- Use eddy current electronic gauges for DFT measurements on nonferrous surfaces
- Test for soluble chemical salt contamination (including ferrous and chloride ions)
- Recognize coating techniques used in specialized circumstances, including pipeline coatings, sheet linings, brick and tile linings, etc.
- Recognize the personality types present in most work environments and some techniques that can be used to reduce friction and improve working relationships
- Recognize the techniques and some of the problems associated with coating concrete
- Recognize some specialized coating techniques, including:
 - spray metallizing
 - hot-dip galvanizing
 - automated coatings application, including dip, roller, flood, and coil coating
- Understand the role of product technical data sheets and material safety data sheets (MSDS) in communication of coatings information
- Understand various generic types of coatings, including fireproofing, antifoulings, high-heat coatings, and temporary protectives
- Recognize common coating failure modes
- Recognize some laboratory testing methods used to establish coating performance criteria as well as evaluate coating failures
- Recognize the role of cathodic protection in corrosion prevention, particularly when used with coatings.

Upon successful completion of CIP Level 2, the inspector attains recognition as ***NACE Coating Inspector Level 2—Certified***, having completed stage 2 of NACE Coating Inspector Training.

Peer Review—Mission Statement

Inspectors must have a minimum of two year's work experience in the coating industry and successfully complete CIP Levels 1 and 2 and the Peer Review examination to attain recognition as a ***NACE-Certified Coating Inspector—Level 3***.

Level 3 Coating Inspectors have proved their technical knowledge and ability to communicate regarding practical issues that may arise on site. They are capable of supervising coating inspection technicians.

Peer Review Examinations are conducted by contemporaries of the coating inspection industry and experts in their field of work.

Level 1—Objectives

The CIP overall is an extensive training program, and Level 1 is the most intensive of the two courses. Level 1 is designed to accommodate the inexperienced candidate. The CIP recognizes that those of you who have 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 available in this course.

On successful completion of CIP Level 1, participants have demonstrated the ability to undertake simple coating inspection work under the supervision of a qualified (Level 3) inspector.



NACE Policy—Use of Logo, Certification Number, and Title

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.

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 attained), and their certification number on business cards.

This 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-Certified Coating Inspector—Level 3**.

John Smith
NACE-Certified Coating Inspector—Level 3
Cert. No. 9650
ACE Inspections, Inc., Knoxville, TN

Individuals who are NACE Coating Inspector Level 1—Certified, NACE Coating Inspector Level 2—Certified, or NACE-Certified Coating Inspector—Level 3, 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.

Update and Renewal Program

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 completed by one of two methods:

- Attendance at the next Coating Inspector Program course or Peer Review
- Completing a home study program

If you take another Coating Inspector Program within a three-year period, the date of your next required update will be three years from the date you completed the most recent course.

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 last renewal:

- 73+ points requires only work experience
- 37 to 72 points requires work documentation and completion of home study program
- 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 provided at the back of this manual.

Notification of the update or renewal process will be mailed 90 days prior to the expiration date of recognition to the address on file at NACE. The notification packets supply all the information and forms needed to begin the update or renewal process. It is important that inspectors keep addresses current with NACE at all times.



Level 1—Overview

For those inspectors wishing to become NACE-Certified Coating Inspector—Level 3, this training course is the first of two that must be attended. We will review the program for this training course.

Also, in a few minutes, we will form teams. Many of our activities are done in small groups, so we are going to divide into teams. You will stay with your team all week. From time to time, there will be team presentations during which each team will select someone from their group to present the results of a team project. We want each of you to make at least one presentation to the class.

Lecture Sessions

Throughout this week we will present lecture sessions covering many topics, including:

- Coating specification
- Coatings and curing mechanisms
- Documentation (records and reports)
- Pre-job conference
- Conflict and decision making
- Ethics for coating inspectors
- Surface preparation
- Conventional air spray and airless spray equipment and techniques
- Test equipment
- Coatings technology



Hands-On Practical Labs

We will have several hands-on practical labs where you will have a chance to get the feel of the different tools and techniques of the coating trades and develop an appreciation for what it takes to do the job right. Some of the equipment you will use on your own practice piece includes:

- Hand and power tools

Used on small jobs and maintenance projects, and in areas where abrasive blasting is not permitted or is not feasible.

- Abrasive blasting

Air is used to propel abrasives to the surface to provide optimal surface cleanliness and roughness.

- Conventional air spray

Air is used to atomize coating. This method can produce a smooth surface and a fine finish.

- Airless spray

Coating under high fluid pressure is atomized without air. Production rates with airless spray are much higher than with conventional spray

Through all this, you will hear the instructors asking a question over and over:

What does this mean to the coating inspector?

We ask this because we want to relate all technical information to the inspector's job. We will be working 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

- Sieve test for abrasives
- Ultraviolet (black) light
- Measurement of wet- and dry-film thickness

You will be required to keep good records of all the tests you perform.

Examinations

At the end of the week, there will be two final examinations: one is written; the other is a hands-on practical examination on selected test instruments.

You must pass both exams and receive a minimum of 70% on your Log Book to proceed to the next course.

The written exam is closed book and consists of multiple-choice and true/false questions. It will last 2.5 hours.

The practical exam covers the tools and techniques for inspection. You will be required to demonstrate how well you know how to perform the coating inspection tests we will be covering this week. You will be assigned tasks and required to record your results. You will be graded on the accuracy of those recorded results.

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

During the week, you will take short written quizzes, all closed book, to help you prepare for the final written exam.

You must pass both the written final exam and the practical exam with minimum grades of 70% on each and hand in your log book (written in ink and legible), which is also graded on a percentage basis with 70% minimum in order to pass Level 1.

You will receive written notification of your exam results as quickly as possible. We won't be able to tell you your results on Friday.

Test results will be mailed from NACE headquarters within two to three weeks. PLEASE DO NOT CALL NACE for results because staff are NOT ALLOWED to give out this information by telephone.

You will be responsible for:

- Your own learning
- Managing your own time



Introductions

Before we get started with technical issues, we'd like to make sure that we all learn more about each other. I would like for each of you to stand, one at a time and introduce yourself to the class. Tell us:

- Your name
- Your company's name and location
- Your job function
- Your experience in coating inspection
- Your hobbies

Team Formation Exercise

Now let's get arranged into teams.

You will be working in these teams for the rest of the week, so right now we will make a permanent shift in the seating arrangement.

Instructions: Team Exercise

You will be working with your team throughout this session on a wide variety of tasks, exercises, and assignments. Please get together with your group and do the following:

- **Team name:** Decide on a team name that represents who you are, tells how you intend to perform during the workshop, and gives your group a *personality*.
- **Reason:** Select your team name for a specific reason. That is, don't just give your team an arbitrary name. Think it through carefully. Be prepared to share your reason with the overall group upon completion of this exercise.
- **Team logo:** Create a logo or trademark for your team that graphically represents your team's name and the rationale behind the name.

- **Expectations and reservations:** As a team, develop a list of expectations and reservations about the course. Summarize the responses of your team on the flipchart.
- **Presentation summary:** On flip charts, summarize all your team's work on this exercise and prepare to deliver a five minute presentation to the entire group. Select a spokesperson to make your presentation
- **Time:** You have 20 minutes to complete your work.
- **Questions:** The instructors are available to answer any questions you have. They will circulate among the teams while you are working.



Team Response: Record the main points of your team's presentation in the spaces below:

Coating Inspector's Job

Throughout the CIP, we will talk in more detail about the coating inspector's job, but for now let's look at his or her job in general.

Coating inspectors ensure—as far as possible—that coating systems are applied according to the coating specification, and they accurately and objectively report the results of all inspection observations. If environmental, time, or other constraints make compliance with the coating specification impossible, inspectors should ensure there is clear written authority for permitting deviations from the specification.

The coating inspector's job responsibilities may vary from job to job, but general duties always include:

- Obtain, read, and fully understand the coating specification. Bring up any questions with the appropriate person, and get them resolved.
- Obtain a clear definition of the authority delegated by the supervisor nominated by the coating specification, particularly with respect to the control of contractors working on the project.
- Determine by measurement and observation that the applicator fully complies with specification requirements and that work performed matches the required standard of quality.
- Determine that all essential raw materials, especially coatings, are stored correctly and used in batches within the manufacturer's recommended shelf life.
- Maintain records of all work done, the conditions under which it was done, and any other appropriate report items required by the supervisor.
- Avoid directing the work of a contractor's employees.

- Determine that all items listed in the coating schedule (or scope) have been completed.
- Ensure that the necessary test instruments and standards required are available at all times and that each instrument is fully functional and properly calibrated.
- Perform inspection duties with a fair and objective approach. Good communications and integrity are essential to performing inspection work that is beneficial to all the contractual parties in a coatings project

The Inspector's Role

For the purposes of the 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 is **NOT** considered to be part of the inspector's role.

Most projects involve a contractual agreement between the owner and the coating application company (*contractor*). Responsibility for performing work according to the specification lies with the contractor.

Inspectors are employed to help identify the quality of work performed and, specifically, to determine whether or not the work complies with the requirements of the specification. Reports prepared by inspectors for all work performed should indicate which work complies with the specified requirements and which does not.

The role of inspectors is frequently misunderstood in the coatings industry. Companies working with Certified NACE Coating Inspectors should know and understand what is expected from the inspectors. They should read and understand both the mission statements and the attestation, which between them define the inspectors' understanding of their project duties and responsibilities.

Before we proceed, we need to explore the use of the words *ensure* and/or *enforce*, which are often used in



industry and may be used in this Coating Inspection Program in defining the role of inspectors and their actions on an inspection project. These words in particular have been misinterpreted or misunderstood in the past.

Disclaimer

As an attendee of this CIP course, you are hereby advised that NACE International's view on inspection is that the function of the inspector is *to inspect and document* the functions described, always working solely within and abiding by the specifications, or according to a contract, or according to whatever document outlines his or her responsibilities and establishes the authority granted to him or her.

By properly inspecting and documenting the work being performed, and by noting that the work is being performed in accordance with a set of specifications, or by issuing a nonconformance report (NCR) on work not being performed according to that specification, and later if the NCR is resolved and duly noted, the inspector is said to *ensure an action and/or enforce a requirement*. This is the only context in which the words *ensure and enforce* are to be used.

You are advised that by fulfilling the requirements of this course, with its qualified terminology, you 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* is intended to convey any meaning of *guarantee* nor any other assumption of responsibility for the quality or execution of any work inspected and documented by the inspector.

The following table is a copy of *The Coating Inspector's Checklist*. This list gives you an idea of all the things inspectors may have to take into consideration on a coating job. By the end of CIP Level 1 we will have discussed every topic.

THE COATING INSPECTOR'S CHECKLIST	
Subject	Check Here (✓)
Specification	
• Have it	
• Read it	
• Understand it	
Pre-job Conference	
• Request one	
• Attend it	
• Participate actively	
• Know and understand safety rules	
Coating Schedule	
• Know where coating activities will take place	
Pre-inspection	
• Locate areas that will be hard to coat	
• Weld splatter	
• Weld flux	
• Skip welds	
• Rough welds	
• Sharp corners	
• Laminations	
Surface Preparation	
• Observe safety rules	
• Correct abrasive	
• Anchor pattern as specified	
• All dust removed	
• Neutral surface	
• Surface as called for in specification	
• Surface defects corrected	

• Weather suitable for abrasive blasting	
Coatings	
• Observe safety rules	
• Coatings are those specified	
• Coatings are correctly mixed and agitated	
• Coatings are correctly thinned	
• Coatings have not exceeded pot life	
Coating Application	
• Observe safety rules	
• Weather OK	
• Ambient conditions OK	
• Clean surface	
• Correct WFT	
• Correct DFT	
• No flaws	
• Runs	
• Dry spray	
• Holidays	
• Other	
• Brush over welds	
Report	
• Take all measurements required	
• Record and report as required	



Level 1

Chapter 1.2

Corrosion and

Corrosion Control

Corrosion and Corrosion Control

Many items or structures are painted primarily for decoration to change their appearance. When protective coatings are used, generally the intention is to protect the surface against corrosion. Most coatings will, of course, both protect and decorate the surface to which they are applied.

Coatings may also have specific functions such as friction-reduction (i.e., dry-film lubricant), non-skid protection for walkways, abrasion resistance, and many other specific purposes.

A basic understanding of the corrosion process will help inspectors understand why protective coatings are used and help them to apply specifications they will encounter.

Everyone has witnessed corrosion in one form or another. There are many examples of corrosion in the workplace and in everyday life.

Definition

NACE defines *corrosion* as follows:

Corrosion is the deterioration of a material, usually a metal, because of a reaction with its environment.

This definition is very broad and recognizes that materials other than steel, such as concrete, wood, and plastics, deteriorate or corrode.

For this discussion, we will be concerned primarily with electrochemical corrosion of steel and other metals used for construction.

In CIP Level 2, we investigate the corrosion of concrete and discover that the deterioration of reinforced concrete is often due to corrosion of the reinforcement (steel) bar.

Corrosion is a natural phenomenon or process that follows the laws of science, so the fact that corrosion occurs should not be a surprise to us. Almost all materials are expected to deteriorate with time when exposed to the elements. For example, when iron or steel are exposed to air and water, we can expect to see rust develop within a few hours, showing the familiar red-brown color of iron oxide. Sometimes corrosion develops within a few minutes.

If other materials, such as copper, brass, zinc, aluminum, or stainless steel, replace the iron, some degree of corrosion can be expected, but it might take longer to develop. One reason for a reduction of corrosion rate with these metals is the potential formation of protective metallic oxides of copper, zinc, aluminum, or chromium.

This oxide layer, although fairly thin, can form a protective barrier against continued attack and slow down the rate of corrosion, almost to a standstill. This natural process is known as *passivation*.

The formation of this surface layer, whether an oxide, carbonate, chloride, sulfate, or other compound, is a major factor in corrosion resistance, particularly if the surface layer effectively separates the metal from the environment.

To be effective, this naturally formed coating must be both diffusion-resistant and moisture-resistant. Unfortunately, ordinary iron or steel does not form such an effective barrier. The rust formed permits oxygen and moisture to penetrate, and the steel continues to rust. Without extra protection, the metal eventually fails.

In most cases, protective coatings are used to form artificial protective layers over the iron or steel surface and prolong its useful life.

It is generally accepted that the usual cause of corrosion of metals involves *electrochemistry*. A flow of electricity occurs from some areas of the metal surface to other

areas, through an *electrolyte*, i.e., any solution capable of conducting electricity, such as seawater, hard water, even moisture on the steel substrate. (Note that distilled or deionized water does not carry the electric current effectively and cannot act as an electrolyte.)

We refer to this corrosion process as an *electrochemical* reaction (sometimes called *galvanic* action), which is a chemical reaction involving the flow of electrical current.

Elements of a Corrosion Cell

For galvanic corrosion to occur, four essential elements must be present:

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

We can illustrate this corrosion process by looking at an ordinary dry-cell battery, which depends on galvanic corrosion to generate electrical power. Note the four elements are present.

- 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 [graphite]), which corresponds to the cathode in a corrosion cell
- A conductive wire, which corresponds to a metallic pathway in a corrosion cell



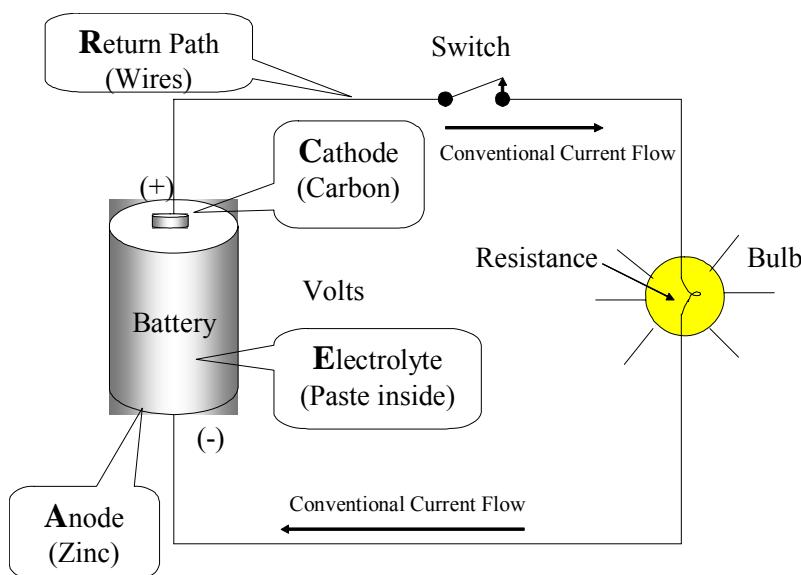


Figure 1 Dry-Cell Battery Schematic

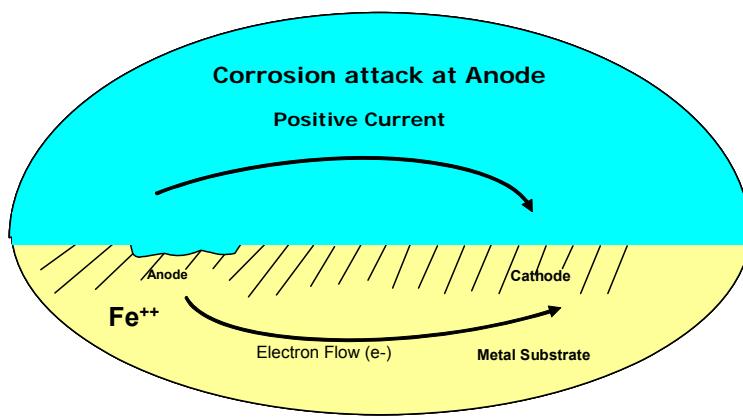


Figure 2 Corrosion Cell

Let's take a closer look at each item.

Electrolyte

The *electrolyte* is a liquid, or corrosive, medium that conducts electricity. 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.

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 left behind pass into the electrolyte and generally combine with ions in the electrolyte. Their presence at the surface of the anode results in the immediate area being negatively charged.

Metallic Pathway

In our battery example, the surplus electrons at the anode flow through the wire and light bulb to the cathode, lighting the bulb in the process.

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 was no metallic pathway, the corrosion reaction could not take place. In the battery example, current cannot flow without a continuous metal pathway (wire) joining the anode to the cathode—in this case through the bulb—and hence the battery cannot discharge current.

Cathode

The *cathode* is the less active area on the electrode (metal surface, or in this case, 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 ions 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.

Thus, the corrosion cycle is complete. If any one of the four elements of the corrosion cell is missing, corrosion will not occur.

Corrosion on Steel Structures

When a steel structure corrodes, all four elements of the corrosion cell are present.

Steel conducts electricity, so it 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.

The anodic and cathodic areas are formed by 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 the case of most other metals.

When a bare steel plate becomes wet from dew or rain, the water can act as an electrolyte. If the plate has been 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 concentration of the dissolved chemicals increases.

Salt (sodium chloride) is present in the marine environment, in produced water 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 Products

Under normal conditions, iron atoms at the anodic surfaces of steel release electrons as part of the corrosion

circuit. The electrons travel through the metallic path to the cathode. The ionizing process carries the electrons through the electrolyte back to the anode, thus completing the electrical circuit.

Atoms of metal (iron) become positive ferrous ions, which react with negative hydroxyl ions that are produced at the cathodic surfaces. The reaction (in the electrolyte) between the ferrous ions and the hydroxyl ions causes the formation of ferrous hydroxides. These, in turn, react with oxygen to form a surface layer of iron oxides (rust) on the steel surface.

Other reactions are possible, depending on the metal, the electrolyte, and other dissolved chemicals present in the electrolyte.

Corrosion Cells

The corrosion reaction can occur in an area smaller than the point of a pin. A steel surface can have many *corrosion cells* and may give the appearance of rusting uniformly over its entire surface.

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

Corrosion may be encouraged on a steel surface by the presence of *mill scale*. Mill scale can be seen on the surface of new iron and steel in the form of blue-black layers of iron oxide, some of which is 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.

This is one reason it is important to remove mill scale from steel surfaces before coatings are applied. We do not want to encourage corrosion on the surface, or to cover active corrosion cells with the coating film.

The Effects of Environmental Factors on Corrosion

High humidity, moisture, or standing water allow corrosion to occur through the creation of an electrolyte. Steel generally corrodes when submerged in water. Humid environments have higher rates of corrosion than dry environments.

The rate of corrosion can be slowed by dehumidifying the air, for example, in a confined space such as a ship's ballast tank or a storage tank.

Oxygen, like water, serves to increase 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) will generally be much slower.

In buried or immersed conditions, it may be that the electrolyte in contact with one area of the metal contains more oxygen than the electrolyte in contact with another area. The area in contact with the higher oxygen concentration will be cathodic relative to the remaining surface. An oxygen concentration cell is formed, which results in rapid corrosion.

Chemical salts can serve to increase the rate of corrosion by increasing the efficiency of the electrolyte. In parts of the country where salt (sodium chloride) is spread on the roads to melt ice, the salt, which is hygroscopic (that is, takes water out of the air), sticks to the cars or to bridge structures, and helps continue the corrosion process all year long.



Temperature—In low temperatures, the rate of corrosion drops; in higher temperatures, the rate of corrosion tends to increase.

Chemicals and gases, like hydrogen sulfide, can react with moisture in the air or on a surface to form an acidic or alkaline solution. Both acid and alkaline electrolytes will cause the rate of corrosion to increase.

Environments and Corrosion

Corrosion rates are affected by environmental influences. Several common environments recognized by corrosion control professionals are:

Chemical/marine (offshore oil rigs and ships)

This is a very severe environment resulting in very rapid rusting. Airborne salts and chemical pollutants may serve to stimulate corrosion. Humidity and seawater provide electrolytes, which also hasten the process.



Figure 3 Chemical/Marine Environment—Offshore Platform

Chemical/high-humidity (coastal oil refinery)

This environment is highly corrosive, because of gases, chemicals, and high humidity, all of which can stimulate corrosion.



Figure 4 Chemical + High-Humidity Environment—Refinery

Marine/high-humidity (splash zone platform piping)

This environment provides an active electrolyte through 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 5 Marine + High-Humidity Environment

Chemical/low-humidity (inland oil refinery)

Low humidity generally makes a less corrosive environment than high humidity. However, both gases and chemicals can stimulate corrosion.



Figure 6 Chemical + Low-Humidity Environment—Power Plant

Rural/low-humidity (inland rural railroad bridge)

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. Examples of rural low-humidity environments are rural Arizona, Wyoming, and West Texas. Other examples include desert oil facilities in Kuwait and Saudi Arabia and most dry or non-industrialized areas.



Figure 7 Rural Environment—Railway Bridge

The Effects of Corrosion

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

Safety

Corroded structures may be unsafe in a variety of ways. Bridges and buildings that must support the weight of extreme loading are obvious examples.

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.



Figure 8 Effects of Corrosion—Safety

Cost

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

Appearance

Peeling coatings and rusting steel are an eyesore in any environment. For many engineers or facility owners, appearance is a major reason for painting their structures.

For all the reasons given above, corrosion prevention is extremely important.



Figure 9 Effects of Corrosion—Appearance

Corrosion Control

Corrosion can be controlled in a variety of ways, including:

- Design
- Inhibitors
- Materials selection
- Cathodic protection
- Protective coatings
- Alteration of the environment

Design

The way a structure is designed can influence its resistance to corrosion. Generally speaking, a design which:

- Avoids entrapment of moisture, chemical salts, and dirt, and
- Allows access for coating operations

will tend to be less susceptible to corrosive attack.

We will discuss design of structures in greater detail elsewhere in the CIP.

Inhibitors

A *corrosion inhibitor* is a substance that, when added to an environment, decreases the rate of attack by that environment.

Corrosion inhibitors are commonly added in small amounts to acids, cooling waters, steam, and other environments.

Inhibitors are also used frequently in oil and gas production. They are introduced into the *downhole* tubing to isolate the walls of the tubing from salt water and other corrosives in gas, crude oil, and drilling fluids often associated with oil production. Inhibitors may also be used in production tubing, flow lines, and transmission pipelines.

A discussion of inhibitors and inhibitive mechanisms *per se* is outside the scope of this course. We will, however, talk about inhibitive coatings later in the week.



Figure 10 Corrosion Inhibitors

Materials Selection

Some metals, such as gold or platinum, corrode very slowly or not at all. Choosing a corrosion-resistant material can help reduce the rate of corrosion.

A *galvanic series* 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.

Materials Selection – Galvanic Series (Seawater at 25°C)

- | | |
|-------------------|-----------------------|
| • Magnesium | ↔ Most Active |
| • Zinc | |
| • Aluminum | |
| • Mild Steel | |
| • Cast Iron | |
| • Copper | |
| • Stainless Steel | |
| • Silver | |
| • Gold | |
| • Platinum | ↔ Least Active |

Changes in ambient conditions or temperature can affect the order of the galvanic series.

By convention, it is said that the more active metals have negative corrosion potentials, and they may sometimes be referred to as *anodic*. The less active metals may be referred to as *cathodic* or *noble*.

General rules of galvanic (dissimilar metal) corrosion are as follows:

- When dissimilar metals are connected, the most active (or anodic) metal is more rapidly corroded, while the more noble (or cathodic) metal tends to be protected and corrodes less.
- As the potential difference between these two dissimilar metals increases, the rate of galvanic corrosion increases.

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.

Cathodic Protection

Sacrificial anodes made of easily corroded metals, such as aluminum, zinc, or magnesium, are connected to the steel structure to be protected. These anodes then corrode instead of the structural steel. When the sacrificial anode is completely corroded, it needs to be replaced.

An alternate form of cathodic protection (called *impressed current*) provides an electrical current to oppose the current of the corrosion cell(s).





Figure 11 Cathodic Protection

Protective Coatings

Coatings provide protection to steel by one or a combination of three mechanisms yielding the following three coating types:

- *Sacrificial coatings*, which are rich in zinc. Whenever a scratch or other damage occurs to the zinc exposed to the steel, the zinc acts as a sacrificial anode and corrodes to protect the steel surface.
- *Barrier coatings*, which keep moisture away from the steel surface. This removes one of the elements of the corrosion cycle, the electrolyte, thus preventing corrosion.
- *Inhibitive coatings* (usually only primers) which, in addition to acting as barriers, actively assist in the control of corrosion by using pigments that can provide an inhibitive effect (similar to corrosion inhibitors). Examples include red lead¹ and zinc phosphate. These pigments react with the absorbed moisture in the coating and then react with the steel to passivate it and thus decrease its corrosive characteristics.

¹ Note that while red lead pigments are no longer widely used in the USA, they are still used in many countries and are often found in maintenance painting operations.

The protection given to steel by protective coatings can be greatly influenced by discontinuities (pores, scratches, pinholes) in the coating film.

The rate of corrosion at a discontinuity in a coating film may be affected by a number of factors, including:

- Type of coating/coating system
- Coating thickness
- Electrolyte present (if any) at the discontinuity
- Presence of adherent mill scale on substrate

We will be discussing these issues in more detail as the week progresses.

Alteration of the Environment

An atmospheric environment may be changed to make it less corrosive. A good example is the use of dehumidification equipment to dry the air in tanks that are being abrasive blasted. By reducing the relative humidity to less than 40% (10 to 15% is possible) corrosion will cease, for all practical purposes.



Figure 12 Dehumidification

We can hold the blast for many hours or days using this method, preventing flash rusting of the blasted surface. When an enclosed space can be sealed, thereby excluding oxygen, corrosion will cease once the prevailing oxygen has been exhausted.



Figure 13 Dehumidifiers and Equipment



Level 1

Chapter 1.3

Coatings Introduction

Coatings Introduction

Liquid-Applied Coatings

This course is concerned primarily with the inspection of coatings applied to a steel surface to prevent or at least slow down the process of corrosion. Most of the coatings used for this purpose have been the traditional kind, those that are supplied in liquid form, applied as liquids to the surface, and then allowed to change into a solid, protective coating film. Let's now turn our attention to these coatings so we can become familiar with some of the more common terms and concepts.

Coating Terms

Coating terms commonly used include:

- Pigment
- Binder
- Solvent
- Curing mechanism
- Coating system

Coating Definition

First, let's define *coating*.

- Coatings are clear or pigmented film-forming materials that protect the surface to which they are applied from the effects of the environment.



Classification of Coatings

Generally, a coating is classified as *organic* or *inorganic*. Most are organic.

An organic coating is one that is made from living things, such as tung tree (tung oil), castor beans (castor oil), linseed (linseed oil), fish (such as menhaden), or from things that once were living, such as coal and petroleum. These coatings all contain carbon.

An inorganic coating is based on the use of inorganic binder materials, such as sodium silicate, calcium silicate, lithium silicate, and ethyl silicate. (Ethyl silicate is organic, not inorganic, but it is frequently included in this list of binders. In the curing process of ethyl silicate zinc, ethyl alcohol is given off and the remaining zinc ferrous-silicate matrix is inorganic.)

Coating Components

Conventional coatings consist of two major components:

- Pigment
- Vehicle

Pigment

A pigment is a **discrete particulate solid** used to impart specific protective or decorative qualities to the coating.

Pigments do not dissolve in the coating; they remain solid, individual particles, whether in the liquid coating or the solid film.

The term **pigment** may also be used to describe inert fillers, such as chalk, talc, or mica, which are used to modify the film properties. In addition to the added bulk in the film, fillers may be used to adjust such properties as *gloss*, *density* or *pigment volume concentration* (PVC).

[**Note:** These properties are discussed in more detail in CIP Level 2.]

Vehicle

The *vehicle* is the liquid base of the coating consisting of *solvent*, *binder*, and any required *liquid additives*. The word *binder* generally refers to the *resin* or resin blend that provides the *film-forming portion*. Binder and pigment compose the dried coating film. Most coatings are named after the film-forming resin (binder).

Functions of Pigments

Pigments are added to coatings to:

- Provide rust-inhibiting characteristics
- Decrease the permeability of the film
- Hide the surface (opacity)
- Provide color
- Protect film from effects of ultraviolet light and weather
- Provide mechanical reinforcement for the coating film
- Perform other functions, including:
 - Self-cleaning and controlled chalking
 - Gloss control—decrease gloss and increase adhesion (bond) or tooth of subsequent coats
 - Assist in drying the coating binder
 - Provide certain desired finishes, such as metallic luster or various glosses
 - Aid in storage properties of paint
 - Increase body consistency so that thicker films may be applied



- Provide galvanic properties and allow sacrificial protection
- Improve inter-coat adhesion (increased pigment size may also improve adhesion to existing coatings)

Hundreds of different pigments are available, and the properties of the pigments vary with manufacturer, method of manufacture, and many other variables. In the United States, commercially available pigments are classified and listed by the National Paint, Varnish, and Lacquer Manufacturers Association in its Pigment Index.

While some pigments are more dangerous than others, all pigments should be regarded as hazardous and proper safety precautions should be taken to avoid ingestion or inhalation. For example, appropriate respirators should be worn when mixing zinc dust into the vehicle of an inorganic zinc-rich coating.

Pigment Shapes

The shape of pigments is an important characteristic and can influence the physical properties of the coating. Some common shapes are:

- Nodular

Nodular pigments are lump-shaped and generally add color (such as titanium dioxide) or are sacrificial (such as metallic zinc). In practice, most commonly used pigments are nodular.

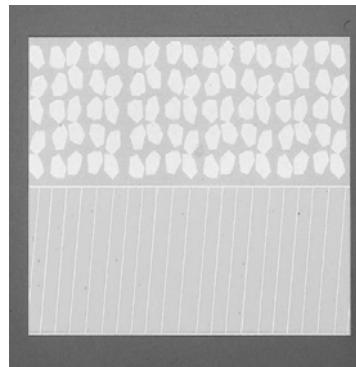


Figure 1 Nodular Pigments

- Acicular (needle-shaped)

Acicular pigments, such as zinc oxide or glass fibers, are used to reinforce and strengthen the coating film as well as provide color.

In the past, asbestos fibers were often added to coatings to provide reinforcement (cohesion) and add some thixotropy. Although no longer used, asbestos pigments may be discovered when existing coatings are removed during maintenance painting.

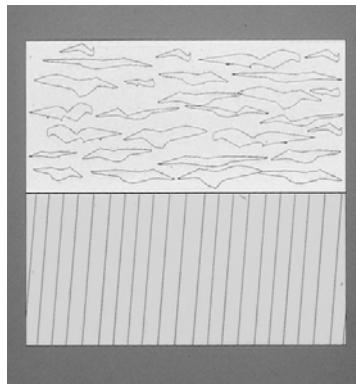


Figure 2 Acicular Pigments

- Lamellar

Lamellar, or plate-like, pigments, such as mica, aluminum flake, glass flake, and micaceous iron oxide, overlap when the coating dries increasing the degree to which the coating is impermeable to moisture.

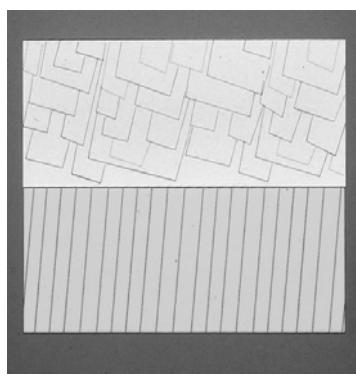


Figure 3 Lamellar Pigments

Composition of Vehicle

The vehicle consists of *binders* (resins) plus *solvents* and *additives*. These are all of the constituents of the liquid phase of the coating and can be divided into two component groups.

- Nonvolatile, film-forming (binder) components
- Volatile solvents
- Additives may be volatile or nonvolatile, depending on their purpose in the formulation.

Binder Resin

The name given to a coating is generally that of its principal resin, e.g., epoxy, vinyl, etc. (About the only time this is not the case is when primers also use the name of the pigmentation, e.g., zinc-rich epoxy, red lead, etc.)

Resins may be natural or synthetic materials and are most often organic (i.e., based on carbon). Most resins require the addition of a solvent to aid application.

To create a protective coating film on a substrate, the binder resins must convert from pliant liquid form (which allows application) to cohesive solid form that adheres to and protects the surface. It is this ability to change from one form to the other that identifies the resin's suitability for use as a binder.

To be suitable for use as a binder in corrosion-resistant protective coatings, the binder should:

- Have good wetting and adhesion properties
- Resist transmission of water vapor and oxygen
- Tolerate variation in application processes
- Resist chemical and physical change in service environment

- Dry within an acceptable period to prevent surface contamination
- Form a stable film and maintain its characteristic properties (flexibility, tensile strength, hardness, etc.) in service



Figure 4 Binder

In the coating selection process, the most critical decision is probably the choice of binder.

Solvents

Most coatings contain solvents. Solvents may be classified as:

- Primary (active)
- Latent
- Diluent

and are added to coatings for a number of reasons, including the following.

The primary (active) solvent dissolves the resin to make a solution of resin and allow its use as a coating vehicle. Many synthetic resins are solids, including MOST alkyd resins, some epoxy resins, chlorinated rubber and vinyl resins.

A latent solvent is often used in conjunction with the primary solvent to make the coating easier to apply, to control the evaporation rate, and to improve the quality of the final film.

Diluents are solutions such as water that are used with active solvents to dilute the coating in the container. Diluents DO NOT dissolve the resin. A combination of an active solvent and a diluent may provide a smoother, tougher film than when the film is cast from the active solvent alone.

The technique of using a diluent such as water as a secondary solvent can be used to create coatings such as water-reducible alkyds.

In some cases, diluents are used to reduce costs. In application, the diluents should leave the coating film **before** the majority of the active solvents or a poor film will result.

The amount of solvent used in coatings varies with the type of resin and the application procedure. The quantity of solvent may vary from perhaps several percent by weight of the vehicle, as in the case of some high-solids epoxy coatings, to roughly 75% by weight of the vehicle in such coatings as vinyl (still used in some parts of the world) or acid-etch primers.

The volatile content is expressed in terms of either weight or volume percent of the vehicle. When calculated on the basis of volume percent, volatile organic compounds (VOCs) may vary from 50 to 90% of the total coating volume for vinyl-type coatings, while for some high-solids epoxy coatings it may be only 5 to 10%.

[**Note:** It is the high percentage of solvents in vinyls (i.e., high VOCs) that has led to reduced use in the United States and elsewhere.]

Addition of solvents to a coating at the application stage decreases both the viscosity and the wet-film thickness that can be obtained by ordinary application methods. In turn, the dry-film thickness will be reduced because of this thinning (effectively a reduction of volume solids percentage). This is the main objection to excessive

thinning of coatings, whether done in cold weather to make application possible or in a false sense of economy.

Adding thinner may also increase the risk of solvent entrapment and may interfere with film formation as the extra solvents evaporate out of the coating.

Characteristics of Solvents

Solvents have two major characteristics that influence their use in coatings. These are:

- Solvency power—The ability to dissolve other chemical compounds (e.g., resins)
- Volatility largely governs the evaporation rate, which is the speed at which the solvent will quit the coating

Only the solvent specified in the coating specification or the manufacturer's technical data sheet should be used to reduce the coating for application. Written permission to use a different solvent must be obtained from the manufacturer's technical representative.

The use of other solvents (e.g., *generic* MEK) may lead to poor film formation. Inspectors should observe and record thinners used to reduce the mixed coating.

Evaporation Rate

Next to solvency, the most important property of a solvent is volatility, which largely governs the evaporation rate. The relationship is not direct, because a stronger solvency for the film-former reduces the rate of solvent release. Evaporation rates influence leveling, flowing, sagging, wet-edge time, and gloss.

The optimum evaporation rate varies significantly with the method of application, from the fastest for spraying to the intermediate for brushing and finally to the slowest for flow coating and conveyor dipping. It may also change depending on whether conventional air spray or airless spray is used.

If application is by dipping or flow coating, evaporation rates affect sagging, freedom from tears at the bottom, and color streaking.

In the case of baked finishes, the volatility of solvents is a contributing factor in bubbling, cratering, and pinholing. Solvents may have a narrow evaporation or a wide range and each may be chosen to modify specific coating application characteristics.

Tables 1 to 7 list some commonly used solvents grouped according to their chemical classifications and show their flash points and evaporation rates. These include:

- Aliphatic hydrocarbons (e.g., mineral spirits)
- Aromatic hydrocarbons (e.g., xylene)
- Ketones (e.g., MEK)
- Esters (e.g., ethyl acetate)
- Alcohol (e.g., methyl alcohol)
- Alcohol Ethers/Ketone Ethers (e.g., Cellusolve)

Evaporation rates are usually expressed relative to n-butyl acetate, which has a flash point of 38°C (100°F) and is assigned a value of one.⁽¹⁾ The evaporation rate is determined under laboratory conditions by allowing a known amount of test solvent to evaporate along with a known amount of n-butyl acetate. The evaporation time in minutes for n-butyl acetate divided by the time for the test solvent is the evaporation rate. A value of 0.5 means the test solvent evaporates half as fast as n-butyl acetate, and a value of 4.0 means it evaporates four times as fast.

The evaporation rates shown in the tables refer to the straight solvent only, not to the solvent blends used in a coating film.

Aliphatic Hydrocarbon Solvents

Solvents of this group are also called *paraffins* and, chemically, they are open chain (also called *straight chain*). The most common of this group are mineral spirits and V. M. and P. (Varnish Makers and Painters) naphtha.

Mineral spirits is sometimes known as *painter's naphtha*. It is a high-boiling-point petroleum product used to dissolve oils, asphalts, and alkyds. Table 1 lists some common aliphatic hydrocarbons and some of their properties.

Table 1 Aliphatic Hydrocarbon Solvents

Solvent	Evaporation Rate (n-Butyl Acetate = 1)	Flash Point °C (°F) Closed Cup
Lacquer diluent	4.0	6°C (43°F)
V. M. & P. Naphtha	1.5	13°C (55°F)
Mineral spirits WHITE SPIRITS	0.10	55°C (131°F)

Aromatic Hydrocarbon Solvents

These hydrocarbons have a closed-chain six-carbon group (often called the *benzene-ring* structure) as a principal part of the molecule. The simplest chemical of this family is benzene; the family also includes toluene (toluol), xylene (xylol), and some higher-boiling-point homologs.

They are active solvents for chlorinated rubber, coal tar, and certain alkyds and are used as diluents in combination with other solvents for epoxies, vinyls, and polyurethane materials. Table 2 lists some solvents of the aromatic hydrocarbon group and some of their properties.

Table 2 Aromatic Hydrocarbon Solvents

Solvent	Evaporation Rate (n-Butyl Acetate = 1)	Flash Point °C (°F) Closed Cup
Benzol (Benzene)	5.0	-12°C (10°F)
Toluol (Toluene)	2.0	5°C (41°F)
Xylol (Xylene)	0.6	28°C (82°F)
High-flash-point Naphtha	-	38°C (100°F)

[Note: Benzene and toluene were both much more widely used than they are now. Their use has been restricted because of health and safety concerns.]

Ketone Solvents

Ketones are oxygenated hydrocarbons of the acetone family and methyl ethyl ketone. These are the most effective solvents for vinyls and are often used in epoxies and other resin formulations. Table 3 lists solvents of the ketone group and some of their properties.

Table 3 Ketone Solvents

Solvent	Evaporation Rate (n-Butyl acetate = 1)	Flash Point °C (°F) Closed Cup
Acetone	9	-10°C (14°F)
Methyl ethyl ketone (MEK)	4	-4°C (25°F)
Methyl iso-butyl ketone (MIBK)	1.6	22°C (72°F)
Methyl iso-amyl ketone (MIAK)	0.5	40°C (104°F)
Cyclohexanone	0.2	54°C (129°F)
Diacetone alcohol	0.2	15°C (59°F)

Ester Solvents

Esters are also oxygenated hydrocarbons, but the ester solvents have a distinctive, pleasant, banana-like odor. The acetate esters are excellent solvents for several different kinds of synthetic resins, including cellulose

esters, acrylics, polyvinyl acetate, and polyvinyl butyrate. Ethylene glycol monoethyl ether acetate (Cellosolve acetate) is used in large volume in thermoplastic acrylic finishes and is noted as the best slow-evaporating solvent for these acrylics based on methacrylate resins.

Like some other solvents, Cellosolve acetate is less commonly used than it once was because of health and safety concerns. [Note: Cellosolve is a trade name of Union Carbide Corp.]

The esters are also used as latent solvents for vinyls and are commonly used in epoxy and polyurethane formulations. Table 4 lists some solvents in the ester group and some of their properties.

Table 4 Ester Solvents

Solvent	Evaporation Rate (n-Butyl Acetate = 1)	Flash Point °C (°F) Closed Cup
Ethyl acetate (95%)	4.1	13°C (55°F)
n-Propyl acetate	2.3	18°C (64°F)
n-Butyl acetate	1.0	38°C (100°F)
Amyl acetate (95%)	0.4	41°C (106°F)
Ethylene glycol monoethyl ether acetate (Cellosolve acetate)	0.2	57°C (134°F)

Alcohol Solvents

Alcohols are oxygenated hydrocarbons and are good solvents for highly polar binders such as phenolics. Some alcohols are used with epoxies. Table 5 lists various alcohol-type solvents and some of their properties.

Table 5 Alcohol Solvents

Solvent	Evaporation Rate (n-Butyl Acetate = 1)	Flash Point °C (°F) Closed Cup
Methyl alcohol	6.0	16°C (61°F)
Ethyl alcohol	2.3	24°C (75°F)
Propyl alcohol	1.0	31°C (88°F)
Isopropyl alcohol (91%)	1.6	19°C (67°F)
Butyl alcohol	0.5	46°C (115°F)
Cyclo-hexanol	<0.1	68°C (154°F)

Alcohol Ethers/Glycol Ethers

Ethers, such as ethyl ether, are not usually used as solvents for synthetic resins because they are very flammable, but they are excellent solvents for some of the natural resins, oils, and fats.

The usual form of ether used in protective coatings is alcohol ether, such as ethylene glycol monoethyl ether, commonly known as Cellosolve (a trade name of Union Carbide). A number of glycol ethers are sold under this designation.

Cellosolve is a good solvent for many oils, gums, natural resins, and such synthetic resins as alkyds, ethyl cellulose, nitro-cellulose, polyvinyl acetate (PVA), polyvinyl butyral, and phenolics. It is a slow solvent and is used in many lacquers to improve flow out and gloss. These materials are combined with other solvents to help achieve solvent formulations that have higher flash points. Table 6 lists some glycol ethers and some of their properties.



Table 6 Ether Alcohols (Glycol Ethers)

Solvent	Evaporation Rate (n-Butyl Acetate = 1)	Flash Point °C (°F) Closed Cup
Ethylene glycol monomethyl ether (Cellosolve)	0.5	46°C (115°F)
Ethylene glycol monobutyl ether (Butyl Cellosolve)	0.06	74°C (165°F)
Ethylene glycol monoethyl ether (Cellosolve)	0.3	54°C (130°F)
Ethylene glycol	0.06	74°C (165°F)

Miscellaneous Solvents

Tetra hydrafuran is a cyclic ether with very strong solvent characteristics for resinous materials such as acrylates, styrene, polyvinyl chloride, rubbers, and epoxies. The nitro paraffins are also good solvents for many synthetic resins. The principal member of this group is 2-nitropropane, which has low toxicity and evaporates at about the same rate as n-butyl acetate. It is a solvent for nitrocellulose, acrylics, and epoxies; when mixed with toluol (toluene), 2-nitropropane is a very good solvent for vinyl chloride acetate resins. Table 7 lists properties of these miscellaneous solvents.

Table 7 Miscellaneous Solvents

Solvent	Evaporation Rate (n-Butyl Acetate = 1)	Flash Point °C (°F) Closed Cup
Tetra hydrafuran	6.0	-15°C (5°F)
2-Nitro propane	1.1	38°C (100°F)

Solution Kickout

When a solvent is added to a resin in increasing amounts, usually there is a point at which the resin precipitates, or *kicks out*. This *dilution limit* is expressed as the percent nonvolatile when precipitation begins and generally is an



indication of the degree to which the resin and solvent are compatible.

When an incorrect solvent is used, this effect may be seen as the formation of a glutinous gel, unevenly distributed in the fluid. The effect is called *solution kickout*. If solution kickout occurs the inspector should not allow the material to be used. In most cases it could not be applied by any normal means.

United States Regulations on Volatile Organic Compounds (VOCs)

Most of the United States and some international communities have regulations limiting the amount of *volatile organic compounds* (solvents) that can be released into the atmosphere. Many coating manufacturers have been reformulating their products to comply with these regulations. The addition of solvents prior to application, to thin the coating, may cause VOC-compliant coatings to exceed VOC limits and should be avoided when possible.

[**Note:** This subject is discussed in the Safety Modules of this program. At the time of writing, only the United States and the United Kingdom have VOC regulations in place. The European Community has regulations that will shortly become law.]

Coating inspectors may be required to check the coating materials on site for compliance with VOC regulations. If any thinning is allowed and is done on site, the inspector must be able to determine the maximum quantity of thinning that remains VOC compliant.

To make that calculation, inspectors must know:

- Allowed VOC content
- Quantity of thinner added
- VOC of activated/mixed coating



Solvent Safety

Solvent safety is concerned with two types of hazards: fire and health.

Fire Hazards—Flash Point

The *flash point* of a solvent is the lowest temperature at which enough vapor will be present above the liquid to be ignited by an ignition source, such as a flame. In addition to open flames, sources of ignition can include static electric sparks, sparks from nails in shoes, sparks from grinding operations, lit cigarettes, and many others.

The lower the flash point, the greater the amount of vapor that will be released from the liquid and the greater the risk of vapor ignition.

Important Safety Terms:

Fire Hazards

LEL = lower explosive limit

UEL = upper explosive limit

It could be said that the lower the flash point of a solvent, the more highly flammable the solvent.

The lower explosive limit (LEL) is the lowest concentration of solvent vapor in air that can be ignited.

The upper explosive limit (UEL) is the highest concentration of solvent in air that can be ignited.

Health Hazards

While some solvents are more immediately and directly hazardous to your health than others, all solvents present a health hazard and should be handled accordingly.

Approved respirators and protective clothing should be used at all times but particularly when handling solvents or when working in enclosed areas.

[Note: National Institute of Occupational Safety and Health (NIOSH) approves respirators in the United

States. Occupational Safety and Health Administration (OSHA) provides regulations to protect workers in the workplace. NIOSH provides recommendations for equipment and practices required for safe working.]

Some terms you may hear when solvent safety is discussed include:

- **TLV—threshold limit value:** A concentration of airborne gases or fumes that can be inhaled for a period of time by workers, according to the applicable safety regulations (e.g., OSHA regulations in the United States).
- **TWA/TLV—time weighted average/threshold limit value:** average concentration of airborne gases or fumes for a stated working period, such as an 8-hour day or 40-hour week.
- **STEL/TLV—short-term exposure limit/ threshold limit value:** Maximum concentration of airborne gases or fumes to which workers can be exposed regardless of the period of time.

IMPORTANT NOTE: All solvents should be handled with care.

Solvents should be stored in accordance with local and federal regulations. If inspectors have any doubts about any on-site solvent or coating handling practice, protective clothing, or breathing apparatus, they should notify the safety supervisor immediately.

Additives

Other materials, called *additives*, may be added to coatings, for several reasons:

- Adjust consistency
- Improve film build
- Make it conductive (for use on concrete)





Level 1

Chapter 1.4

Coatings & the Inspector

Coatings and the Inspector

Coatings are generally known and referred to by the name of the resin or film-forming agent. Your manual lists some of the types of coatings a coating inspector might expect to encounter. Inspectors should remember that a simple generic description (e.g., epoxy high build) may not be sufficient to differentiate between the products of different manufacturers.

There are many different types of protective coatings and more in constant development. Inspectors cannot expect to know everything there is to know about modern coatings nor to keep up with the changes that occur from day to day. Learning to read and understand the manufacturer's technical data sheets is essential.

We discuss coatings types at various points in CIP, together with application criteria, special considerations, and failure modes. At this time, we'd like to consider the inspector's role regarding coatings, including some typical quality control issues that affect inspectors.

Inspection Issues

The inspector must be alert to quality control issues at every stage of work, including:

- During surface preparation
- During mixing and thinning operations
- During coating application



Surface Preparation

During surface preparation the inspector should:

- Determine that the specified surface preparation is attained. If it is not, performance of the coating system is likely to be reduced. Faults such as adhesion failure between coatings and substrate may occur, allowing corrosion.
- Check for residues of oil, grease, fingerprints, chemical salts, and dust deposited on the surface after surface preparation. These may cause coating film defects or premature failure, e.g., pinholes, fisheyes, loss of adhesion, etc.
- Observe the process, documenting and reporting any defective or noncompliant activity

Coating inspectors are generally involved with surface preparation activities on a daily basis, helping to identify the standards required and judging—together with the contractor—whether or not the specific standard has been achieved.

Additional inspection may be required between the coats of a multi-coat system. At the time of coating application, no visible contamination of the surface is allowed, and in some cases chemical testing of the surface may be required by the specification. Contamination that has occurred since the surface preparation operation or since application of the previous coat should be removed.

Mixing and Thinning

Before mixing begins, the inspector should try to establish that coatings do not appear to have been damaged by age, improper storage conditions, handling, etc. Old, rusty, or dirty cans would imply that there may be a problem. Products in cans that appear to have been opened previously should also be carefully examined.



Coating materials that appear to be very *liquid* may indicate severe settlement of pigment and require significant mixing or even remanufacturing at the factory. Coatings that appear to have separated or gelled should also be carefully examined. If in doubt, the inspector should quarantine the containers and call for the manufacturer's opinion, preferably given in writing if the coatings are to be used.

During mixing and thinning, the inspector should ensure that the:

- Coating is mixed thoroughly. The specific effects of failure to mix thoroughly vary between different types of coatings, but they will generally result in reduced protective qualities of the coating and waste of expensive pigment materials.

Failure to mix components sufficiently or in the correct proportions may result in poor film-forming characteristics, inadequate or non-uniform cure, or partial separation of components after application.



Figure 1 Mixing Coatings

- Correct amount of thinner is used. Too much thinner may result in reduced dry-film thickness, together with runs and sags. Too little thinner may cause the coating to *cobweb* or *dry spray*. A non-uniform film with poor integrity, pinholes, or poor appearance may result.

- Correct type of thinner is used. In general, thinner should not be used unless necessary. Any thinner other than that cited in the specification or manufacturer's data sheet is the wrong thinner.

Inspectors can best judge the mixing process by being present when mixing takes place.

Sampling of Coatings

If coating samples are required, they would generally be taken at the time of mixing. Samples of the required volume, including individual components of multi-component systems, are collected in clean, unused containers and clearly labeled with the relevant details, including:

- Name of coating
- Manufacturer's name
- Batch number
- Date sample retained
- Inspector's name
- Identity code for tracking sample, if required.

All samples should be agitated (or mixed) prior to retention, to ensure a uniform sample is collected. This applies to both liquid and solid materials.



Coating Application

During coating application the inspector should determine that:

- Correct coating thickness is attained. Inspectors, in cooperation with the applicators, should ensure that WFT is monitored during application and that DFT is measured once the coating is sufficiently dried.



Figure 2 WFT Measurement

When coatings are too thick, increased stress is developed in the coating during the cure. Stress is likely to lead to cracks (including mud-cracking). Thick coatings may also have slow or improper cure time, runs, and sags, solvent entrapment, pinholes, or voids in the coating, and other defects may occur.

When coatings are too thin, they generally provide inadequate coverage of the surface, particularly primers applied to blast cleaned surfaces. The most common result is premature failure due to rust bleedthrough (a characteristic rust rash appears).

- Specified time-to-coat after cleaning time is observed. Surface may have deteriorated and begun to rust. This may prevent the coating from adhering properly to the substrate.

- Specified recoat interval is observed. Coatings applied too soon after the previous coat may result in solvent entrapment or improper cure leading to a variety of defects including wrinkling, blistering, and delamination.

Coatings applied after too much time has lapsed since application of the previous coat may be applied over contamination by spills or airborne particles. In addition, intercoat adhesion failure may occur with those types of coatings that have cured, a subject that will be discussed later.

- Specified surface temperature is observed. If the substrate is too cold, cure may be slowed. In addition, poor flow characteristics may result in reduced adhesion, poor coating film formation, and an irregular surface.

If the substrate is too hot, the coating may blister or pop because of too rapid solvent release.

- Specified coating is applied.

Inspection of Plural-Component Coatings

When a job involves the application of coatings that cure by chemically-induced polymerization, the inspector should ensure:

- Converter is added to base. Failure to add converter to base before use means the coating may appear to dry but will not cure. It may run or sag and probably will not withstand intended service.
- Correct proportion of converter is added to base. If an incorrect proportion of converter is added to the base, the cure will not be complete. Pot life may be affected. The applied film may have poor chemical and corrosion resistance. The coating may set up in the spray pot or lines.





Figure 3 Mixing Plural-Component Coating

- Correct *sweat-in* or *induction* time is allowed. For some coatings of this type, the manufacturer will recommend the coating be allowed to sit for a period of time after mixing of the converter and base before application. Typical induction periods are 10, 15, or 30 minutes, although these times are temperature dependent. This allows the base and converter to diffuse and the polymerization reaction to begin uniformly throughout the coating material.

Incorrect sweat-in time may lead to inadequate cure or to separation of the components during the application or curing process. In extreme cases, craters or fisheyes may occur.

- Pot life is not exceeded. Once the base and converter are mixed, the polymerization reaction begins, and it continues until it is complete.

There is usually a limited period of time during which the two-component coating must be applied. This is described as the *pot life*.

As the mixed coating ages and approaches the end of its pot life, its viscosity increases. The coating may still be liquid, even though its pot life has expired. The coating inspector should check to see

that coatings that have exceeded their pot life are not applied.

Applicators may be tempted to try to apply a coating that has exceeded its pot life, sometimes using thinner to reduce its viscosity for spraying. If this is done, the coating is likely to have poor sprayability, low film build, and sags, and it may not cure properly.

The finished film may have poor integrity, air entrapment, pinholes, sags, inferior film thickness, and poor performance in service.

- Temperatures are monitored. It should be noted that many functions of film formation and coatings cure are temperature related. Higher temperatures are likely to reduce curing time, pot life, etc., and lower temperatures are likely to increase those same properties.

Observation of ambient temperatures during application and cure should be part of the inspector's quality control task.

Some specialized plural-component coatings, such as those that are mixed during the spraying operation, may have very short pot life and/or induction time. Monitoring of times and temperatures is particularly important for these products.

Remember that in all cases the coating specification must be adhered to unless permission to deviate from the specification has been obtained from the owner's representative.

In addition to the tasks described above, other tasks may be assigned by the specification for a particular project. These may include monitoring of safety regulations, monitoring handling and disposal of hazardous materials, or any other agreed tasks. The scope of the inspector's duties should be agreed with the employer and discussed in detail at the pre-job conference.

Inspectors should document all of the tasks they perform.



Level 1

Chapter 1.5

The Coating Specification

The Coating Specification

In this section, we will ask the following questions:

- What is a specification?
- What are the general elements or contents of a good specification?
- Why is a specification important?
- What are the responsibilities of coating inspectors with regard to specifications?

We also will review a typical specification, and learn more about the pre-job conference and documentation (recording and reporting).

Coating Specification Definition

First of all, what is a specification?

Let's start with the dictionary 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.

In real life, we tend to modify a formal definition to suit our own purposes, so here we simply say:

A coating specification is a formal document that tells the contractor (applicator) what to do and where to do it, but generally doesn't tell him or her how to do it.

Note: 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 as to defy interpretation by anyone, including the person who wrote it.

For example, a few years ago a registered professional engineer in the United States 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 tender the job? Many questions are unanswered and must be asked:

- What's *clean*?
- What's a *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 all parties concerned. If allowed to stand, the owner would be lucky to get a decent job.

Often, the specifier copies specifications from a previous job without due regard to their accuracy, practicability, and adaptability to the current job and without accountability for any advances in technology.

We are sure that many of you have worked with coating specifications and may have seen good ones as well as poor ones. We are also confident you will agree that a well-prepared specification will go a long way toward making a job go smoothly and pleasing all parties—the



owner gets a good job and is happy and the contractor makes money.

When we are through discussing the coating specification, we will talk about the responsibilities of the coating inspector in relation to the specification.

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 his or her supervisor or with the owner's representative any aspects of the coating specification that seem inaccurate or impractical or that he or she does not understand.

The Coating Specification and the Coating Inspector

It is important to realize that almost every user of coating inspection has his or her own 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. An independent, particularly, will find his or her job changes depending upon the client.

Some owners regard the inspector as a project supervisor and assign him duties like supervising safety issues or labor or keeping track of and ordering materials, in addition to 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 the 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 is **NOT** considered to be part of the inspector's role.

With this in mind, let's examine various parts of the specification and consider the role of the inspector, particularly his or her duties and responsibilities in relation to the specification.

Elements of a Typical Coating Specification

Most specifications are formal, structured documents.

What would you expect to find in a good coating specification? A good coating specification will contain 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

We will examine each of these elements of a coating specification.

Scope of Work

This section describes the work to be done and when and where it will be done. There should be a listing in the Scope or separately (such as in an appendix) of each item to be coated, as well as a list referring to all areas that are to be protected and are not to be coated. This section may also indicate the purpose of the coating project and any unusual or specific limitations that the contractor may encounter.

Following is an example:

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 the 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 for 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 will be 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.

Inspector's Responsibilities Regarding the Job Site

Inspectors should make a walk-through of the job site in order to become thoroughly familiar with the surroundings. They should note each item to be coated or left uncoated as described in the Scope of Work Section (or in a separate coating schedule) and should obtain any maps or drawings that would be helpful. If necessary, on complex projects, a specific list of exactly which items are to be coated and which are to be kept free of coatings may be made.



If there is more than one inspector on the job, each one should know which items he or she is responsible for, and the supervising inspector should ensure that each item to be inspected is assigned to someone.

Check to see that all identity plates, breather holes, electrical equipment, metering and monitoring instruments, gauge glass covers, etc. that are to be left uncoated are properly covered and protected during the coating operations. You should check from time to time to see that the necessary protection remains in place until the job is completed.

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 or **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 or make changes to the specifications. He or she 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. He or she 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.

Reference Standards

The specification generally will include a list of published standards referenced by particular sections or parts of the document. Any part of a referenced standard may be binding on all parties as the entire standard, unless an exception is noted.

Inspector's Responsibilities Regarding Standards and Codes

Generally the specification will require the contractor to work *in a safe manner in accordance with all applicable federal, state, and local codes, etc.* It is the liability of the contractor to observe and follow such codes. However, a prudent inspector would determine what codes are applicable and acquire a working knowledge of them.

Also, a coating specification will 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.

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 will have his or her own safety manual, which will cite specific safety requirements, such as:

- Wearing of hardhats
- 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.

Inspector's Responsibility Regarding Safety

Safety is the responsibility of all workers involved at the job site. The employer has the prime liability for safety, but the inspector should be knowledgeable enough to recognize safety violations because they involve his or her 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
- 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 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)



Safety Checklist

The following safety checklist may be helpful to you as you observe work or if you should be called on to monitor safety practices on a coatings project.

General safety

- Locate nearest telephone
- Identify restricted areas
- Locate fire alarm
- Locate fire extinguisher and fire blankets
- Locate moving objects, cranes, and traffic
- Identify and observe safety warning tags and signs
- Learn facility alarms, evacuation procedures, and general emergency protocols

Ladders

- Periodically inspect for loose, worn, or damaged rungs
- Wear shoes with heels
- Do not carry any tools in hand while climbing
- Face ladder while climbing; never jump from a ladder
- Guard against danger of metal ladder coming in contact with electric power lines
- Tie off ladder

Scaffolding

- Periodically inspect for damage or deterioration
- Ensure scaffolding is plumb and level
- Ensure handrailing is provided on all scaffolding
- Do not ride scaffolding on rollers when it is being moved
- Verify inspection tags are valid and in place



Power Tools

Verify that:

- Safety guards are fitted and operational
- Dust collection systems are operational when working with hazardous materials

Abrasive Blast

Ensure that the following are installed and in working order:

- Deadman valve
- Pressure control valves
- Adequate moisture and oil separators
- Protective clothing (hoods and gloves)
- Filtered and regulated air-supplied respirator

Make certain that:

- Entire system is grounded, including hoses, operator, and work piece
- Hose couplings are wired shut
- Abrasive hose is stored in a dry place
- Abrasive hose is curved around, not bent at 90° angle
- Nozzle is never pointed at human body or breakable object
- Abrasive hose is inspected for damage and wear

Spray Application

To prevent fire hazards, see that:

- No ignition sources are present when flammable materials are used
- Applicator minimizes use of low flash point materials



- Adequate ventilation is provided
- Spray booth is clear of exhaust fumes from previous spraying
- No rags become soaked with flammable liquid in spray area

Personal Protection

Make certain that:

- Goggles and safety glasses are worn
- Regulated air respirator is used
- Operator is positioned upwind of object being sprayed

Hose and Gun

Determine that:

- Hoses are inspected periodically for weak and worn spots
- Hose connections are correct and tightened
- Hose is never disconnected or recoupled while under pressure
- Pressurized unit is never left unattended
- Gun is grounded through hose connections
- Gun is never pointed at human body
- Gun has required trigger guard
- Operator uses electrically conductive hose in airless applications

Solvents and Coating Materials

While all solvents and materials should be handled carefully, according to manufacturer's specifications, some are especially dangerous and require particular caution. Those solvents and materials include:

- Acetone, MEK (methyl ethyl ketone) solvents



- Vinyl solvent-solution coatings
- Epoxy coatings and compounds
- Neoprene-hypalon (synthetic rubber) coatings
- Any coating that contains lead or mercury
- Aromatics (xylene or toluene [xylol or toluol])
- Cellosolve or Cellosolve acetate
- Urethanes with isocyanate curing agents

Test Equipment

See that:

- Holiday detectors are grounded
- No volatile substances are present when high-voltage detectors are in use
- Equipment is suitable for the environment in which it is used, e.g., intrinsically safe in hazardous confined spaces

Material Safety Data Sheets (MSDS)

In many countries, including the United States, material safety data sheets are required on the job. These data sheets were 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 5.2, MSDS and Tech Data Sheets.

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 in the pre-job conference.

Most important, 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, then it is better that he/she get 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.



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

Surface Preparation

It is generally believed that fully 60 to 80% of all premature coating failures are attributable to inadequate or improper surface preparation. This section then 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 would 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 this 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 follows:



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.

Inspector's Responsibilities Regarding Surface Preparation

Standards

Standards are an essential part of quality control of painting operations and are discussed in many other modules of this 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

Anchor Profile

Know exactly what anchor pattern tolerances are allowed. If the specification states a minimum 38- μm (1.5-mil) anchor pattern (surface profile), 33 μm (1.3 mil) is not acceptable.

A well written specification will require a surface profile range, such as between 25 to 50 μm (1.0 and 2.0 mil), or will express surface profile with a variable, such as 38 μm (1.5 mil) \pm 12.7 μm (0.5 mil). Be sure to clarify this point at the pre-job meeting.

More is not necessarily better. An anchor pattern that is too deep is out of specification just as much as one that is too shallow. It is unfair to the client to allow the contractor to get by with substandard cleaning. It's also unfair to the contractor to require a higher degree of cleanliness than that specified. After all, cleaning is expensive and the contractor tendered 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.

Coating Materials

Selection of coating materials involves matching a coating with the environment and in-service conditions to which it will be exposed. The specifier must be able to assess 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 the opportunity exists for periodic inspection and maintenance may not be as critical as selection for use on buried or submerged surfaces or as a lining for a vessel.

The specifier has several options available in selecting coatings for the project. Examples of some of these options are:

- Selection according to generic formula, such as SSPC Paint #20, AWWA C-204 Interior System #8, MIL Spec. C-15203, etc.
- Selection of 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—This is the adoption of a specific coating or coating system, usually based on known field performance, generally supplied by a single manufacturer or approved equal. The specifier has determined that coating materials from one manufacturer are acceptable but is also willing to consider other products. The specification lists one



manufacturer's coatings by name and indicates *or 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 his or her 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.

Inspector's Responsibilities Regarding Coating Materials

Make sure that the coatings and allowable thinners used are those specified. Know where the coatings will be 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-type product, be sure the correct components are stirred properly, then combined as specified and the combined material mixed thoroughly. Observe manufacturer's recommended *induction* or *sweat-in* times.

Know the volume of solids, wet-film and dry-film thickness specified and allowable tolerances, dry and recoat times, and time for proper cure.



Sampling Coatings

The specifier may require the contractor or inspector to take *retain* samples of the coatings being used on the project. He or she may spell out the sampling procedure, including number of samples to be taken, labeling procedures, storage requirements, etc. The sampler should use only clean containers when taking partial samples to avoid contaminating the sample. Samples may be partial retains (250 mL to 1 L [metric] or 0.5 pint to 1 quart [U.S.]) or unopened containers (5 or 20 L, 1 or 5 gal units). The inspector may be required to visit the manufacturer's plant to take samples of the coating.

Inspector's Responsibilities Regarding Sampling of Coatings

The coating specification may require the inspector to take samples of the coating materials on-site. The inspector should follow the specification carefully:

- Select coatings to be sampled at random
- Ensure coatings are thoroughly mixed
- Remove the sample to the sampling container in the amount specified
- Label the sample container as specified to indicate the following:
 - Product name and number
 - Color
 - Batch number
 - Date the sample was taken
 - Inspector's name



After the sample has been taken, the inspector taking the sample should ensure that the coating container is well sealed and the samples are stored under conditions that will not damage them. To avoid sampling error, some clients prefer that a complete unit (unopened) be taken as a sample and sent to a testing lab, where the material can be mixed and sampled under more controlled conditions.

Coating Schedule

In most instances, when the project is relatively simple, coating schedule information will be included in the scope of the specification.

When the coating project is more complex, this information may be listed separately, 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.

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 would be to require operators to be qualified according to the ASTM Standards D 4227 and 4228 or to the NACE International 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 use in determining the level of work competence.

Inspector's Responsibilities Regarding Workmanship

Understand the nature of the work to be performed.

Be sure you have a copy of the manufacturer's latest instructions and be sure you thoroughly understand them.

At the pre-job conference, you should clarify performance expectations of workmanship.

Observe work as it is performed and report any unacceptable work to your supervisor, to the owner's representative, or to the contractor for correction.

Stay safe. You are responsible for your own safety and for personally following all safety requirements set for the job. Report any questionable conditions or practices to the safety engineer immediately.

Application

This section defines the approved methods of 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)

A good specification will state the minimum and maximum dry-film thickness (DFT) of each coat of the coating system and total minimum and maximum allowable DFT. In addition, the specification may call for



stripe coating in which case it would 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 such statements as *apply a full-bodied stripe coat* or *achieve full and complete coverage*. Measurements of stripe coat DFT are likely to be unreliable due to the proximity of edges, sharp corners, or weld seams.

Inspector's Responsibilities Regarding Application

Ensure that the coating application is done as specified in a workmanlike manner, free from defects.

Know exactly what thickness tolerances are allowed. A good specification will state a minimum and a maximum DFT for each coat of the system and for the total system, for example, 100 to 150 μm (4 to 6 mils) per coat and 300 to 450 μm (12 to 18 mils) for the total system. If this is not the case, then you should 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 your responsibility is to ensure the specified DFT range is achieved. You do a disservice to both your client and to the contractor if you try to insist on an extra topcoat just to make sure that any thin spots or defects you may have missed are covered.

If the contractor fails to meet the specifications to any substantive degree, and you have made a reasonable effort to gain compliance, then it is important for you to bring this to the attention of your supervisor or to the owner's representative so he or she can determine what remedial actions should be taken. The information you transmit and your recommendations may have an important bearing on the decisions made. Your report should be accurate and provide an objective view of the situation.

In extreme cases, the 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 by the designated supervisor or owner's representative, not by the coating inspector.

Work Schedule

It is generally the responsibility of the contractor to establish his or her own schedule of work and submit it to the engineer for approval prior to starting the job. (Note: The owner would be reluctant to tell the contractor how to schedule his or her 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 at least 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 commence at 7 a.m. when the gates do not open until 9 a.m. In such a case as this, the contractor may have a valid claim for the 2 hours of standby time.



Other known restrictions and limitations should also be designated.

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

Repair and Remedial Coating Work

The specification may identify procedures for repair work.

The specification should require the contractor to repair any damage to the coating work and may 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.



Inspector's Responsibilities Regarding Coating Repair and Remedial Work

The procedure for coating repair 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.

Inspection

As stated earlier, coating specifications vary and are usually tailored to meet the requirements of a particular job. Quite naturally, then, we would expect the inspection scheme to vary also. Some owners may call for inspection by their own staff; some require inspection by independent personnel hired for the project. Others may require the contractor to provide his or her own inspection and quality control, with the completed job 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 (visual, holiday detection, etc.)
- Documentation (record keeping, reports, etc.)

In the best of cases, a specification may provide an outline of procedures for the inspector to follow in performing his or her duties. Such procedures would define the inspector's task and may contain such rules as:

- 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 inspector's responsibilities and authority
- An organizational chart showing the chain of command and the inspector's position
- If the guidelines do not exist, then the inspector should establish his or her own procedure, which should contain the same elements. These elements should relate to the various sections of the specification we have just mentioned.

Inspector's Responsibilities Regarding Inspection

Throughout our discussions we have referred to the general duties of the coating inspector. Very briefly now, let's summarize some typical responsibilities of the inspector.

- 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 any questions you may have 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., you plan to use.
 - Determine your responsibilities and authority.
- During work:
 - Perform quality control tasks in accordance with responsibility allocated and document all activities.
 - Verify that work complies with the requirements of the specification.
 - Report all non-compliant work and deviations from written specified requirements, including modifications agreed at the pre-job conference or any similar meeting.

Documentation

This normally will be 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, remembering that readers may not have specific knowledge of the job or the project location.





Level 1

Chapter 1.6

Teamwork and Subarctic Survival Exercise

Human Relations

Some people might ask *What does the coating inspector need to know about human relations? All the coating inspector does is enforce the specification. It's all down in black and white and the contractor and vendors either meet it or they don't.*

We're going to talk about human relations for two main reasons.

First, good human relations is the **oil** that keeps the wheels on the job running smoothly; without it, the friction could cause them to burn up. I'm sure you all have known people who really knew their stuff, but who were a real pain in the neck to work with.

Second, we're going to discuss human relations because we hope the skills you learn in this course will help you get ahead in your job. People who can get along well with other people generally move up in their companies faster than those who don't.

The following describes some options people have when you tell them bad news.

Bad News

When the coating inspector breaks bad news to someone:

The person might:	In which case the coating inspector might:
1. Work with the inspector to solve the problem	1. Help with the solution to the extent of stated responsibility and authority
2. Agree to do something, then not do it	2. Restate the problem and work to get the other person's commitment to follow through on the solution
3. Ignore the situation entirely	3. Advise his or her supervisor
4. Become hostile and defensive, and argue	4. As a last resort, shut down the job if granted the authority to do so

It is important for you as a coating inspector to understand what psychologists call *defensive behavior*.

Defensive Behavior

Defensive behavior is a term you might not be familiar with, but I'm sure you've come across it at one time or another. It occurs when someone feels 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

For example, saying: *If you weren't so careless, this mistake wouldn't have happened* may cause defensiveness.

- Manipulative behavior

This is playing politics and trying to maneuver people to suit your own ends.

- Authoritarian, bossy behavior

Saying, for example: *I'm the inspector here and you'd better look sharp or I'll shut down the job* may elicit a defensive response.

- Lack of concern/indifference

Appearing to not care about problems on the job that may be beyond the control of the people working on the job can make them defensive.

- Know-it-all attitudes

These attitudes may be expressed in such statements as *Look, I've been doing this for 15 years, and there isn't anything I don't know about this subject.*

To avoid coming across in a way that could produce a defensive reaction, try to be:

- Objective, descriptive

Rather than saying *That's the worst excuse for surface preparation I've ever seen*, state the problem in objective terms: *That whole wall still has loose mill scale and rust, and the specification calls for a near white blast.*

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

The key: Concentrate on solving the problem.

Conflict

If there is one thing there is no shortage of in the coatings industry, it is opinions and differences of opinion. These differences of opinion can, and frequently do, lead to conflict. One opinion plus another opinion equals conflict. Conflict is a daily reality for everybody.

There are at least three ways of handling conflict:

- First, by avoiding it.

You can look the other way and, for example, ignore substandard surface preparations. Or you could leave the situation entirely by quitting your job.

- Second, by smoothing things over.

You could try to smooth over the issue by delaying dealing with it, resolving minor points while ignoring the major issue, and postponing the confrontation until later.



- Third, by resolving it.

Two of the resolution options are **power** and **negotiation**.

Power can be either physical (like a punch in the nose), or based on authority (like firing someone or shutting down the coating job). Power strategies are sometimes appropriate, but should be used sparingly. The problem with power strategies is that they end up in win-lose confrontations and the losers may respond with sabotage, trying to get even somehow, or being otherwise nasty and disagreeable. The best use of power may be subtle. Knowing when and how to use power must be developed with a conscious effort.

Negotiation is working to arrive at a decision that everyone involved accepts that is, to arrive at a *consensus*. Successful negotiation requires the ability to:

- Determine the real problem
- Initiate a situation where everybody wins, or at least nobody walks away defeated
- Listen to the other person's side of the story. It is not necessary to agree, but you should listen carefully to what the person has to say. Sometimes it is helpful to respond to that person by summarizing what he or she has said—to be sure you understand what was said and to indicate your interest in what the person has to say

Steps to negotiate conflict successfully include:

- Diagnosing the real problem
- Stating the problem objectively
- Letting every person involved have his or her say
- Discussing various solutions
- Deciding together on the best solution



- Determining who is going to do what to be sure the solution is carried out
- Following up to be sure the solution is carried out

This last item will frequently be the responsibility of the coating inspector, because the ultimate responsibility of the inspector is to ensure that the specification is carried out.

Since listening is such an important part of successful conflict resolution, let's take a look at some ways to improve your listening skills.

Improving 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 the other person thinks he or she said.

Some people are very uncomfortable with conflict and attempt to avoid it whenever possible. But conflict, 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 called *synergy*, from the words *synthesis* and *energy*.

Subarctic Survival Situation

The objectives of this exercise are:

- To experience group behavior when faced with a difficult problem
- To analyze your team's behavior
- To learn skills/techniques for improving teamwork on the job as a coating inspector

This is called the *Subarctic Survival Situation*. A complete description of the situation and instructions are given on the inside of the front cover of the booklet I will give to you.

Briefly, the situation is that your team has crash landed in the arctic. Your position is shown on the map on page 2. On page 3 is a list of items you have managed to salvage from the plane before it drifted away and sank in the lake it crashed in.

After I hand out the booklet, on your own and without discussing it with anyone, read the information on page 1 and study the map on page 2. Then we will watch the first section of a video that will set up this exercise. After that portion of the video, turn to page 3 and in the column on the left side under the heading *Step 1*, place a **1** next to the item you consider most important to your survival, a **2** next to the item you consider second most important, and so on, until you complete ranking all 15 items.

We'll take only 15 minutes to do this. OK, it's now _____. We have 15 minutes; let's try to have this step completed by _____.

Effective Groups

Before we take the next step, let's talk a little about effective groups. You work with all kinds of groups—some are formal and many are informal.

As we said earlier, you work with groups on the job as a coating inspector. What would you say are the characteristics of effective groups? What would you say are the characteristics of groups that are ineffective?

Write class responses on a flip chart and, when finished, summarize the posted characteristics.

Characteristics of Effective Groups

Effective groups tend to:

- Share and build on each other's ideas and information.
- Openly examine and resolve differences.
- Be conscious of their own operations/processes.
- Discuss objectives/tasks of the group until they are well understood and accepted.
- Reach decisions through examination and comparison of differences and alternatives (consensus vs. voting or steamrolling).
- Develop supportive relations that promote:
 - Listening to divergent ideas
 - Suppression of ridicule
 - Respect for others in giving and receiving information



Achieving Consensus

Before you start working in your team, let's look at some suggestions on *achieving consensus*.

Definition of *consensus*:

- Group solidarity in sentiment and belief
- General agreement; the judgment arrived at by most of those concerned

Guidelines for achieving consensus:

- Avoid arguing for your position only because it is your opinion. However, accept the notion that it is okay to be influenced.
- Change your opinion only when convinced. Persuade and be persuaded based on logic.
- Avoid conflict-reducing techniques such as voting, bargaining, compromising, coin tossing, averaging, or withdrawing.
- View differences as helpful, rather than as obstacles.
- Avoid accepting an individual decision solely on the basis of experience, position, or aggressive behavior.
- Accept the possibility that you as a group can do well on the task.

Team Exercise

Now let's go back to the Subarctic Survival Exercise.

First, decide whether you are going to stay and wait to be rescued or if you are going to try to walk out. This will be a group decision.

Then, discuss each of the 15 items salvaged from the plane and again arrive at a group decision regarding

which item is most important (No. 1), which item is next most important (No. 2), and so on. Write your group responses in the second column with the heading *Step 2*.

When your team has finished, write your decision on a flip chart and select a spokesperson to report on your group decisions. Although you may change your mind regarding the ranking, please do not change the answers you put down in the *Step 1* column.

You have 45 minutes to complete this step. It is now _____, please try to finish by _____.



Expert Analysis

Now we have heard the answers the experts gave. A description of who these experts are is included on the last page of the situation booklet. Now, I'm no survival expert myself. You may disagree with some or all of their answers, but they are the ones we'll use for this exercise.

The expert opinion on whether to walk or stay is: **Stay!**

The experts said that attempting to walk out would almost certainly be fatal, particularly for people unfamiliar with the terrain and basic subarctic survival tactics.

On the other hand, the experts feel that a group that stays has an excellent chance of being spotted and picked up within a day or two, especially if they keep a signal fire going day and night and have other fixed distress signals.

Deciding to walk out is not, however, an unusual decision. In our society in particular, we have a tendency to fall into an **activity trap**. There is a strong feeling that doing something (walking out) is better than doing nothing (staying). In this particular case, walking out can become an end itself, drawing attention away from the primary objective, which is survival.

As you reflect back on your group discussion and on some experiences you may have had on the job, you may be able to see where **activity** has become an end unto itself and has drawn attention away from focusing on solving the real problem.

Team Evaluation vs. Expert Analysis

Now, find the differences between the numbers in column 1 and column 3 and write them in the corresponding spaces of column 4. Then add up the numbers in column 4 and write the total in the box at the bottom of the page.

Then do the same for column 5, finding the differences between numbers in columns 2 and 3. Then add up the numbers and write the total in the box at the bottom of the page.

Then go ahead as a team and find the average individual score by adding up all individual scores on your team and dividing by the number of persons on your team. As soon as you have the average individual score and the team score, let me know and I'll post the scores on the flip chart.

[It should become apparent that the team scores are generally lower than the average individual score. Comment briefly on this as an indication of how, in many instances, groups may be able to produce a better outcome by working together to solve a common problem.]

Next, for each team, indicate the number of individual scores lower than the team score. You should find out that relatively few individuals scored better than their team. This indicates that teamwork is effective; the shared opinions of the group consider more options and provide an extra perspective that helps make effective decisions.

It is possible that up to half of the team (or more) gets a better score than the team working together. This is an indication that the team may not have processed its information or knowledge very effectively; in other words, the team was not working together effectively.

Summary

We covered a lot of ground in this section but to recap some of the key concepts we found that:

- The coating inspector is part of a team
- Conflict will occur

- Conflict can be positive
- Teams can sometimes produce better results than individuals





Level 1

Chapter 1.7

Self-Study Questions

Chapter 1.1—Introduction

1. NACE CIP Level 1 Mission Statement. After Level 1, the inspector should be able to:
 - a. Undertake simple coating _____ under _____
 - b. Read and comprehend a _____
 - c. Use simple _____
 - d. Comprehend and use _____
 - e. Recognize inspector's job as _____ of a _____ effort
 - f. Recognize importance of _____ meetings
 - g. Recognize need to determine _____ and _____.
2. Referenced standards—inspector's responsibilities are:
 - a. To _____, _____, and _____ standards
 - b. To ensure _____ is fully _____ of the intent of the standards
 - c. To ensure _____ is fully aware of the standards referenced.
3. Coating inspector's job is to:
 - a. Understand _____
 - b. Define _____
 - c. _____ specifications
 - d. Check _____
 - e. _____ required _____
 - f. _____ all items completed
 - g. Ensure _____ available and instruments _____



Chapter 1.2—Corrosion

1. Corrosion is the _____ of a material, usually a _____, because of a _____ with its environment.
2. Some metals, like zinc, aluminum, copper, and brass, form protective _____ when exposed to the atmosphere.
3. The four elements of a corrosion cell are:
 - a. _____
 - b. _____
 - c. _____
 - d. _____
4. The anode _____ in the electrolyte.
5. Corrosion is an _____ reaction, also called a _____ action.
6. The electrolyte conducts _____.
7. Steel contains many _____ and _____ areas on its surface and corrodes when in contact with _____.
8. Chemical salts that dissolve in water help make a good electrolyte, which helps the flow of _____.
9. True or False - Chlorides and sulfates are examples of chemical salts.
10. Circle the correct answer. Mill scale is **anodic** or **cathodic** to the steel surface.
11. Oxygen can _____ and help _____ the rate of corrosion.
12. Generally, the rate of corrosion is _____ at low temperatures.
13. The effects of corrosion are on _____, _____, and _____.

14. General rules of galvanic corrosion when dissimilar metals are connected are:
- The _____ metal corrodes to protect the _____ metal.
 - As the _____ between the two metals _____, corrosion is increased.
15. True or False - When connected to copper in a moist environment, zinc or magnesium will corrode to protect the copper.
16. Three types of coatings are:
- _____
 - _____
 - _____ (also called _____)

Chapter 1.3—Coatings Introduction

- Coatings may be _____ or _____.
- Coatings consist of two major components, _____ and _____.
- A vehicle is the _____ of the coating consisting of solvent, _____ and any _____ that may be required.
- The _____ generally refers to the _____ or _____ blend that provides the film- forming component.
- Pigments are used in coatings to:
 - Provide rust _____
 - Decrease _____ of the film
 - Hide the _____
 - Provide _____
 - Protect the film from _____ and _____.



6. The choice of the _____ (resin) is the most critical part of selecting a coating.
7. The vehicle consists of the _____ (resin), _____, and additives.
8. The binder is a _____-_____ material and changes from a _____ state to a _____ state.
9. The _____ the flash point of a solvent, the greater its _____.
10. The lower explosion limit is the lowest _____ of _____ in the air that can be ignited.

Chapter 1.4—Coatings and the Inspector

1. When on the job, the coating inspector must be alert during certain operations, such as:
 - a. _____
 - b. _____ and _____
 - c. _____.
2. During surface preparation, the inspector should ensure:
 - a. Specified surface is _____
 - b. _____ is as specified.
3. During mixing and thinning, the inspector should see that the:
 - a. Coating is _____
 - b. Correct _____ of _____ is used
 - c. Correct _____ of _____ is used.

4. During application, the inspector should determine that the:
- Correct _____ is attained.
 - Specified time to coat after _____ is observed.
 - Specified _____ is observed.
 - Specified _____ is observed.
 - Specified coating is _____.
5. During application of chemically induced-polymerization coatings, the inspector should ensure that the:
- _____ is added to the _____.
 - correct proportion of _____ to the base.
 - Correct _____-in _____ is observed.
 - _____ is not exceeded.

Chapter 1.5—Coating Specification

- A _____ is a document that tells the _____.
 - _____ to do and
 - where to _____ it,
 - but does not tell him, _____ to do it.
- The _____ is the inspector's _____. The inspector should _____, _____, and _____ the specification.
- The scope describes the _____ to be done. It may list the items to be _____.
- The pre-job conference is where all parties can discuss and clarify the _____.

5. The specifier may select coatings to be used by any one of the following procedures:
 - a. _____ formula
 - b. _____ criteria
 - c. _____ source
 - d. _____ equal
6. True or False - The specification never defines what is meant by good workmanship.
7. NACE CIP defines the inspector's role as a _____ technician. Supervision is not part of that role.
8. The inspector's responsibility regarding safety is to _____ and _____ any unsafe conditions or practices.
9. At the pre-job conference, the inspector should get a clear understanding of the _____ and his or her _____ and _____.
10. True or False - In a typical coating specification, the coating schedule may be part of the section called Scope.
11. True or False - The specification usually will identify areas that are NOT TO BE coated.



Level 1

Practical Math Assignment

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.

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	1,000 μm = 1 millimeter (mm)
3 feet = 1 yard	1,000 mm = 1 meter (m)
1,760 yards = 5,280 feet = 1 mile	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



Test yourself on English/metric conversion by calculating the following conversions.

Problem 1. Length

$$100 \text{ in.} = \underline{\hspace{2cm}} \text{ cm}$$

$$10 \text{ cm} = \underline{\hspace{2cm}} \text{ in.}$$

$$20 \text{ m} = \underline{\hspace{2cm}} \text{ ft}$$

$$20 \text{ m} = \underline{\hspace{2cm}} \text{ yd}$$

Problem 2. Liquid (Note: gal., qt., etc are taken as U.S. units of volume)

$$3 \text{ gal} = \underline{\hspace{2cm}} \text{ L}$$

$$6 \text{ L} = \underline{\hspace{2cm}} \text{ gal}$$

$$6 \text{ L} = \underline{\hspace{2cm}} \text{ qt}$$

$$15 \text{ L} = \underline{\hspace{2cm}} \text{ qt}$$

Problem 3. Area

$$3 \text{ ft}^2 = \underline{\hspace{2cm}} \text{ m}^2$$

$$6 \text{ m}^2 = \underline{\hspace{2cm}} \text{ ft}^2$$

$$6 \text{ m}^2 = \underline{\hspace{2cm}} \text{ yd}^2$$

$$100 \text{ ft}^2 = \underline{\hspace{2cm}} \text{ m}^2$$

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?

$$\frac{15}{60} \times 100 = 0.25 \times 100 = 25\%$$



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.



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	

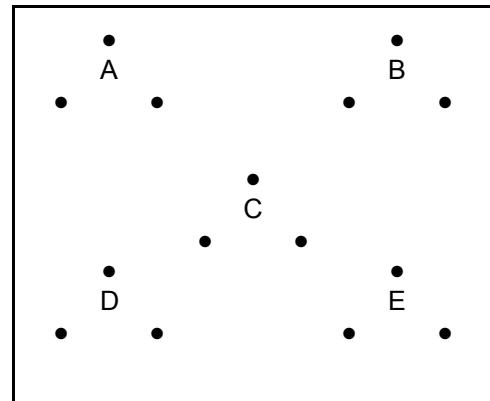
Practice Problem 5

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	
Checksum	500	

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:

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						

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



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 ft² 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.)



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:

$$\frac{\text{DFT}}{\% \text{ solids by volume}} = \text{WFT}$$



The same formula works with both English and metric measurements.

<u>DFT (mils)</u> = WFT (mils) % solids by volume	<u>DFT (μm)</u> = WFT (μm) % solids by volume
--	--

Examples:

English	Metric
<p>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?</p> <p>Since we have a low and high value for DFT, we calculate a low and high value for the desired WFT.</p> $\frac{4 \text{ mil DFT}}{0.30 \text{ solids by volume}} = 13.3 \text{ mil WFT}$ $\frac{6 \text{ mil DFT}}{0.30 \text{ solids by volume}} = 20.0 \text{ mil WFT}$ <p>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.</p>	<p>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?</p> <p>Since we have a low and high value for DFT, we calculate a low and high value for the desired WFT.</p> $\frac{100 \mu\text{m DFT}}{0.35 \text{ solids by volume}} = 285.7 \mu\text{m WFT}$ $\frac{125 \mu\text{m DFT}}{0.35 \text{ solids by volume}} = 357.1 \mu\text{m WFT}$ <p>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.</p>

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	

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:

$$\frac{\text{DFT} (1 + \% \text{ thinner by volume [TBV]})}{\% \text{ solids by volume}} = \text{WFT}$$

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



Example:

English	Metric
<p>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?</p> <p>Step 1: Calculate % volume thinner.</p> <p>8 pints = 1 gal 1 pint = 1/8 gal 1 pint - 0.125 gal</p> <p>So the number we will use for our % thinner by volume is 0.125 gal.</p> <p>Step 2: Calculate WFT range.</p> <p>Low WFT = 3 mil DFT x (1 + .125 TBV) (0.35 SBV)</p> $= 3 \text{ mil} \times \frac{1.125}{0.35} = 3.4 \text{ mil}$ $= 9.6 \text{ mils}$ <p>High WFT = 4 mil DFT x (1 + .125 TBV) 0.35 solids by volume</p> $= 4 \text{ mil} \times \frac{1.125}{0.35} = 4.5 \text{ mil}$ $= 12.9 \text{ mils}$	<p>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?</p> <p>Step 1: Calculate % volume thinner.</p> <p>0.5 liters/5 liters = 1/10 = 10%</p> <p>So the number we will use for our % thinner by volume is 0.1 L.</p> <p>Step 2: Calculate WFT range.</p> <p>Low WFT = 75 μm DFT x (1 + .10 TBV) (0.35 SBV)</p> $= 75 \mu\text{m} \times \frac{1.10}{0.35} = 82.5 \mu\text{m}$ $= 236 \mu\text{m}$ <p>High WFT = 100 μm DFT x (1 + .10 TBV) 0.35 solids by volume</p> $= 100 \mu\text{m} \times \frac{1.10}{0.35} = 110 \mu\text{m}$ $= 314 \mu\text{m}$

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.)

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 .

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 ft² if the average DFT is 12 mils?

1 gallon covers 1,604 ft² at a WFT of 1 mil. At a WFT of 12 mils, the area covered (by one gallon) is:

$$\frac{1604}{12} = 133.7 \text{ ft}^2.$$

To cover 1,000 ft² at this same thickness, volume required is:

$$\frac{1,000}{133.7} = 7.48 \text{ gals.}$$

How many liters of material are required to coat an area of 100 m² if the average DFT is 300 µm?

1 liter covers 1,000 m² at a WFT of 1 µm. At a WFT of 300 µm, the area covered (by one liter) is:

$$\frac{1,000}{300} = 3.3 \text{ m}^2.$$

To cover 100 m² at this same thickness, volume required is:

$$\frac{100}{3.3} = 30.3 \text{ liters}$$

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
$1,604 \times 0.60 = 962 \text{ ft}^2 \text{ at 1.0 mil dry}$	$1000 \times 0.60 = 600 \text{ m}^2 @ 1 \mu\text{m dry}$
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: <u>$600 \text{ m}^2 @ 1 \mu\text{m} = 4 \text{ m}^2/\text{L}$</u> 150 µm
<u>$962 \text{ ft}^2 @ 1.0 \text{ mil} = 160.3(160) \text{ ft}^2/\text{gal}$</u> 6.0 mils	

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:



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).	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).
$160 \text{ ft}^2/\text{gal} - (160 \times 0.20 \text{ loss}) = 160 - 32 = 128 \text{ ft}^2/\text{gal}$	$4 \text{ m}^2/\text{L} - (4 \times 0.20 \text{ loss}) = 4 - 0.8 = 3.2 \text{ m}^2/\text{L}$

This same information is often expressed in the following formulas:

Theoretical Spreading Rate	
English	Metric
$\frac{\% \text{ SBV} \times 1604 \text{ (ft}^2/\text{gal)}}{\% \text{ solids} \times \text{DFT (mils)}}$	$\frac{\% \text{ SBV} \times 1000 \text{ (m}^2/\text{L)}}{\text{DFT (\mu m)}}$

Practical Spreading Rate
Theoretical spreading rate – (theoretical spreading rate \times %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:

$$\text{Material Consumption} = \frac{\text{Area (ft}^2 \text{ or m}^2)}{\text{Practical Coverage (gal or L)}}$$



Example	
English	Metric
<p>The following data are presented for a given coating:</p> <p>Recommended DFT = 5 mils</p> <p>% Solids by volume = 45%</p> <p>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?</p> <p>Theoretical spreading rate (ft^2/gal) $= \frac{0.45 \times 1,604}{5} = 144 \text{ ft}^2/\text{gal}$</p> <p>Practical spreading rate $= 144 - (144 \times 0.10) = 129.6 \text{ ft}^2/\text{gal}$</p> <p>Material to order = $\frac{5,000 \text{ ft}^2}{129.6 \text{ (ft}^2/\text{gal)}} = 38.58 \text{ gals}$</p> <p>Sensible order = 39 gallons</p>	<p>The following data are presented for a given coating:</p> <p>Recommended DFT = $125 \mu\text{m}$</p> <p>% Solids by volume = 45%</p> <p>The contractor must apply this coating to 500 square meters and anticipates a loss of 10%. How many liters must the contractor order?</p> <p>Theoretical spreading rate (m^2/L) $= \frac{0.45 \times 1,000}{125} = 3.6 \text{ m}^2/\text{L}$</p> <p>Practical spreading rate $= 3.6 - (3.6 \times 0.10) = 3.24 \text{ m}^2/\text{L}$</p> <p>Material to order = $\frac{500 \text{ m}^2}{3.24 \text{ m}^2/\text{L}} = 154.32 \text{ liters}$</p> <p>Sensible order = 155 liters</p>

Practice Problem 11	
English	Metric
<p>Recommend DFT = 6.0 mils</p> <p>% Solids by volume = 54%</p> <p>thinner added = 10%</p> <p>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?</p> <p>b) What WFT must be applied to achieve the intended DFT?</p>	<p>Recommend DFT = $150 \mu\text{m}$</p> <p>% Solids by volume = 54%</p> <p>thinner added = 10%</p> <p>a. The contractor must apply this coating to 650 square meters and anticipates a loss of 15%. How many liters must the contractor buy?</p> <p>b) What WFT must be applied to achieve the intended DFT?</p>

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

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 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 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

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

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



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

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

Table 4**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

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



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

$$\frac{\text{Allowable Coating} \times 128 \text{ oz/gal}}{\text{Thinner} - \text{Allowable}} = \text{Allowable thinning in oz/gal.}$$
$$\frac{(\text{VOC lbs/gal}) - (\text{VOC lbs/gal})}{(\text{VOC lbs/gal}) - (\text{VOC lbs/gal})}$$

3. To calculate in grams per liter

$$\frac{\text{Allowable Coating} \times \text{VOC thinner}}{\text{Thinner} - \text{Allowable}} = \text{Allowable thinning in gr/l.}$$
$$\frac{(\text{VOC gr/l}) - (\text{VOC gr/l})}{(\text{VOC gr/l}) - (\text{VOC gr/l})} \text{ (gr/l)}$$

4. Example

	<u>lbs/gal</u>	<u>gr/l</u>
Allowable VOC	3.5	420
VOC coating	3.15	378
VOC thinner	6.85	822

$$\text{A. } \frac{(3.5) - (3.15)}{(6.85) - (3.5)} \times 128 = \frac{(3.5)}{(3.35)} \times 128 = (.104) \times 128 = 13.37 \text{ oz/gal}$$

$$\text{B. } \frac{(420) - (378)}{(822) - (420)} \times 822 = \frac{(42)}{(402)} \times 822 = (.104) \times 822 = 85.48 \text{ gr/l}$$

Temperature (Fahrenheit to Centigrade)

$$^{\circ}\text{F} = \frac{9}{5} \text{ } ^{\circ}\text{C} + 32$$

$$^{\circ}\text{C} = \frac{5}{9} (^{\circ}\text{F} - 32)$$

F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
-25	-31.7	1	-17.2	26	-3.3	51	10.6	76	24.4	125	51.7
-24	-31.1	2	-16.7	27	-2.8	52	11.1	77	25.0	150	65.6
-23	-30.6	3	-16.1	28	-2.2	53	11.7	78	25.6	175	79.4
-22	-30.0	4	-15.6	29	-1.7	54	12.2	79	26.1	200	93.3
-21	-29.4	5	-15.0	30	-1.1	55	12.8	80	26.7	225	107.2
-20	-28.9	6	-14.4	31	-0.6	56	13.3	81	27.2	250	121.1
-19	-28.3	7	-13.9	32	0	57	13.9	82	27.8	275	135.0
-18	-27.8	8	-13.3	33	0.6	58	14.4	83	28.3	300	148.9
-17	-27.2	9	-12.8	34	1.1	59	15.0	84	28.9	325	162.8
-16	-26.7	10	-12.2	35	1.7	60	15.6	85	29.4	350	176.7
-15	-26.1	11	-11.7	36	2.2	61	16.1	86	30.0	375	190.6
-14	-25.6	12	-11.1	37	2.8	62	16.7	87	30.6	400	204.4
-13	-25.0	13	-10.6	38	3.3	63	17.2	88	31.1	425	218.3
-12	-24.4	14	-10.0	39	3.9	64	17.8	89	31.7	450	232.2
-11	-23.9	15	-9.4	40	4.4	65	18.3	90	32.2	475	246.1
-10	-23.3	16	-8.9	41	5.0	66	18.9	91	32.8	500	260.0
-9	-22.8	17	-8.3	42	5.6	67	19.4	92	33.3	525	273.9
-8	-22.2	18	-7.8	43	6.1	68	20.0	93	33.9	550	287.8
-7	-21.7	19	-7.2	44	6.7	69	20.6	94	34.4	575	301.7
-6	-21.1	20	-6.7	45	7.2	70	21.1	95	35.0	600	315.6
-5	-20.6	21	-6.1	46	7.8	71	21.7	96	35.6	625	329.4
-4	-20.0	22	-5.6	47	8.3	72	22.2	97	36.1	650	343.3
-3	-19.4	23	-5.0	48	8.9	73	22.8	98	36.7	675	357.2
-2	-18.9	24	-4.4	49	9.4	74	23.3	99	37.2	700	371.1
-1	-18.3	25	-3.9	50	10.0	75	23.9	100	37.8	725	385.0
-0	-17.8										





Level 1

Chapter 2.1

Environmental Test Instruments

Environmental Testing

Environmental, or ambient, conditions can greatly affect all phases of a coating operation. This section will examine specific environmental conditions and tests that are most likely to be of concern to the coating inspector.

Environmental Conditions Affecting the Coating Job

Environmental conditions that can affect a coating job are:

- Surface (substrate) temperature
- Ambient conditions, including:
 - Temperature
 - Relative humidity
 - Dew point
 - Wind velocity
 - Airborne contaminants (e.g., chemical fumes, auto exhaust, salt spray)

Test Instruments

Instruments used to measure environmental conditions include:

- Surface-contact thermometer
- Sling psychrometer (whirling hygrometer)
- Psychrometric charts



Surface Temperature

The magnetic surface-contact thermometer is one of the most common instruments for determining surface temperature.

The instrument consists of a bimetallic sensing element, protected from drafts. The instrument includes two magnets on the sensing side which are attracted to the steel surface.

The instrument must be allowed to stabilize before measurements are made; stabilization time can vary, but is likely to be at least 5 minutes.



Figure 1 Magnetic Surface Contact Thermometer

Other field instruments used for determining surface temperature are *direct-reading thermocouple/thermistors*. This instrument has a sensing probe that provides a direct temperature readout. It takes only a few seconds for the instrument to stabilize before measurements can be made.



Figure 2 Direct Reading Thermocouple

With any instrument used to determine air and surface conditions, measurements should be made at the actual locations of work. The steel surface temperature should be measured at a variety of points within the area to be painted, including those that are likely to be hotter or colder than the norm.

Moisture may condense if the surface temperature is at or below the dew point and will occur first at the coldest points. This can cause flash rusting of blasted steel, leading to poor performance of the applied coating film or other types of coating failures.

At hotter points on the surface to be coated, coating failure may result when the coating is applied to a substrate whose temperature is too high. Film formation problems are most likely to occur as a result of rapid solvent release, and poor wetting of the surface.

Recommended upper and lower limits for surface temperature during coating application can be determined from the coating technical data sheet or directly from the coating manufacturer.

The surface-temperature thermometer may give a false reading if it is used in direct sunlight. The location of measurements should represent the surface that is to be coated.

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

Ambient Conditions

The temperature and relative humidity of the surrounding air affect both the blast cleaning and coating processes.

Temperature

Ambient air temperature is more likely to affect coating application than the blasting operation. The rate of solvent evaporation and the rate of curing are both affected by ambient temperature. When temperatures are too low, coatings may not dry or cure. When temperatures are too high, coatings may not wet the surface (i.e., flow into good contact with the surface) and may have problems with film formation.

Relative Humidity

Relative humidity (RH) is a measure of the amount of moisture in air compared to saturation level and may affect the coating operation.

Many coating specifications restrict coating application when the relative humidity is expected to be too high, i.e., greater than 80, 85, or 90%, depending on the coating type and the environment in which it is applied. When the RH is too high, solvents do not readily evaporate, and malfunction of the coating cure reaction may occur. Coatings exposed to high RH after application often show coating defects such as *blushing* and poor gloss or, for epoxies, *amine blush*. Waterborne coatings are—generally—more likely to be affected by high RH than other types of coating.



Some coatings (e.g., inorganic zinc silicate) require a minimum RH to cure properly and must be *misted* (i.e., sprayed with water) if the humidity is especially low.

Dew Point

Dew point is the temperature at which water vapor will condense, leaving water on the surface. A high dew point is an indication of high relative humidity. Dew point is an important consideration when blast cleaning, because moisture condensation will cause freshly blasted steel to rust.

When coating is to be done outdoors, newly cleaned surfaces should usually receive the first protective coat long before nightfall, when lower temperatures may cause condensation on the surface. This consideration is particularly important with blast cleaned surfaces. Even indoors, a blast cleaned surface should not remain uncoated overnight, if at all possible. Many coating specifications state coatings should be applied within 4 hours of the completion of blast cleaning.

Dew point can be an important consideration in the overall coating process. A film of moisture between coats can cause premature coating failure. To help prevent such occurrences, a dew point/surface temperature safety factor has been determined. Final blast cleaning and coating application should not take place unless the surface temperature is at least 3°C (5°F) higher than the dew point.

Sling Psychrometer

The *sling psychrometer* (sometimes called a whirling hygrometer) is the type of psychrometer most often used in coating inspection. It is used to measure the ambient air temperature (dry-bulb temperature) and wet-bulb temperature as close to the work site as is practicable. This information is then used to calculate the dew point and relative humidity.





Figure 3 Sling Psychrometer

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*. The dry-bulb thermometer measures the air temperature; the wet-bulb thermometer measures a lower temperature, resulting from the latent heat loss due to water evaporation from the wetted sock. The faster the rate of water evaporation, the more cooling occurs, resulting in lower humidity and dew point temperature.

The sling psychrometer is used by saturating the sock with clean water and whirling the instrument rapidly for about 40 seconds. A reading of the wet-bulb temperature is then taken. The process is repeated (spinning and reading without additional wetting) until the temperature stabilizes. When the wet-bulb reading remains constant, it should be recorded. The dry-bulb reading is also read, *after* the wet-bulb reading has stabilized. This dry-bulb reading is recorded.

If the sock becomes dirty, as it frequently does when used near blasting or coating work sites, it should be replaced; otherwise, inaccurate readings may occur.

The fan-operated psychrometer operates in a similar way to the sling psychrometer, but air is moved using a fan rather than slinging the instrument. After about 2 minutes, the temperature stabilizes. Only the wet-bulb temperature is observed, and when it remains stable, both wet- and dry-bulb temperatures are recorded.

Care should be taken when temperatures are below 0°C (32°F). Sling or fan-operated psychrometers are not reliable because of the water freezing. If the temperature is this low, humidity should be determined using a direct-readout humidity instrument. It is unusual for coatings to be applied in such low temperatures anyway.

Electronic Hygrometers

Electronic instruments are available to determine relative humidity, air temperature, and dew-point temperature. These instruments are convenient and easy to use. Accuracy may vary, and calibration is necessary at frequent intervals. In addition, the instruments must be accurate near the top of their scale (i.e., close to 100% RH), because this is the critical point at which decisions on whether to work or not must be made by the contractor or the inspector.



Figure 4 DEWcheck Electronic Hygrometer

Psychrometric Tables

After the dry-bulb and wet-bulb temperatures are measured, *psychrometric tables*, such as those of the United States Department of Commerce Weather Bureau, are used to determine the relative humidity and dew-point temperature of the air.

The difference between the dry-bulb temperature and the wet-bulb temperature is calculated. This difference is called the *wet-bulb depression*. The dry-bulb temperature and wet-bulb depression can be found on the vertical and horizontal axes of the look-up tables respectively, and their point of intersection locates the relative humidity or dew-point temperature, depending on the particular table.

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 the table based on a barometric pressure equivalent to 30 in. of mercury. For absolute accuracy, barometric pressure should be determined and the appropriate table used to determine RH and dew point.

Special calculators may also be used to determine RH and dew point temperature.

Results of measurements are generally shown in a daily report, using a standard format such as that in the following table.

Inspection Details—Ambient Conditions					
Time-->					
Wet-Bulb Temperature					
Dry-Bulb Temperature					
RH (%)					
Dew Point					
Steel Temperature					
OK to work - Yes/No?					

Ambient Conditions—Wind Effects

Wind can affect the coating job in several ways:

- Blowing abrasives past the boundaries of the abrasive-blast work area to where coatings are being applied
- Causing excessive drift or overspray of sprayed coatings
- Accelerating solvent evaporation after application
- Contributing to formation of dry spray
- Blowing contaminants, such as sea spray, salt, blast abrasive, dust, or sand, onto the work surface

The coating inspector should be alert to any effect the wind may have on the coating job. If the wind is harmful to the coating job, the coating inspector should advise his or her supervisor immediately and should also advise the contractor, if he or she has authority to do so.

High wind speed sometimes represents a safety hazard. When work is performed at some height, winds of 64 kph (40 mph) or more are considered to be dangerous. When work is performed on offshore platforms, safety boats and rescue craft cannot operate reliably, 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 data concerning weather conditions for the current day or accurate historical records of past conditions. Weather forecasts for the next day and for several days in advance may be found by contacting the weather bureau.

Bureau records may also be useful for checking conditions when records of weather conditions were not kept on site or when the accuracy of recorded measurements is suspect.



Airborne Contaminants

Debris

Dust, dirt, oil, mud, sand, leaves, blowing papers, and insects are *debris*. These contaminants can be blown onto the work surface and often become included in wet paint films. Inclusions may cause premature failure through loss of adhesion or other coating defects.

Chemically Active Contaminants

Salt spray, industrial waste, auto exhaust, chemical fumes, and other airborne contaminants can affect coating life by enhancing the efficiency of the electrolyte in the corrosion process or by forming deposits on the surface that lead to premature loss of adhesion.

When salts become bonded to steel by chemical reaction, they are not easily removed by conventional surface preparation methods (e.g., solvent cleaning, dry abrasive blasting, etc.). In recent years, the significance of such deposits has been increasingly recognized.

The most common salts known to cause problems with coating films applied to steel are:

- Sulfurous compounds generated by industry, particularly those that burn fossil fuels, e.g., coal and oil.
- Chloride compounds, particularly sodium chloride, most often generated by sea winds and likely to be deposited near marine environments.
- Nitrogenous compounds mostly generated in urban environments where vehicle exhaust output is high. The effect of nitrate contamination is most likely to be found on bridges and similar structures associated with roads. Lightning also generates about 40,000,000 tons of nitrogenous compounds per year (worldwide).

Soluble salt contaminants encourage corrosion and should be washed from surfaces wherever possible to reduce corrosive effects. In their natural state, these compounds are not, however, at their most dangerous. Chemical reaction between the compounds and the underlying substrate (most often steel) creates a new set of compounds, many of which are electrochemically bound to the surface. These include:

- Sulfur dioxide reacts with moisture to form sulfurous and sulfuric acids. These, in turn, react with steel to form ferrous/ferric sulfate.
- Sodium chloride reacts with iron to form ferrous and ferric chlorides.
- Nitrogen compounds react with iron to form nitrates of iron.

As we have already said, reacted salts bound with the substrate iron are not easily removed by dry blast cleaning. Contaminated surfaces may be blast cleaned thoroughly and have the appearance of clean metal, but in high relative humidity can be seen to turn dark rapidly, often within minutes of completion of blasting. This flash rusting is an indication of the presence of salts.

When coatings are applied over such contaminants, the contaminants act as a focus for corrosion activity under the coating, drawing and holding moisture and increasing the tendency to form blisters.

Removal of these contaminants can be more difficult when the steel is severely pitted. In such cases, a combination of wet abrasive blasting or high-pressure waterjetting followed by dry abrasive blasting may be required to reduce the amount of contamination to an acceptable level.

Note that proprietary compounds may be added to wash water or waterjetting solution to aid removal of soluble salts. Tests have shown that levels of surface contamination may be significantly reduced by using such soluble-salt removers. These are, generally, slightly acidic compounds that aggressively dissolve more of the

soluble salts and appear to leave a surface for coating that is chemically *cleaner* and still suitable for coating application.

The effect of soluble salts as contaminants has long been recognized. Unfortunately, the industry has not yet arrived at a consensus on acceptable maximum levels of contamination. Nor has industry developed a standard procedure for the detection and evaluation of these soluble salts. Currently NACE, jointly with SSPC, is working to develop such a standard test method. It is expected that this joint effort will lead to some recommendations for acceptable maximum levels of soluble salts, where to test, when to test, and how often to test surfaces prior to coating.

ISO also has an active committee dealing with soluble salts¹ with input provided by consensus bodies in many countries, including the United States.

Test methods described in this section represent the current state-of-the-art, but do not constitute standards or recommendations made by NACE International. Written guidelines produced by the standards authorities are generally in draft form at the time of writing (August 2002).



Figure 5 Soluble Salt Remover

¹ ISO-15235-1, Technical Report: Levels of Water-Soluble Salt Contamination (Chlorides and Sulfates) Before Application of Paints and Related Products

Tests for soluble salts are most often performed after surface preparation and before application of coatings but may also be performed prior to any surface preparation work. For example, tests for the presence of chlorides may be performed on pipe delivered to a pipe coating plant as deck cargo on a ship or barge. If levels are found to exceed $10 \mu\text{g}/\text{cm}^2$, pipe should receive extra treatment (acid wash) prior to normal surface preparation. If levels are measured at less than $10 \mu\text{g}/\text{cm}^2$, pipe proceeds to the coating plant in the usual way.

(Note: Levels of surface salt contamination are generally measured in metric units, most often micrograms per square centimeter [$\mu\text{g}/\text{cm}^2$]).

If salts are detected, and perhaps measured as exceeding specified minimum levels, further action may be required by the specification. It should be understood that the coating specification must clearly define both acceptable limits of salt contamination and action(s) to be taken if limits are exceeded.

Typical test that may be performed by inspectors include:

- Collection of test samples by:
 - Washing or swabbing
 - Rubber sample holders
- Testing liquid samples by:
 - Indicator paper
 - Kitagawa tubes
 - Liquid chemistry
 - Conductivity measurement

Examples of each of these tests follow. The sample is collected, then tested. In this developing technology, collection and testing may be performed in a variety of combinations.

Sample Collection

Washing or Swabbing

The steel surface may be washed with distilled water to collect a test sample. The most common method used is defined by ISO and requires washing an area of 15 cm x 15 cm with a liquid sample of 22.5 mL.

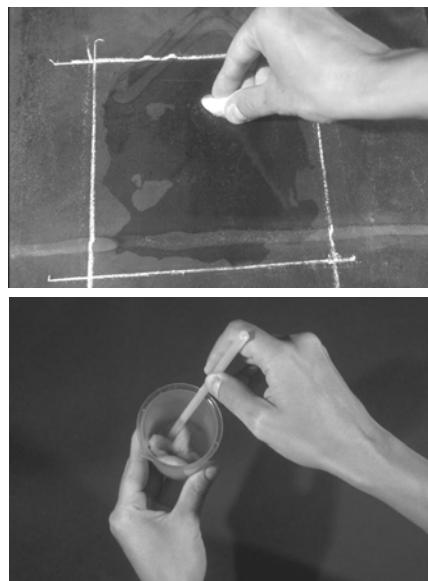


Figure 6 Washing/Swabbing to Collect Sample for Testing

Rubber Sample Holders

Two proprietary sample holders are commonly used—the *Bresle* patch or the *Chlor-Test*®. Each uses a specific volume of test solution, although the Bresle Patch is generally used with distilled water and the *Chlor-Test*® kit with a proprietary test solution.

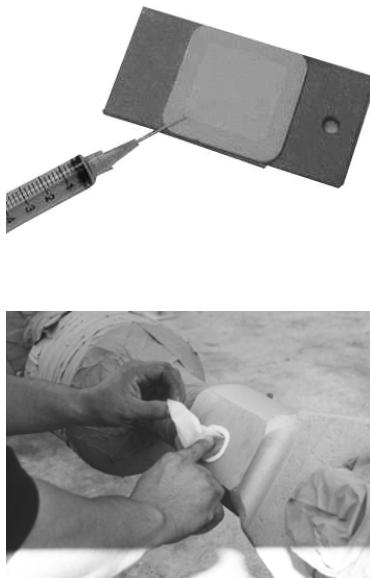


Figure 7 Rubber Sample Holders

Testing Liquid Samples

Indicator Paper

Proprietary indicator papers are made and provided by many suppliers. These include:

- Potassium ferricyanide paper, used to detect the presence of soluble iron. The orange paper turns blue when soluble iron is drawn from the surface into the paper.
- Merkoquant iron test sticks, which can detect soluble iron salts by color comparison in a range of 0 to 100 ppm or 0 to 1,000 ppm, depending on the test stick chosen.
- Quantab test papers, which draw the test solution onto a vertical scale by capillary action, and indicate the quantity of chloride ions in a test solution

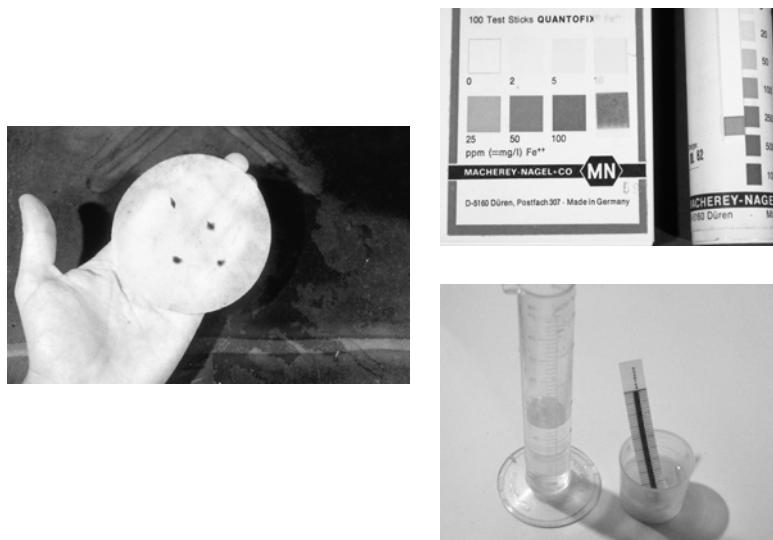


Figure 8 Indicator Papers

Kitagawa Tubes

Glass tubes, containing test reagent chemicals, draw the test liquid up the tube by capillary action. The development of a color change inside the tube (which has a scale) indicates the chloride quantity in the test solution. Most common Kitagawa tubes measure chloride levels in 60, 200, and 2,000 ppm increments. Sulfates are analyzed using turbidity units and nitrates are usually analyzed using photo-sensitive reagents impregnated onto a plastic strip which results in a color change, when present.



Figure 9 Kitagawa Tubes

Liquid Chemistry

Once collected, test samples may be tested by any chemistry laboratory. A wide variety of tests may be performed, and highly accurate results can be attained. It should be remembered that most sample collection methods are not themselves very accurate.

Conductivity Measurement

Electrical conductivity measurements indicate the total soluble-salt presence but cannot indicate the specific salts that are present. Test samples are measured using a resistance meter. It is common then to perform mathematics on the test result to derive an indication of chloride concentration in the test solution.

Soluble Salts in Specifications

There are many variations in test methods, in the surface tolerances of different coatings, and in opinions regarding soluble salts. If inspection is to be effective, the specification should very clearly state:

- Limits to be accepted
- Specific salts to be limited
- Test method to be used

A typical specification clause may say:

Blast cleaned surfaces shall be tested for soluble salts prior to 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 ft² (10 m²). 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 such testing is to be meaningful, inspectors, owners, and contractors must all be familiar with the test methods and materials associated with soluble salts. Specified requirements that cannot be achieved and inconsistent testing are likely to lead to confusion.

Contamination by soluble chemical salts is discussed in more detail in CIP Level 2.





Level 1

Chapter 2.2

Inspection Procedures

Inspection Procedures

In this section, we will examine a sample inspection procedure that relates to an ongoing coating project on an offshore drilling platform.

The role of a third-party coating inspector may change significantly from one job to another. To help you get the flavor of the job, we will now present an outline of one coating inspection job on an offshore drilling platform, which was undertaken by a NACE-Certified Coating Inspector—Level 3. This sample procedure was prepared by a company that performs inspection work offshore in the Gulf of Mexico.

Sample Inspection

0600: Attend contractor's safety meeting; contribute, but do not try to conduct the meeting. This is a good time to bring up any safety concerns you may have and to review any specific instructions given by the client.

0630: While the contractor is rigging equipment for the day's work, record ambient conditions in the area where work is to proceed. Record the data in the daily report or logbook, including:

- Ambient temperature
- Relative humidity
- Surface temperature (in coldest and warmest areas)
- Dew point

Remember that the steel surface temperature should be at least 5°F (3°C) above the dew point.

0700: As blasting operations begin, observe and record:

- Is the required safety equipment being used?
- Are the required safety procedures being followed?

If not, immediately notify the contractor's foreman and request correction. Do not approach workers directly unless there is a life-threatening situation. The contractors are responsible for the safety of their personnel. You are responsible for your own safety, and you are required to observe the safety regulations of your own company as well as those of the owner and relevant federal and state agencies.



Caution: Be careful to avoid accepting responsibility for safety enforcement. That is the job of the safety supervisor. Your job is to observe, document, and report.

0800: Set up paperwork for the day. Use this time to catch up on any paperwork not completed to this point. Do all the reporting required, and check the calibration of your inspection equipment.

0900: Contractor's break time. Inspector should:

- Check blasted areas. Use an oil-free chalk (or other agreed marker) and mark all areas that do not meet the required standard. In some cases, you may need to note which areas are concerned to help with your recheck prior to painting.
- Take surface profile readings and check the ambient conditions again.
- Record all your measurements.
- Inform the foreman of areas which require additional blast cleaning. Be aware that the blaster may not have finished blasting in that area, and do not overreact at this intermediate inspection stage.
- Recheck any wrapped or masked equipment.

0920: Observe contractor's operations.

- Check DFT on areas coated the previous day. Mark any areas that have insufficient thickness.
- Look for pinholes, runs, sags, misses, dry spray, etc.
- Log the results of your inspection

1130: Take lunch at the same time as the foreman so the two of you can check on blasted areas while the crews are shut down for lunch.

It is important for the foreman to be involved in the inspection procedures so that he or she can inform the crew of any areas that may need to be reblasted.

1200: Inspect blasted areas and mark areas that are not acceptable. Be sure to use the oil-free chalk. Also inspect areas that were blasted early in the day for any sign of turning or rust bloom.

Note: *Rust bloom* is the red-brown discoloration that affects blasted steel when it is left uncoated long enough for the rust reaction to begin.



- Inspect adjacent areas for overblast. Mark these areas.

Note: Most overblast can be prevented by having a blaster keep the work in-square. This means working in a disciplined way, with the blaster finishing one area before moving on to another.

- Inform the foreman of areas marked for reblast.
- Inspect areas that were wrapped or masked.

1245: Crew should return to work to reblast all areas marked for rework, and to square up areas in which they are working.

- Check to see that the bottoms of all flanges and other items have been completed.

1400: Crew should be squared up and ready to halt blasting operations. Blasted areas should be blown down with clean air and vacuumed (where feasible) before the final inspection.

- Inspect areas and mark any that require additional work.
- Inspect again until all areas to be coated are satisfactory.
- When blast-cleaned areas are satisfactory and accepted, inspect the areas for loose abrasives or dust contamination before allowing coating operations to proceed.
- Inspect for dust contamination using the transparent tape method.

1430: Inspector should:

Before coating application:

- Check to see that specified coatings, thinners, etc. are being used.
- Record batch numbers of the coatings and thinners and dates of manufacture.
- Take retained wet sample, if required; use clean containers when taking a partial sample.

During mixing operations:

- Check that coatings are mixed according to the specifications and the manufacturer's mixing instructions. If thinner is used, make sure it is measured accurately.

During spraying operations:

- Ensure that equipment is the type specified and conforms to the manufacturer's recommendations.
- Observe and record air pressures used for the pot and for atomization.

- Observe and record the WFT measurements made by the painters. A painter should possess and use a wet-film gauge and monitor his or her own application WFT. If you have approval, you should spot check the work to ensure that the WFT achieved is that which will produce the desired DFT when the coating dries.

The inspector should be on the job site at all times when paint application is underway, checking all stages of the application and observing the overall quality of the coating application. Often, the final coating film quality can be predicted by the manner in which the painter is using the spray gun. Observe:

- Is it too far from the surface?
- Is it too close?
- Is it being arced?
- Is it adjusted properly, producing a uniform spray pattern?

If the gun is delivering an uneven pattern, such as a wet center with dry spray at the edges, you may be able to help the foreman again by pointing out the problem.

During coating application, check the ambient conditions again, and record your findings.

1630: Inspector should:

- Observe the clean-up procedures.
- Count the quantity of paint materials used and record.
- Check the coating film for runs, sags, and misses before the coating dries.
- Request additional work on defective areas.

1700: Inspector should:

- Check job site at the end of a working shift to ensure that all equipment has been secured and trash removed from the area. If required, obtain a Material Usage Report from the contractor for documentation purposes.
- Complete all paperwork at this time.

Inspection Procedures Summary

Every tool in your inspection kit has a specific function that should be included in the inspection procedure you follow.

Inspectors are responsible for:

- Using their equipment properly.
- Ensuring the equipment is calibrated.
- Recording the results of all inspections.

It is very important that inspectors follow a proper inspection procedure that is within the bounds of the specifications.

Inspection procedures may be defined by the client or may come from the inspector's understanding of the project. Inspection should be done in the proper sequence. Failure to do so could lead to time delays and cost the owner or contractor considerable time and money.

The inspector must be alert, mentally into the job, and attentive to details. Small details may mean a lot. For example, without a properly sized functioning spray tip, the contractor can't paint; production time and the blast may be lost. Without a battery, an inspector may not be able to make a measurement or conduct an inspection step, thus delaying the contractor and, maybe, final acceptance by the owner.

The inspector must know everything that is happening and everything that is scheduled to take place to be able to coordinate events between the contractor and the company representative.

Inspection Procedure Checklist

- Pre-job conference—on-site inspection
- Obtain specifications, data sheets. Read and compare.
- Pre-inspect equipment and materials.
- Inspect safety equipment and rigging for your own protection. The inspector, unless authorized, cannot tell the contractor how to do the rigging.
- Calibrate equipment daily before use.
- Ensure protection of owner's equipment.



- Monitor ambient conditions.
- Perform visual inspection of blasting/painting operation and machinery.
- Perform required tests on blasting/painting operation.
- Ensure proper housecleaning.
- Record all the functions performed.



Level 1

Chapter 2.3

Practice Piece

Specification

Coating Specification ARC-CS2

for
Exterior Painting of Petroleum Product Storage Tanks
owned by
Alpha Refining Company, 10920 Bledsoe Avenue, Roaming Creek, VA 17216

1.0 General scope

- 1.1 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).
- 1.2 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, 1987 prepared by Echo Engineering Co.) for location of the above described tanks and appurtenances.
- 1.3 All instruments, recorders, gauge glasses, and galvanized surfaces associated with the tanks shall be protected throughout the work and protected against damage or overcoating.
- 1.4 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, 1999. Tenders will be due on or before 14.00, November 5, 1999, and the contractor will be required to commence work on or before April 19, 2000. All coating work covered by this specification must be completed on or before June 21, 2000, subject to a penalty of \$5,000 for each day completion of the job is delayed beyond June 21, 2000.
- 1.5 The owner has inspected these tanks and believes there is no lead in the existing paint on these tanks.
- 1.6 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.
- 1.7 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.

2.0 Terms and definitions

- 2.1 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.
- 2.2 **Owner** means the registered owner of the facility, or his or her designated representative.
- 2.3 **Applicator/contractor** means the successful tender submitter responsible for doing the coating work.
- 2.4 **Foreman** means the applicator's representative on site who is the responsible party for the contractor.
- 2.5 **Inspector** means the person designated to carry out the inspection procedures according to the specification.
- 2.6 **Specifying engineer** means the person with the authority to resolve nonconformance or make changes to the specifications.
- 2.7 **Specifier** means the person who drafted the specifications. He or she may or may not also be the specifying engineer.
- 2.8 **Coating manufacturer** means the supplier of the coating materials used on the project, or a designated representative.

3.0 Reference standards

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 Air

CODE OF FEDERAL REGULATIONS (CFR)

29 CFR 1910.134 Respiratory Protection

29 CFR 1910.1000 Air Contaminants

29 CFR 1910.1200 Hazard Communication

FEDERAL STANDARDS (FED-STD)

FED-STD-595 (Rev. B) Colors Used in Government Procurement

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

SSPC – THE SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC Guide to VIS 1 (1989) Guide 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

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

Sa 2 ½ Very Thorough Blast Cleaning

4.0 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:

Use of breathing apparatus in accordance with 29 CFR 1910.134 (owner may require respirator fitting for all contract personnel).

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).

Warning signs shall be posted around the perimeter of the blast area, and information provided in accordance with 29 CFR 1910.1200 (Hazard Communications).

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.

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.

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.

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.

5.0 Pre-job conference

This specification, together with all relevant job standards for surface preparation, primer, topcoating, 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.

6.0 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.

7.0 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- μ m) plastic

sheeting or 20-oz (0.62-gm/cm²) 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. [Note: 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 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 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.

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%.

8.0 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.

All coating application shall be by conventional airspray 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.

9.0 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 multi-component 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.

10.0 Workmanship

All work shall be performed in strict accordance with these specifications and 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.

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*.

11.0 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

12.0 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.

13.0 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.

14.0 Inspection and reporting

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. 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:

Environmental Conditions

- Magnetic steel surface thermometer
- Sling psychrometer and psychrometric charts

Surface

- Surface comparators (ISO and Keane-Tator)
- Testex replica tape

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)

Equipment and air supply

- Blotter test
- Hypodermic needle pressure gauge

Abrasive

- Sieve test
- Vial test

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 inspector's responsibilities and authority
- 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 ¹ (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 ² (4.0/6.0 mils, 100/150 µm) [white]	Amercoat 385 ³ (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]

¹ Carbozinc 11 is not water-borne zinc

² CarboLine 890 is not water-borne epoxy

³ Amercoat 385 is not water-borne epoxy

Report Form

NACE International Coating Inspector Program

Inspector Name: _____

Date: _____

Site Location: _____

Client NAME: _____

Ambient Conditions at Worksite	Delete as necessary	Time	Time	Time	Time	Time
Air Temperature	°F/C					
Wet Bulb Temperature	°F/C					
Relative Humidity	%					
Steel Temperature	°F/C					
Dew Point	°F/C					

Abrasive Blasting : Type/Grade of Abrasive _____ **Specified Standard** _____ **Abrasive Checked for cleanliness (Y/N)** _____ **pH:** _____

Surface Profile Measurements	Average	minimum	Maximum	Hrs. left Uncoated	Comments / Attach tapes
Location	mils/µm	mils/µm	mils/µm		
General Comments					

Coatings

Location	Manufacturer's Name & description	Batch Number(s)	Application Method	Color	Avg. DFT before	WFT Measurements		DFT This Coat	
						Minimum	Maximum	Minimum	Maximum
1.									
2.									
3.									

Coat #	Mixing & thinning	Storage	Holiday Test ?	Defects/Comments
1.				
2.				
3.				



Level 1

Chapter 2.4

Documentation

Inspection Documentation

The coating inspector will almost invariably be required to provide his or her client with some documentation of his or her inspection. Even if documentation is not specifically required, good practice dictates that accurate, detailed records be kept.

Inspection records should show all environmental conditions and items involved in the pretreatment, cleaning, materials, and application for a coating job.

Good inspection documentation can provide much valuable information on the durability of coatings and the economical protection they afford. Conversely, this type of information is lost through poor record keeping or no record keeping at all.

Some organizations do keep records. Sometimes, though, the records are of little value when it comes to determining the protection afforded and the cost of protection per year. A company that has a well developed coatings program, including ongoing maintenance, benefits greatly from detailed reporting of the inspection process on coating projects.

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 inspection of each coating project, along with proper inspection reporting, 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

While personnel move about in (and outside of) a company, records usually remain with the facility. Good



records then can provide the maintenance department with detailed information on what was coated, with what materials, when, how, by whom, and at what overall cost.

An important part of the inspector's job is maintaining regular communication with the owner's representative and with the contractor. In addition to frequent, relatively informal conversation on the job, that communication takes the form of regular reports and meetings.

Objective and professional records are important, not least because they may be used for reference at a later date, and may even be examined in a court of law, when disputes arise. Accurate statements of the facts must be made in a way that is complete, clear, and concise.

Exactly what kind of reporting is to be done by the inspector should be identified in the coating specification or developed during the pre-job conference. As previously mentioned, a common understanding of specifications must be ensured during the pre-job conference.

Documentation may include:

- A daily written report using standardized forms
- An inspection log or notebook used to record all inspection activity
- Routine reports
- A weekly progress meeting

The daily reports and routine reports generally are customized for each project.

Inspector's Logbook or Daily Report

Some inspectors record their field measurements and observations in a small bound book called a *daily logbook*. The inspector will record all of his or her activities and those of the contractor.



Usually the pages are numbered and the information is recorded in ink. Corrections are made by striking through the error and entering the correction along with the inspector's initials. The inspector should initial each page as he or she records information.

Some inspectors use the logbook in the field and then transfer that information onto a daily report form. Normally the inspector retains his or her own personal logbook and can use the log as a means of communicating with his or her supervisor.

Many inspectors view this practice of keeping both a logbook and a daily report form as duplication of effort, and elect to use only a daily report form instead. Here the inspector records any measurements taken directly onto the report form.

As an alternative, the inspector may elect to use a battery-operated, portable tape recorder to transcribe his or her field notes. Later he or she will transfer these notes onto the daily report form.

No single procedure is best and no single daily report form is best. Whatever report form or method of recording is used should be agreed to by the client and the inspector.

Daily Reports

Daily reporting is the most common form of inspection reporting and is 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.

The daily report is helpful in cases of a coating failure. The report can help determine why the coating failed and what can be done to ensure that the repair will be successful.

Daily reports can be an aid 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 your supervisor and are an indication that you are doing your job.

The forms used for daily reports vary from company to company. Usually they are quite detailed and cover all aspects of the job, including:

- Environmental conditions, such as dew point, humidity, air and substrate temperatures, and wind direction and speed
- Details of surface preparation, such as pre-surface condition and the types and grades of abrasive
- Description of equipment and personnel on the job
- Details of coating application
- Locations of the work inspected that day
- Deviations or nonconformances
- Explanation of any work stoppages
- Estimate of the percentage of work completed
- Results of inspection and the standards and specifications applied

As mentioned before, detail is important to the usefulness of the daily report. Diagrams and photographs may be used to document the location or progress of the work. When possible, actual test results, such as the piece of replica tape used to measure the anchor pattern, may be attached to the report. Measurements made should be recorded.

Other Routine Reports

The inspector may elect or may be required to maintain reports on such things as materials inventory and instrument calibration history.



Materials Inventory Reports

The reports contain information on the inventory of materials, such as coatings, thinners, abrasives, etc., on the job and normally are submitted periodically.

It is good practice for the contractor to use coatings in a structured manner, and the inspector may look for:

- Coatings with the same batch number kept together
- First-in-first-out rotation of materials

Instrument Calibration History Reports

Calibration reports normally contain information on how frequently each instrument is to be calibrated. Each instrument should carry a label showing its own serial number or special identifying label and when it was last calibrated.

The inspector may be required to record on the daily report the serial number of each instrument used.

Weekly Reports

In addition to daily reports, a weekly report may be required. The weekly report may be less detailed and written in layman's terms, 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 go to the client, the company doing the inspection, and the engineer on site to ensure that everyone is well informed on the progress of the job. **Note:** The contractor **does not** generally receive a copy of these reports.

The weekly report is often a general narrative summary of progress and events and may be used by the project manager for his or her weekly progress report.



Report Formats

There are at least as many recording formats as there are clients. Some forms require recording such items as:

- Location (general and detail)
- 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.

The forms we will use in this course to record the coating job done on the practice piece will be a customized logbook that consists of many forms organized into a logical time sequence. This allows you to compile information in logical sequence, from first analyzing the specification to the pre-job conference and on to the work itself. We'll discuss each of the sections of the logbook, which are:

- 1. Specification Review
- 2. Pre-Job Meeting Minutes
- 3. Technical Facts of the Project Specification
- 4. Scope of Work
- 5. Safety Data
- 6. Coating Inspector's Checklist
- 7. Inspection Details



- 7.1 Ambient Conditions
- 7.2 Pre-Cleaning
- 7.3 Initial Preparation
- 7.4 Surface Preparation
- 7.5 Measurement of Anchor Profile
- 7.6 Coating Application
- 7.7 Dry-Film Thickness Measurements
- 7.8 Holiday Detection
- 7.9 Final Inspection
- 7.10 Nonconformance Report

Coating Inspector's Logbook

Basic Principles

- All written reports should be compiled in ink so they cannot be easily altered. It is perfectly OK to make changes, but they should be clearly shown as changes and preferably initialed by the person making the change.
- Spaces on forms should not be left blank. The recipient of the report cannot decide whether the space is blank because there was no information or because the writer failed to see the question. All spaces should either be completed with the required information or a line or perhaps *N/A* (not applicable) should be written in the space.
- When inspection reports provide a table for collection of data, all sections of the table should be completed. Any spaces not required should be deleted.
- Reports should be signed and dated by the writer.



- Reports are best when they are completed at the appropriate time. For example, daily reports should be completed each day, while the information is fresh. The report is more likely to be complete, and the information is not modified by subsequent experiences.

Specification Review

It is essential for coating inspectors to read and understand the specification. Notes made while reading the document help to identify the significant points, particularly those issues that may require clarification.

1. Specification Review

Specification Title: _____

Revision Number: _____

Notes of significant Issues:

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 make sense when read after some time has elapsed and the memory has faded.



2. Pre-job Meeting Minutes

Date of Pre-Job Meeting: _____

Location : _____

Those Present: _____

_____Minutes:

_____**Technical Facts of the Project Specification**

Following various pre-job discussions and perhaps correspondence, some of the critical data that applies to a project may have been officially changed. This summary of the facts would then differ from the specification documentation.

3. Technical Facts of the Project SpecificationPre-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: _____



Scope of Work

The summary here adds specific knowledge—where required—of the work piece, structure, or location where coatings work is to take place.

4. Scope of Work

Mild Steel panel, 12 inches (30cm) square, with welded 'v'-section protruding from front of panel. Special Instructions:

Safety Data

Safety is most often the responsibility of a safety professional who provides written instructions and/or verbal safety briefings to workers and instructors. Specific guidelines for safe working should be recorded.

5. Safety Data

List the main points of your Safety Briefing for the Project:

Coating Inspector's Checklist

This checklist is provided as a memory jog. If inspectors are able to confirm that each of these aspects is taken care of or has been considered (by checking the box), then the job is most likely on track for success. Any deviations or omissions should be reported.



6. Coating Inspector's Checklist**Specification**

Have it Read it
Understand it

Pre-Job Conference

Request one Attend it
Participate actively
Know and understand safety rules

Coating Schedule

Know where all coating activities will take place

Pre-inspection

Identify areas which will be hard to coat
Check for:
Weld spatter Skip welds

Inspection Details

Reports in this section require inspectors to record the results of their inspection activities.

Ambient Conditions

The number of times that ambient conditions are measured during each working shift depends significantly on the ambient conditions. In cold or humid conditions, many checks would be made in each day. When ambient conditions are easily within specified limits, and the weather is stable, fewer measurements would be made.

At least one measurement for each specific work area should be recorded.

Pre-Cleaning

This section requires a record of visual inspection of the pre-cleaning process plus the results of any specified tests, such as use of the UV light to determine grease contamination. An initial record of the condition of the structure before work begins may also be useful.



Removal of soil should be recorded, as should solvent cleaning. Dimension checks may also be made at this stage and should be recorded.

Initial Preparation

Activities such as grinding of sharp edges or removal of laminations or weld spatter should be recorded.

Other activities such as ultrasonic inspection of areas that have been ground smooth or removal of dye-penetration test fluids should also be recorded.

Surface Preparation

This section requires inspectors to observe the cleaning process and report on the finished results. Particular attention should be given to whether the work complies with the specified standard.

If a transparent tape test is required to demonstrate the surface cleanliness, the tape should be attached here and the result (which may require judgment) recorded.

Measurement of Anchor Profile

Measurements of anchor profile should be recorded. When replica tape measurements are made, the tapes should be attached to the report.

Coating Application

Specific inspection data, such as appropriate batch numbers and WFT measurements, are required for all coating applied. Where expected measurements cannot be made (e.g., when inorganic zinc coatings are applied on hot days and the drying rate is too fast for effective WFT measurements to be made), reasons for the lack of measurements should be provided.

Dry-Film Thickness Measurements

DFT measurements should be made at the frequency specified. In the logbook example, a grid of 15 individual measurements is provided to correspond to the frequency of SSPC-PA 2.

In general, DFT measurements provided for each coat are **total** DFT, including all coatings applied to date. Computation of individual coatings thickness may be useful as a guide and allow comparison with specified limits, but measurements made should be recorded exactly as made.

Holiday Detection

Where holiday detection is performed, the details of the inspection activity should be recorded. The instrument used and the number of defects found should be reported. It is common to provide a diagram showing the location of holiday defects.

Where test voltages are adjustable, the instrument should be set in a way that is defined by the specification, or agreed on in writing with the owner, and the details recorded.

Final Inspection

Final inspection often includes preparation of a *punch list* of unfinished or noncompliant items.

Nonconformance Report

Nonconformance reports (NCRs) are an increasingly common feature of the inspection world. They were developed as informational tools within the discipline of quality assurance, designed to report the occurrence of defects and also record the actions that resolved the problem.

Most NCRs provide space for reporting the problem, for proposing a solution, and for recording the remedial action. At each step, the participants sign the form to

indicate that authoritative decisions have been found and implemented.

Inspectors and operators are sometimes *afraid* of NCRs, believing them to be critical or damaging. In their original purpose, they are intended to gather management information 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.



Daily Report Form (sample, typical)

Ambient Conditions Take at Worksite	Delete as necessary	Time	Time	Time	Time	Time
Air Temperature	°F/°C					
Wet Bulb Temperature	°F/°C					
Relative Humidity	%					
Steel Temperature	°F/°C					
Dew Point	°F/°C					

Site Location:
 Project: _____
 Date: _____
 Inspector's
 name: _____

Signature: _____

Abrasive Blasting Type/Grade of Abrasive _____ Specified Standard _____ Abrasive checked for cleanliness (Y/N) _____ pH (Y/N) _____

Surface Profile Measurements (Locations)	Minimum	Maximum	Hrs. left Uncoated	Comments / Attach tapes

Coatings

Coat #	Paint Manufacturer's Name	Batch Number	Application Method	Color	DFT Before	WFT Measurements			DFT (total) This Coat		
						Min	Max	Average	Min	Max	Average
1.											
2.											
3.											

Coat #	Mixing	Thinning	Storage	Holidays	Defects/Comments
1.					
2.					
3.					

International Maritime Organization (IMO) Forms for Ballast Tank Inspection

DAILY LOG			Sheet No.						
Ship:	Tank/Hold No.:	Database:							
Part of structure:									
SURFACE PREPARATION									
Method:	Area (m ²):								
Abrasive:	Grain size:								
Surface temperature:	Air temperature:								
Relative humidity (max.):	Dew point:								
Standard achieved:									
Rounding of edges:									
Comments:									
Job no.:	Date:	Signature:							
COATING APPLICATION:									
Method:									
Coat No.	System	Batch No.	Date	Air temp.	Surf. temp.	RH%	Dew point	DFT* Meas.	Specified
*Measured minimum and maximum DFT. DFT readings to be attached to daily log.									
Comments:									
Job. no.:	Date:	Signature:							

NONCONFORMITY REPORT		Sheet No.:
Ship:	Tank/Hold No.:	Database:
Part of structure:		
DESCRIPTION OF THE INSPECTION FINDINGS TO BE CORRECTED		
Description of findings:		
Reference document (daily log):		
Action taken:		
Job no.:	Date:	Signature:



Level 1

Chapter 2.5

Pre-Job Conference

Pre-Job Conference

The pre-job conference takes place prior to starting work and provides the opportunity for the personalities involved to get to know and understand each other and to get a clear picture of everyone's responsibilities and authority.

During this meeting, it is important that the people who will be working on the project—the owner, the contractor's on-site foreman or foremen, the coating supplier, and the inspector(s) have the opportunity to:

- Understand what is required by the owner's specification and what restrictions, if any, apply
- Discuss and analyze procedures and processes to be used
- Establish communication lines so that all parties are aware of the reporting structure and information flow of the project
- Determine the decision-making process to resolve conflicts

Pre-job meetings should be required by the owner, and the requirement is often defined in the specification. Typically, the time and date cannot be specified, but a required period of notice (e.g., 2 weeks, in writing) may be stated. Certain attendees may also be required by definition, including the project engineer, the contractor's site supervisor, and the inspector.

Typical specification statements may say:

A pre-job meeting shall be held prior to commencement of the work. At least 14 days notice of the meeting shall be provided by the project engineer in writing. Attendance shall include the project engineer, the site supervisor allocated to this project, and the coating inspector.



As with most formal meetings, an agenda for the meeting should be prepared and a chairman selected. If either one (or both) of these issues are not predetermined, the first duty of the meeting is to deal with them, making an agenda and electing a chairman.

Project issues discussed at the pre-job meeting, particularly those that may be controversial, must be accurately documented. The meeting should be recorded in the form of minutes of the meeting, and the recording secretary should preferably be experienced in the skill of taking minutes. The use of a portable tape recorder may be agreed, but both skill and knowledge are required to create the written minutes.

It is very difficult to participate fully in a meeting and act as the recording secretary. Coating inspectors should resist acting in this capacity and focus on full participation.

Persons present at the meeting may choose to keep their own shorthand notes to later verify that the official minutes are a true record of what has been discussed.

While an agenda is stated at the beginning of the meeting, there is an opportunity to add items for discussion. Inspectors should ensure that all of the topics they want to discuss are listed. Preparation is the key, and the details of the specification should be reviewed in detail prior to the start of the meeting.

Discussion of the items on the agenda is then taken in order. Prime importance is generally given to such issues as:

- Timing, including when the job starts, how long it is going to take, and the likely proposed finish date
- Access to the site, including available operating hours, provision of power supplies, water, showers and toilets, etc.



- Site accommodations, including office accommodations, lunch rooms, testing equipment (such as cleaning trailers related to lead removal projects), and materials storage, scaffolding, tarpaulins, secondary containment, and other requirements
- Communications issues, such as site telephones, circulation of reports, etc.
- Safety requirements, including any special briefings or site-specific precautions such as emergency situation training for operators where appropriate

Pre-job meetings are not always well organized. When they are not, a useful strategy may be to read the specification, starting at the beginning and working through to the end. This may seem unusual, since all participants should—in theory—have gained a secure knowledge of the documents during the tendering and/or project preparation stages. Many specific details may have been neglected, and the act of reading the specification, together with discussion of many of the specific clauses, helps to highlight problem areas.

In particular, the inspector's objective should be to determine difficult areas, specification clauses where interpretation may be different.

Another specific area to address is inspection test methods and interpretation of results.

In summary, the inspector's duties include:

- Prepare for meeting (do homework first).
- Read specification.
- Collect standards and technical data.
- Discuss inspection testing methods, including frequency of test performance and corrective action where noncompliant areas are found.



- Raise all potential problems.
- Determine authority before meeting, if possible, through discussion with employer.
- Ensure that all project personnel know what the inspection responsibilities are going to be.

Any questions regarding the following must also be resolved and agreement made between all parties concerned:

- The conduct of the job
- Requests to modify job conditions
- Proposed changes to the specifications
- Contractor submittals (i.e., required documentation)
- Change orders or waivers

Minutes of the meeting should document answers to all questions, along with any other practical information, and should be distributed to all the parties concerned before any work begins.

The minutes along with any change orders issued become part of the contractual agreement between the owner and the contractor and are therefore important legal documents. The information contained in these documents may significantly influence the conduct of the job.

Working with the Team

The pre-job conference, in addition to dealing with technical matters, is generally a most helpful opportunity to meet the people involved in the project. This is **one of the most important aspects** of any coating job—the people who are involved and how the coating inspector may help the job go smoothly by working well with the rest of the **team**.



The persons who might participate in this meeting, or who might somehow be involved in the total project, can include any or all of the following:

- Company management
 - Plant operator
 - Project manager
- Other company personnel
 - Purchasing agent
 - Design engineer
 - Safety engineer
 - Quality assurance personnel
- Other contract personnel
 - Suppliers
 - Fabricator
 - Coating manufacturer
 - Coating contractor
 - Coating inspector or supervisor. If the job is large enough to have more than one inspector, then all inspectors scheduled should attend. The same would be true for more than one paint foreman: all should attend.

The inspector should receive a copy of the meeting minutes and retain this copy for possible future reference.

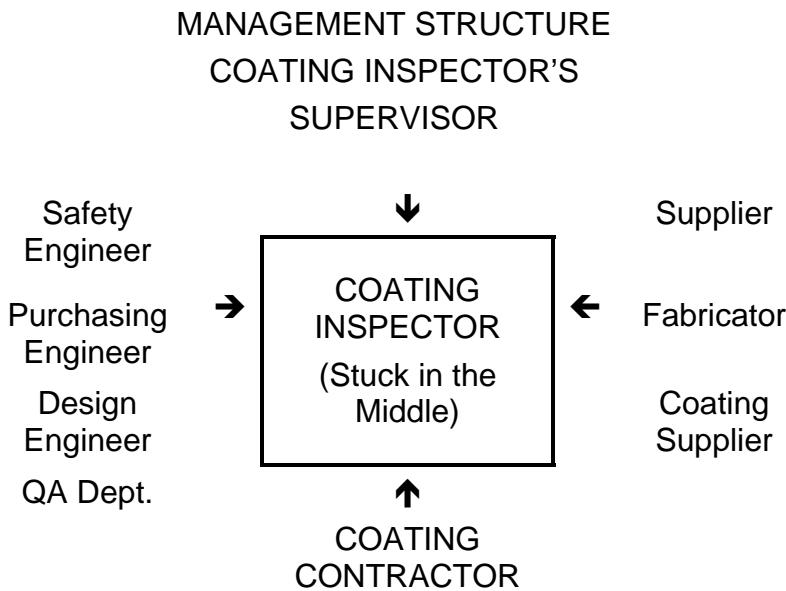
If the inspector hears of a pre-job conference and has not been invited, then the inspector's supervisor or owner's representative should be contacted for an invitation.

One of the things evident in the diagram that follows is that the coating inspector is right in the middle. That's



probably how an inspector feels sometimes: caught in the middle!

The Coating Inspector's Relationship with "the Team"



It shows that the inspector may come in direct contact with:

- Inspector's supervisor
- Other company personnel
- Coating contractors
- Material suppliers

Coating inspectors:

- Generally don't supervise anyone, except perhaps other inspectors
- May be asked to work directly with any or all of the other team members
- Should be aware that the other team members may interact with each other independently of the coating inspector(s)

Inspector's Duties on the Job:

To avoid trouble and to keep from getting caught in the middle of a disagreement, the inspector should:

- Be on time when scheduled for an inspection task and not hold up work
- Take accurate measurements and keep accurate records
- Be objective, logical, calm, and fair
- Be knowledgeable
- Earn the respect of everyone early in the project

Working smoothly with all the team members is one of the important tasks the coating inspector faces. These relations can be improved if clear cut organizational lines of authority and responsibility have been established. All reporting and decision-making functions should be kept within these lines. Ideally, the inspector should be the company's representative and have full authority for accepting and rejecting the work; however, it is recognized that the ideal is not always attained.

Overall, the inspector is responsible for protecting the client's interests by ensuring, within the bounds of authority granted, that the coating system is applied according to the specification.

The inspector's work can be a great help to the contractor by:

- Making early identification of poor practice which could result in expensive rework
- Ensuring fair and competent interpretation of the coating specification. The inspector, in performing specified duties, can help the contractor enforce the specification and get the work done properly.





Level 1

Chapter 2.6

Surface Preparation Overview

Surface Preparation Overview

For practically every coating process, such as phosphating, galvanizing, electroplating or painting, the initial cleaning and preparation of the surface to be coated is a step on which the subsequent success of the coating system depends.

Surfaces must be prepared before protective coatings are applied, if good results are to be obtained. Modern coatings require both a clean surface and a roughened surface if they are to achieve long-term stability, unless they are specifically designed for application to poor surfaces. It has been estimated that up to 75% of all premature coating failures are caused either completely or in part by inadequate or improper surface preparation.

Surfaces to which protective coatings are applied may include:

- Mild steel alloys
- Concrete
- Aluminum, zinc, copper, and other metals
- Stainless steel
- Wood
- Plastic

In this program we will discuss each of the surfaces named above, while recognizing that steel and, to a lesser extent, concrete are the most common surfaces prepared and painted for protection.

The activities of surface preparation prior to application of coatings 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, which can prevent adhesion or mechanical bonding of the paint to the surface
- Residues of (nonvisible) chemical salts, which can induce corrosion after coating
- Rust on the surface, which interferes with the coating bonding to the surface
- Loose or broken mill scale, which can cause early coating failure, and tight mill scale, which can cause later failure
- Rust scale, which cannot be protected by any coating and cannot maintain adhesion to steel
- Anchor pattern (formed by surface preparation actions):
 - may be so rough that peaks are formed which are difficult to adequately protect with paint, or
 - 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, which prevent adequate thickness of coatings over the irregularities
- Surface condensation which, if painted over, may result in blistering and delamination failure



- Old coatings that may have poor adhesion or may be too deteriorated for recoating
- Existing coatings that may be incompatible with and affected by the application of maintenance coatings

Surfaces to be painted often require some pre-cleaning. Inspection for contamination, including heavy deposits of grease, soil, dust, dirt, or cement splatter, is an important part of the overall coating process. Loose dirt and debris must be removed, and the surface to be coated should be completely available for paint application.

Inspection 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, before coating begins
- Between each application of coating in a multi-coat system

Design Defects

Many structures are not designed with the coating process in mind. Design flaws and fabrication faults can easily complicate the procedures used to achieve a successful coating system. The applicator or the inspector or even the coatings used cannot be held responsible for problems arising out of the work of designers, engineers, and/or fabricators.

However, the inspector may be able to provide a valuable service by helping to identify problem areas resulting from a particular design and/or fabrication of the work piece and by providing assistance in solving some of the problems.

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

Hard-to-Reach Areas

Hard-to-reach areas are difficult to coat properly. Special attention is required to ensure proper coating. For example, stiffening members on the inside of a vessel create an area that may be hard to reach for coating. Many tall vessels are built with little thought given to how the interior surface can be maintained.



Figure 1 Design Problem—Hard-to-Reach Area

To aid access for maintenance, designers should incorporate supports for painting accessories such as cradles or scaffold and allow easy access for such equipment.

Riveted and Bolted Construction

Riveted and bolted construction can leave gaps and areas that are difficult to clean and coat. It is difficult to protect bolts in this condition. Riveted and bolted construction should be replaced by welding where possible.

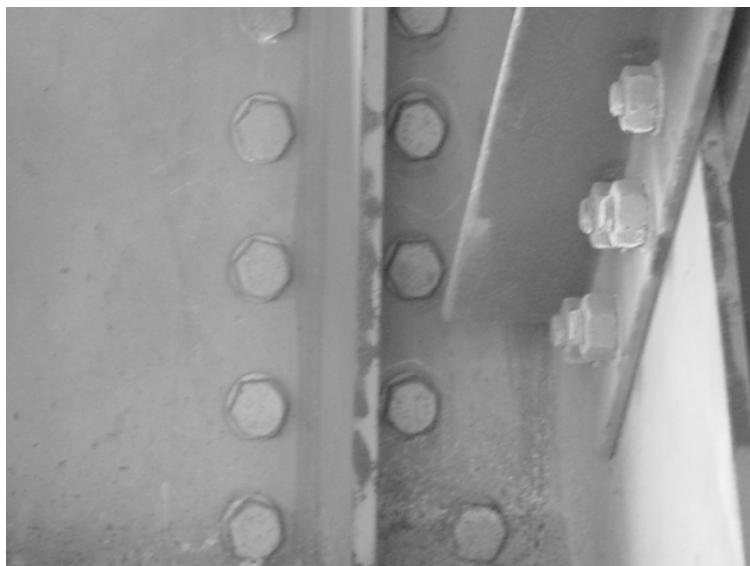


Figure 2 Design Problem—Bolts

Welds

Welds generally present rough, discontinuous areas on a plane surface and may have many sharp edges. Often welds are not cleaned properly, leaving weld spatter, slag, and acid flux residues. If these imperfections are not removed, corrosion may be encouraged.

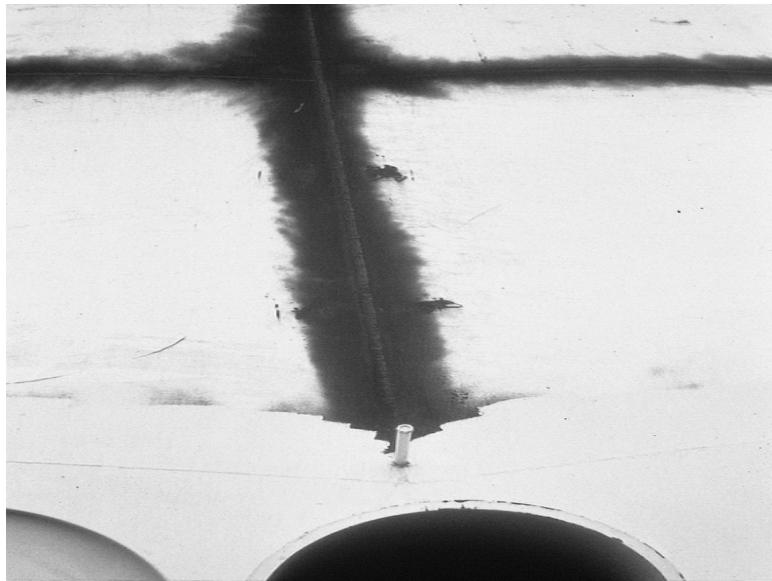


Figure 3 Design Problem—Welds

Weld areas, especially in tanks and vessels, should be cleaned, ground smooth or flush depending upon the operating conditions, and stripe coated. Grinding of welds, however, is not always advisable, and 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 achieve a good bond and a coating failure is likely to occur, resulting in corrosion. Removal of such contamination can be difficult. Repeated applications of solvent may be required until the remaining traces cannot affect coating adhesion or bleed back into the coating.

Gaps

Skip welds, sharp edges, crevices, and back-to-back angles can lead to early coating failures. These problems may occur as a result of lack of foresight at the design stage or may be due to poor practices by the fabricator.



Figure 4 Design Problem—Gaps

Generally, overlapping plates and roof plates are skip-welded creating an area inaccessible for coating. Moisture can migrate between the plates and corrosion can occur.

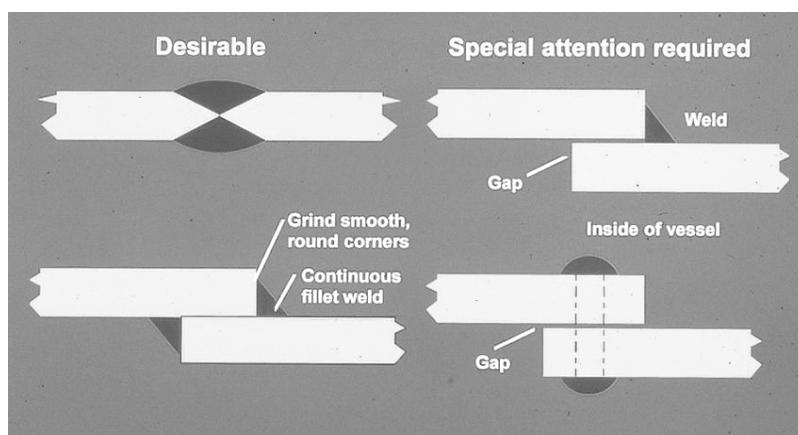


Figure 5 Design Problem—Overlapping Surfaces

Back-to-Back Angles

Frequently in construction back-to-back angles are used. Often the back sides of these angles are not coated but sometimes are precoated with galvanizing or with inorganic zinc.

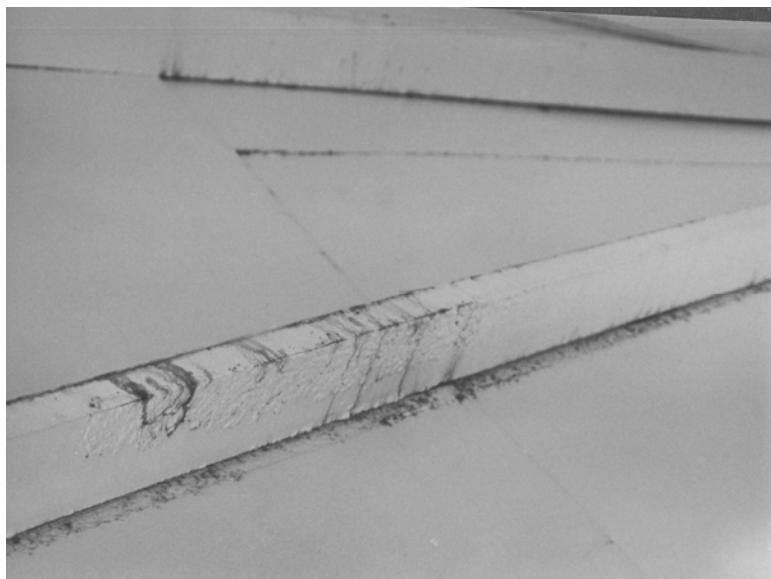


Figure 6 Design Problem—Angles

The area between the angles may be impossible to clean and coat. The void space around the angles could be sealed with caulking or mastic to prevent corrosion and the possible undercutting of coating at the edges.

Edges

In a typical structure there are many linear feet of edges, most of which are not rounded. In particular, sheared edges and flame-cut edges created during fabrication are likely to be sharp and to be problematic in the coating process. Coatings generally have a tendency to shrink and pull back from edges, leaving a thin and less protective coating.



Figure 7 Design Problem—Sharp Edges

Edges should be stripe coated at least once during the coating process, preferably once for each regular coat to provide additional coating thickness at the edge.

Corners (Exterior and Interior)

Exterior corners behave like sharp edges and the same tendency for corrosion occurs. They should, as a matter of good practice, be stripe coated as with edges.

There are two potential problems with interior corners:

- Coatings applied over interior corners will shrink in much the same way as on sharp edges, tending to form a bridge with poor contact to the substrate. This is sometimes known as the *wallpaper effect*.
- The corner may allow the accumulation of dirt or trash, and the coating could be applied over a contaminated surface. Like other surfaces, inside corners should be cleaned free of dirt, dust, etc., and preferably stripe coated before application of the main coating.

Overlapping Plates

Crevices between overlapping plates can allow the accumulation of moisture and, because it may be impossible to clean and coat this area, corrosion is likely to occur.

Threaded Areas

Rivets, bolt heads, and nuts are all difficult to coat and care is needed to ensure that all surfaces are adequately cleaned and coated. There are many crevices and sharp edges associated with threads that may allow the initiation of corrosion.

Faying surfaces (i.e., surfaces being joined to create a friction grip) are a special case and should either be cleaned and left uncoated or coated with a tested and approved coating. Tests are defined by British Standards and by ASTM to establish suitability for this purpose. Inorganic zinc coatings are probably the most common coatings used for this purpose.

Construction Aids

Temporary construction aids, 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 become over coated along with the original coating application. In these cases, surface preparation or coating application may be less than ideal and early coating failure occurs.



Figure 8 Design Problem—Construction Aids

Construction aids should be removed, the surface properly prepared, and a proper coating applied to avoid a premature failure of the surrounding coating.

Other design problems that could lead to early coating failure include:

- Dissimilar metals in contact with each other creating a galvanic cell, which can start the corrosion process and cause a coating failure. Where dissimilar metals must join, all connected dissimilar metals should be coated.
- Depressions in the outer surfaces which may accelerate corrosion by restricting the flow of runoff or drainage of water or by collecting dirt or other trash
- Crevices that can trap water or corrosive liquids
- Poor ventilation which slows the evaporation of condensing moisture

Steel Surface Defects

It is not widely appreciated that *surface preparation* does not just mean the removal of mill scale, rust, and contaminants, but also includes suitable *dressing* of the steelwork to remove all surface defects that could break through the paint film or prove difficult to protect adequately by painting. Typical examples include:

- Sharp edges
- Surface laminations
- Cracks and crevices
- Inclusions

It should be remembered that 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.



Surface Laminations and Shelling

The most common type of surface defect on steelwork is surface lamination, generally caused by the steel rolling process. It is important that all such defects are removed by grinding as no painting system can effectively protect them. In the case of small shelling and surface laminations, even if these do not project above the surface, they may later curl upward and penetrate or disrupt the painting system.

Cracks and Crevices

Any form of crack or deep crevice will form a danger to the protective treatment as it cannot be effectively filled or sealed by the coating system. It will contain impurities, gather entrapped moisture and air, then provide a location for corrosion under the paint system. All such cracks and crevices should be ground out, unless too deep for such treatment, in which case they should be filled or sealed by welding and then ground smooth.

Coating inspectors should report defects such as cracks, even though the responsibility for any decisions regarding treatment may rest with a structural engineer.

Inclusions

All forms of surface inclusions, such as rolled-in mill scale, should be removed. Methods used include chipping and/or grinding. Weld filling may be used to restore the surface, in some cases, if necessary.

Ideally, the project specification will require correction of fabrication errors. The inspector must ensure these defects are corrected as called for in the specifications. If correction is not called for by the specifications, they should be prepared and coated as well as possible.

The inspector should accurately locate these areas and document them in his or her daily inspection report. This information could be most useful to the owner for future maintenance and as an aid in determining any premature failures.



Any gaps and small, hard-to-reach, or inaccessible areas where failure can occur should be avoided. Welding should be done only where enough space exists for smooth treatment of the weld.

Since threads are very difficult to clean and coat properly, threaded outlets should be replaced, when possible, by flanged or pad-type outlets, which may be more easily accessible to the painter.

A final design weakness can be the use of dissimilar metals. Where dissimilar metals are connected (i.e., there is a metallic pathway) the possibility for bimetallic corrosion exists. 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—probably pitting—at the anodic area.

Protective coatings should preferably be applied to the cathodic area only. If the anodic metal is also to be coated, the coating film must be pinhole-free to prevent focused corrosion initiating at pinholes in the film.

Fabrication Defects

The inspector may be responsible for looking for and documenting fabrication defects. If the coating specification calls for repair of these defects, then repairs should be completed before further work proceeds.

Fabrication defects can fall into several broad categories:

- Imperfect welds, including:
 - Weld spatter (also known as *weld splatter*)
 - Skip welds
 - Rough welds
- Laminations
- Gouges



- Sharp corners and edges
- Sharp bends and angles

Imperfect Welds

Weld Spatter (also called *splatter*)

Weld spatter describes particles of molten metal produced during welding and thrown onto the surface adjacent to the weld. It can sometimes be easily removed with an impact tool such as a chipping hammer, but mostly must be ground down with a disc or angle grinder if it is to be successfully removed.



Figure 9 Fabrication Defect—Weld Spatter

Weld spatter may be up to 500 μm (20 mils) or more in height over the substrate and is difficult to cover with adequate coating thickness. The resulting thin coating film over the weld spatter may break down early in service, allowing the development of corrosion, which may subsequently spread beneath the coating film. Consequently, the treatment of the weld spatter is important, and it must be removed by mechanical means before any blasting required by the specification.

In tanks, vessels, etc., where coatings are used for 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.

Skip Welds

Proper welding technique is also important. 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 will more than offset the extra cost of welding.

The *best* method to seal the area is with a continuous weld, which should then be cleaned and ground smooth, and stripe coated along with the regular coating. If continuous welding is not possible, caulking of the overlap joints using a caulking compound that is compatible with the coating system may be possible over the prepared joint before stripe coating. Epoxy and silicone-based caulk have both been used with success.

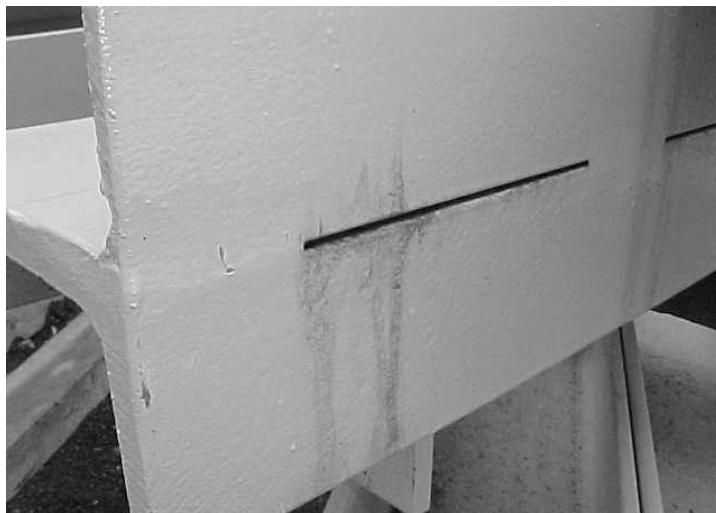


Figure 10 Fabrication Defect—Skip Weld

Rough Welds

Rough welds should be ground or otherwise repaired to remove sharp edges and other irregularities. Voids in the weld may be bridged over by the coating. Sharp ridges and spikes are difficult to coat; the coating pulls back from the edge of the ridge and is much thinner at that point. It is important that all welds be ground or

otherwise repaired to yield a relatively smooth surface. Undercuts and pinholes should be filled with welding.



Figure 11 Fabrication Defect—Rough Weld

Laminations

Laminations, scabs, rollovers, and other defects of this type must be corrected to expose areas that are inaccessible to cleaning and coating. Slivers, laminations, and other defects that may penetrate the coating should be removed.



Figure 12 Fabrication Defect—Lamination

Gouges

Sharp indentations of any kind make the creation of a continuous coating film difficult. Coatings applied to gouges may bridge over the gouge, creating a void where corrosion can occur. These indentations should be rounded so that the entire surface can be evenly and completely coated.

Sharp Corners and Edges

Because of surface tension, coatings tend to pull back from sharp edges, particularly during the shrinking phase that occurs during drying and/or curing. Sharp edges should be rounded.



Figure 13 Fabrication Defect—Sharp Corner/Edge

Sharp Bends and Angles

Coatings can bridge over the base of a sharp bend or angle, creating a void which can trap moisture, thus causing corrosion. This condition cannot easily be changed or corrected, so extra care is required during coating application. The application of a stripe coat by brush may be helpful to ensure adequate coverage is achieved.

NACE publishes the standard recommended practice RP0178, "Fabrication Defects, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service." In the design process, the design engineer, working jointly with the coatings engineer or specifier, could use this illustrated standard along with an accompanying weld replica as a valuable guide to avoid many of the common design faults and fabrication defects that can adversely affect the entire coating scheme.

The same standard may be quoted in specifications, providing a visual guide to the conditions that are acceptable after the pre-cleaning stage of surface preparation. A companion replica is available to help inspection, showing various degrees of preparation of welds 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 inspecting or preparing for work. They should carefully report these areas in writing and should bring them to the attention of their supervisor or the owner's representative.

Similarly, identification of fabrication defects that may lead to inadequate coating performance is important. Defects should be identified and documented, and corrective action should be taken. Responsibility for remedial action is often a subject of dispute. Coating performance will be much better (and therefore more economical in the long term) if the defects are repaired prior to or during surface preparation activities.

Conditions of Steel Surfaces

New or used unpainted steel may be categorized in any one of four general conditions, described and illustrated by two common pictorial standards:



- SSPC-Vis I
- ISO 8501-1

The general conditions are Rust Grades A, B, C, and D, described as:

- 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 surfaces completely covered with rust; pitting visible

These initial conditions affect the degree of surface preparation that is necessary or can be achieved. They are described in more detail and fully discussed in the section of CIP on surface preparation standards.

Adequate cleaning of surfaces, including aluminum, wood, concrete, zinc (galvanizing), and steel, especially previously used steel, is essential to achieve proper performance of the coating system selected. The nature and condition of the surface to be prepared and painted affects the degree of surface preparation work that is to be done.

A severe environment, marine or chemical, normally requires a higher degree of cleanliness to ensure good performance of the coating system. A more rural environment—with less pollution—will allow better performance of the same coating system or the same performance when applied to a lesser degree of surface preparation.

Coating systems vary significantly in their ability to bond to steel. Some coatings with good wetting properties, such as epoxy mastics, medium- and long-oil alkyds, and some bituminous products, will adhere better to a less thoroughly cleaned surface than others. All systems,



though, will perform better on a properly cleaned surface with a good surface profile.

Surface Preparation Methods

Techniques available for surface preparation include:

- Solvent cleaning
- Hand tool cleaning
- Power tool cleaning
- Flame cleaning
- Acid pickling
- Blast cleaning, using shot or grit
- Waterjetting, using water only
- Wet abrasive blasting, using water with injected abrasives

Each of these techniques must be controlled by specifications, and standards are available to help define the process.

Surface Preparation Standards

Surface preparation techniques are often used in combination with each other. Solvent cleaning, for example, is a pre-cleaning method before blast cleaning. Fabrication defects may be *dressed* with power tools before blast cleaning or waterjetting.

Probably the most common method of surface preparation of steel for painting is dry abrasive blast cleaning. The same visual standards referred to above (SSPC-Vis 1, ISO 8501-1) provide pictorial standards that can be used to judge and compare blast cleaned standards with work on site. The standards most commonly used for inspection verification include:

- “White Metal,” NACE No.1/SSPC-SP 5/ISO Sa 3



- “Near White Metal,” NACE No. 2/SSPC-SP 10/ISO Sa 2½
- “Commercial,” NACE No. 3/SSPC-SP 6/ISO Sa 2
- “Brush-Off,” NACE No. 4/SSPC-SP 7/ISO Sa 1

Although these four pictorial representations are shown in the same standard that describes surface conditions A, B, C, and D, the result achieved is independent of the starting condition, except that the appearance may be affected by the original condition of the surface (e.g., if the surface is pitted).

These standards and many others apply to the various types and degrees of surface preparation. They are available from many organizations, including:

- NACE International
- SSPC—The Society for Protective Coatings
- ISO—International Organization for Standardization
- Many other national standards bodies

We shall discuss both the cleaning methods and the appropriate standards.

Metal Surfaces for Painting

The first step of surface preparation must be to consider the specific surface to be coated. Amongst those metal surfaces that are often coated, the factors affecting selection of surface preparation method or coatings to be used may vary. Such surfaces may include:

- New or unpainted steel surfaces
- Mill scale
- Corroded steel surfaces
- Corroded zinc or zinc-galvanized surfaces



- Corroded aluminum surfaces

(Note: Preparation of concrete surfaces for painting is discussed elsewhere in the CIP program.)

New or Unpainted Steel Surfaces

New, unpainted steel is relatively easy to clean. Provided that the surface has not been exposed to corrosion in a chemical or marine environment, the biggest problem is likely to be removal of mill scale deposits. Blast cleaning, using either shot or grit, 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 of coatings.

Tightly adhered mill scale can be difficult to remove without blast cleaning.

New, unpainted metals such as aluminum or zinc can be prepared by light blast cleaning to both clean and roughen the surface. Adequate adhesion of coatings to the prepared surface may be difficult to achieve any other way. Chemical or solvent cleaning may be possible, but special paint primers—such as *acid-etch primers*—must then be used to achieve good performance.

Mill Scale

Mill scale is formed by 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.

The adhesion of mill scale to steel is unpredictable and may vary from tightly adherent to lightly adherent. If the mill scale is over coated, failure of the coating can occur due to delamination of the mill scale from the steel surface.

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 anode

For best results, new steel should be cleaned by abrasive blasting to remove mill scale and to provide an anchor pattern for optimum coating adhesion.

Corroded Steel Surfaces

Surfaces that have been exposed to the environment, and have subsequently corroded, may be more difficult to clean. The surface is often rough and may have deep pits and other irregularities. When chemical contaminants have become bonded to the surface through a chemical (corrosion) reaction, removal may require special treatment.

The processes used for cleaning corroded steel are generally the same as those used for cleaning new steel and include hand and power tools, blast cleaning, and perhaps waterjetting.

Corroded Galvanized or Zinc-Coated Surfaces

Zinc exposed to the atmosphere develops a passive film of zinc oxide and/or zinc carbonate. Provided they are tightly adherent, these layers can aid the adhesion of paints due to their relative roughness. Loosely adherent or powdery salts should always be removed before painting.

Water washing may be effective at removing most loosely adherent zinc salts, provided a pressure wash technique is used, and plenty of clean, fresh water is available. This technique is less effective than blast cleaning.

Zinc surfaces should be lightly blast cleaned (brush-blasted) to roughen the surface prior to painting, or treated 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 will enhance coating adhesion to the substrate. Current thinking suggests better results are obtained by blast cleaning before coating rather than relying on etch primers to provide good adhesion.

Oil-based coatings such as alkyds or epoxy esters perform poorly when applied over galvanized or zinc-coated surfaces because of a reaction between the coating and the zinc surface called *saponification*. This reaction, the formation of *soap*, causes degradation of the oil-based binder and consequent loss of adhesion of the coating to the zinc surface.

Corroded Aluminum Surfaces

Aluminum oxidizes in the atmosphere much like zinc and zinc-coated surfaces to form a passive film of aluminum oxide. The surface should be lightly blasted or wire brushed to remove powdery or loosely adherent aluminum salts before coating. Surface treatment with a special aluminum treatment (e.g., etch primer) may be required before coating. A primer with known compatibility and strong adherence to the clean surface should be selected.

Other surfaces that are commonly painted include plastics, wood, and concrete. All of these require special surface preparation and coatings suited to their special characteristics. A discussion of surface preparation for these surfaces can be found in the advanced surface preparation module.



Coatings Selection

The choice of surface preparation method is often determined by the choice of coating system. Coating systems should be matched to the degree of surface preparation desired or possible.

If coatings are to be successful with very little surface preparation, they must be chosen for their surface tolerant characteristics.

Most coatings need better standards of surface preparation. Modern high-performance coatings are likely to require blast cleaning to a high degree of cleanliness and, in some cases, may also require that the surface is free of chemical contamination.

The degree of cleaning required is closely related to the type of coatings to be used, although, in general, a better standard of cleaning will provide better long-term protection for any coating system.

- Some coatings are more tolerant of poor surface conditions than others.
- In general, better surface preparation leads to better coating life.
- Specifier selects coatings and surface preparation fit for purpose.

Solvent Cleaning

Solvent cleaning is a method for removing all visible oil, grease, soil, drawing and cutting compounds, and other soluble contaminants from steel surfaces. Solvent cleaning is intended to be used prior to the application of paint and in conjunction with surface preparation methods specified for the removal of rust, mill scale, or paint.

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. It 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
- use of alkaline cleaners

A variety of solvent-cleaning materials may be encountered.

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 used 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.

The last wash or rinse should be made using clean solvent 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 the adhesion of the coating 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 38°C (100°F) may be used as a general purpose solvent under normal conditions. In hot weather (26 to

32°C [80 to 90°F]), high-flash-point mineral spirits with a minimum flash point of 50°C (120°F) should be used.

Most solvents are potentially hazardous and may be ingested in breathing air by applicators, helpers, or others when solvent cleaning is performed. Working spaces should be monitored for solvent fumes, and concentrations in air breathed by workers should be below limits defined by federal, state, or local regulations for *threshold limit values* (TLV). Appropriate fresh air masks should be used in confined spaces and when the safe concentration may be exceeded. The fresh air supply should be free of carbon monoxide (CO) or other contaminants from other sources such as engine exhausts, etc.

The concentration of solvents in air should not exceed the lower limit of flammability, known as the *lower explosive limit* (LEL) or a fire or explosion could 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 have become so stringent as to 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.

Often alkaline cleaners are combined with surfactants (wetting agents), inhibitors, and detergents to form proprietary products and should be used according to the manufacturer's recommendations. These products are often used at elevated temperatures.

In the cleaning process, a slightly soapy film may be left on the surface. This film must be removed, usually with a high-pressure, hot-water rinse. Residues that remain on the surface will affect the adhesion of the coating to the metal.

A pH paper test could be made 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.

Safety precautions should be followed in using the alkaline cleaners and chromic acid. Both may cause burns and/or dermatitis. Workers should wear rubber gloves and safety goggles or eyeglasses, and where these materials may be applied by spraying, respirators should be used.

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, and collection of the waste or used materials is essential. Used materials cannot be washed into the normal drainage system or allowed to run off into the general water system.

Detergents. Increasingly strict regulations regarding the use of organic solvents and the safety considerations in 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, and 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 65 to 100°C (150 to 212°F).

Emulsion cleaners typically are proprietary products and should be used 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 to be cleaned and they function by wetting, emulsifying, dispersing, and solubilizing the contaminants.

Generally, the emulsion cleaners on the surface leave a thin film of oil which must be washed away with hot water, steam, solvents, detergents, or some type of alkaline cleaning agents.

Water is a common, if not powerful, solvent and may be used to good effect in cleaning a surface. We will discuss its use later when we discuss waterjetting and wet abrasive blast cleaning.

In the use of any cleaning method, appropriate safety precautions must be taken. Also, it is important to thoroughly rinse surfaces, particularly when alkaline or acidic materials are used, to minimize the amount of soil remaining and to remove residues of cleaning materials that could adversely affect subsequent coating performance.

Manual or Hand Tool Cleaning

Hand tool cleaning is a method to prepare steel surfaces using nonpowered hand tools. Hand tool cleaning removes all loose mill scale, rust, paint, and other detrimental foreign matter. Adherent mill scale, rust, and paint are not generally intended to 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.

A standard commonly used to control the hand tool cleaning process is "Hand Tool Cleaning," SSPC-SP 2 (comparable to ISO 8501-1, St 2 or St 3). Visual standards such as SSPC-Vis 3, ISO 8501-1, or any other visual standard agreed upon by the contracting parties,

may be used to specify the surface finish required or to verify the condition achieved.

Both standards define the use of a dull putty knife to determine whether or not contaminants are firmly adherent. **Note:** Some inspectors have been known to use a sharpened putty knife, which violates the standard.

Tools used in hand cleaning include:

- Wire brushes
- Scrapers
- Chisels
- Knives
- Chipping hammers

When hand tool cleaning operations commence, certain procedures are followed:

- The surface is inspected to determine its condition and the presence of heavy layers of rust and to detect any foreign substances, such as oil, grease, or dirt.
- Solvent/emulsion cleaning may be specified or required to remove oil, grease, or dirt. Heavy layers of rust should be removed by chipping.
- The surface is cleaned with any of the hand tools previously mentioned and then inspected prior to coating. The coating should be applied within the time period required by the specification.

Manual cleaning is the slowest and perhaps least satisfactory method of surface preparation. Normal tools used are wire brushes or 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.



Figure 14 Hand Tools

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 advantages of being portable and not requiring support power supplies. They are most suitable for use when small areas of work are to be prepared in the vicinity of other workers or when access is difficult, such as when maintenance is performed on communication towers 100 m (300 ft) in the air.

Manual cleaning should only be used when weather or some other factor precludes the use of another more efficient process.

Hand cleaning is one of the oldest methods of surface preparation. It is most often used:

- When power-operated equipment is unavailable
- Where the work is inaccessible to power tools
- Where 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.

Power Tool Cleaning

Power tool cleaning is a method of preparing steel surfaces by using power assisted mechanical cleaning tools. These tools are essentially similar to the tools used for hand tool cleaning, but a power source, such as electricity or compressed air, is used.

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. 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.

The most commonly used power tools include:

- Rotary wire brush
- Impact tools, such as:
 - Chipping hammer (scaling hammer)
 - Needle scaler
 - Piston scaler
 - Rotary scaler
- Grinders and sanders
- Flap wheels



Rotary Wire Brushes

Machine design is of two general types:

- Straight, or in-line
- Vertical, or right-angle

Overworking the surface with a wire brush may be detrimental because excessive burnishing develops a polished surface, which provides a poor anchor for most coatings. Rotary power wire brushes can also easily spread oil and grease over the surface; therefore, solvent cleaning is an essential step before power wire brushing.

Problems with polishing the surface rather than providing a roughened surface are particularly likely with this technique; therefore, the use of rotary wire brushes is considered to be less desirable than other forms of power tool cleaning.



Figure 15 Rotary Wire Brush

Impact Tools

Chipping/scaling hammer—the most widely used type of impact tool. A chisel is inserted into the power tool and the impact from an air-operated or electrically operated piston is transmitted to the chisel and, in turn, to

the surface to be cleaned. Chisels may be of different shapes and materials. Scrapers and special chisels can be suitably mounted into pneumatically or electrically powered impact tools.

Scaling or chipping hammers are generally a slow, costly method of cleaning the surface, but in some cases (such as when considerable rust scale or heavy paint formation must be removed), they prove to be economical.

Great care must be exercised in using these tools because of the tendency to cut into the surface excessively, removing sound metal and leaving sharp burrs where the paint will fail prematurely.

These tools may be used to remove some tight mill scale and surface rusting, but in general practice this is not the most practical or economical method. There is a high possibility of gouging the metal, which must then be smoothed to do a thorough job. The tools must be kept sharp, or they may drive rust and scale into the surface.

Needle scaler—A needle gun, or needle scaler, consists of a number of hardened steel rods which are vibrated against the surface. It is slow in operation and suffers from the same problem as other power tools since it has a burnishing effect when producing a relatively clean surface. It does, however, produce a surface profile.

The needle scaler is effective on welds, corners, and irregular surfaces. Some needle scalers may be fitted with vacuum devices when they are used to remove lead-based paint to comply with regulations regarding lead abatement. Any other coatings judged to be hazardous may also be removed with dust containment and collection devices fitted to the power tools used.





Figure 16 Needle Scaler

Piston scalers—Piston scalers operate in a similar way to scaling hammers, but the piston also acts as the impact tool. A hammer piston, which takes the place of the chisel, 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 operated in one tool; also, large assemblies with as many as 15 pistons are available for use on flat, horizontal surfaces, such as steel decks.



Figure 17 Piston Scaler

A wide variety of chisels are available for different types of work.

Rotary Scalers

These tools can be used advantageously on large areas to remove rust and scale. Care must be exercised to prevent the cutters of these large rotary scalers from cutting the metal to such an extent that metallic points extend far above the surface causing early paint failure due to insufficient paint coverage.

If these tools are used to remove mill scale and rust from the surface, it is very likely that the surface will be very rough and care must be taken to ensure that all peaks of the anchor pattern are covered by the coating applied.

Grinders and Sanders

Grinders and sanders are often employed to prepare surfaces for painting. Machines used for this purpose 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 this type of cleaning equipment must be selected properly. Too coarse an abrasive will create a deep anchor that may be unsuitable for good paint performance. An abrasive that is too fine may cause early clogging of the grinding wheel or sanding disc, thus making the process inefficient.

Grinding is well suited for removing weld spatter, smoothing weld seams, or rounding off sharp edges or corners. Grinders are frequently used in repairing minor fabrication defects. The anchor profile produced can be extremely good, with complete removal of rust and mill scale; however, such methods of cleaning are very expensive for large areas.

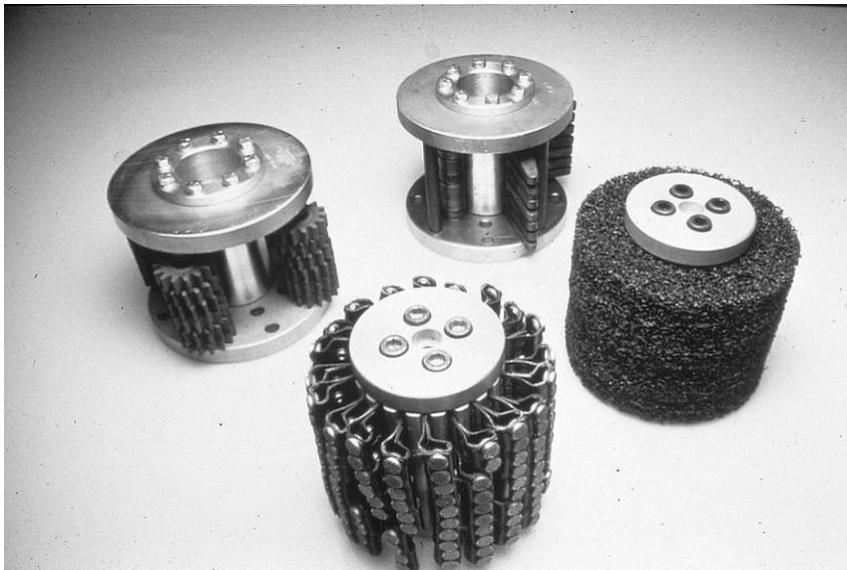


Figure 18 Grinders and Sanders

Disc Sanders

Also available are pneumatic and electrically operated sanders that have a flat pad or abrasive surface in contact with the metal to be cleaned. Some of these motor-driven sanders have an orbital motion.

Flexible shafts are used on a small scale to operate rotary wire brushes and grinding wheels. On other grinding equipment the discs or wheels are mounted directly to the main shaft of the motor of other portable or stationary units.

Vacuum Connections

Many authorities are concerned with eliminating dust emissions from work that involves removal of old coatings. For that reason, many power tools are now fitted with collectors and vacuum lines that gather most dust as the tool is used.

The effects of the power tools on the surface remains the same, but the equipment is heavier and more difficult to handle. Acceptable results can still be achieved.

Power Tool Cleaning to Bare Metal SSPC-SP 11

In 1989, SSPC adopted a new standard, SP 11, titled “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.

SSPC-SP 11 calls for power tool cleaning to produce a bare metal surface and to retain or produce a profile, where a clean, roughened, bare metal surface is desired but where abrasive blast cleaning is not feasible or is not 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 lower portion 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 25 μm (1 mil).

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 this method produces surfaces that look like near-white or commercial blast, they are not necessarily equivalent to those surfaces produced by abrasive blast cleaning.

Some of the suitable tools and media used to achieve surfaces according to SSPC-SP 11 are¹:

- The Mini-Flushplate—Desco Mfg. Co. Inc., Long Beach, CA

¹ (Source : SSPC Painting, Manual, Vol. 2. 1991. pp. 57-60)



- Needle guns—Aro Corp., Bryan, OR and VONARX Air Tools Co., Englewood, NJ
- Grind-O-Flex wheels—Merit Corp., Compton, CA
- Nu-Matic air-inflated wheels—Nu-Matic Grinders, Euclid, OR
- 3M Heavy Duty Roto-Peen flap assembly and 3M Scotch-Brite Clean ‘n’ Strip Discs and Wheels—3M Co., St. Paul, MN

While quicker than using hand tools, the work is still labor intensive and relatively expensive. Removal of rust and other contamination from the bottom of pits and irregularities in the surface is very difficult.

In response to increased environmental regulations, many power tools are produced with vacuum recovery systems designed to collect any dust (particularly old paint) generated by the cleaning operation.

A major disadvantage of using power tools is the burnishing effect likely to be produced on the metal surface. This polishing effect, inherent with power tools, is the most unsatisfactory feature of this method. A polished surface affects the quality of paint adhesion and the effect should be avoided if coatings are to be applied.

Hand and power tool cleaning are most often used when an existing coating system is upgraded or repaired and may be the appropriate choice when there is a limited quantity of *breakdown* of the existing coating system. Some users have said that failure or deterioration of less than 20% of the coating system indicates that it would be appropriate to use repair techniques with hand or power tool cleaning, but there is no general agreement on this figure.



Level 1

Chapter 2.7

Case Study 1-A

Case Study I-A—Ethics

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 have taken place. A small local contractor has been hired to do the work. To cut his costs, the contractor has arranged the work schedule so that every Saturday, he comes in by himself to do some spray painting.

John Simmons has been an employee at one of Razorback's subsidiary plants for several years, working in the plant's quality control department. When the coating operations began, John found himself appointed as Razorback's newest coating inspector.

He found that this involved a substantial increase in his workload with no increase in pay. He was frequently required to work several hours per day overtime 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 inspection for the day and was working by himself in the field office finishing his summary final inspection report. He heard the door open and looked up to see the contractor walk in.



“Hey, Simmons . . .” the contractor began “Look, I really appreciate your 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’d like 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 a brown envelope, apparently filled with cash, with a \$50 bill on top.



Discussion Question

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:



Level 1

Chapter 2.8

Environmental Test Instruments Practice Lab

Environmental Test Instruments (*Practice Lab*)

What we want to do now is to put into practice what we learned earlier, to use a sling psychrometer, United States Weather Bureau tables, and a surface thermometer to determine the dew point, steel temperature, and relative humidity.

Please divide into your teams and complete the attached assignment. You have a maximum of 40 minutes to use the instrument and record your results. Everyone should take this opportunity to actively use the sling psychrometer and the tables. You will need to understand the instrument and how to use it on your final practical examination.

It is _____ now. We will reconvene at _____.

Measuring Humidity and Determining Dew Point

Note: For guidance, consult ASTM E 337, Method B.

Procedure

I. Equipment Required Total Per Class

1. Sling psychrometers, complete with red-spirit thermometers (Celsius or Fahrenheit, as appropriate)
2. Magnet surface thermometers (-10 to 60°C [0 to 150°F])
3. United States Weather Bureau tables or look-up chart (Celsius or Fahrenheit to match psychrometers and thermometers)
4. Jar of distilled water One
5. Wick (sock) covering for thermometers Four each
6. Spare red-spirit thermometers Two

II. Purpose of Practice Lab

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



III. Task Procedure

1. Each team is issued the following:
 - a. Sling psychrometer
 - b. Wick (sock)
 - c. Distilled water
 - d. Surface thermometer
 - e. United States Weather Bureau tables
2. Each student will be required to perform the following exercises:
 - a. Allow the surface thermometer and red-spirit thermometers to come to equilibrium in the classroom.
 - b. Attach thermometer to metal plate and record temperature immediately, after 5 minutes, after 10 minutes, and, finally, after 15 minutes.
 - c. Whirl the psychrometer properly until a stable reading is obtained for the wet-bulb. Record the wet-bulb and then the dry-bulb readings.
 - d. Consult Weather Bureau tables to determine humidity and dew-point values. Record these data. Otherwise, consult look-up chart.
3. Repeat procedure in outdoor setting. Students are to make the above determinations both indoors and outdoors.
4. Complete inspection record on following page, then answer two questions on the next following page.



Environmental Instrument Test Lab Data

Date: _____

Location: In Class

Time-->				
Wet-Bulb Temperature				
Dry-Bulb Temperature				
RH (%)				
Dew Point				
Steel Temperature				
OK to work - Yes/No?				

Location: Outdoors

Time-->				
Wet-Bulb Temperature				
Dry-Bulb Temperature				
RH (%)				
Dew Point				
Steel Temperature				
OK to work - Yes/No?				

[Note: Use metric or Imperial units as appropriate]



Station 1: Environmental Test Equipment

Equipment: Sling psychrometer, surface thermometer, magnetic-coated steel test panel, ambient condition charts

Answer both questions

Problem A—Measurements—Using the test equipment provided, and assuming a barometric pressure of **1 bar (76 cm or 30 in.** of mercury) determine the following (Use either °C or °F):

	°C	°F
1. Steel surface temperature		
2. Dry-bulb temperature		
3. Wet-bulb temperature		
4. Wet-bulb depression		
5. Dew point		
6. Relative humidity (%)		

Problem B—Look-Up—Given the following data, determine the dew point and relative humidity using either °C or °F (one column only), using the ambient condition charts provided.

	°C	°F
Steel surface temperature	18	65
Dry-bulb temperature	21	70
Wet-bulb temperature	18	64
Wet-bulb depression		
1. Dew point		
2. Relative humidity		
3. Based on generally accepted specification criteria would you, as a coating inspector, allow painting to take place? Yes or No?		

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).



Dry Bulb Temp	Chart for Calculation of Relative Humidity and Dew Point 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
75	96/74	91/72	86/71	82/69	78/68	74/66	70/64	66/63	62/61	58/59	54/57	51/55	47/54	44/51	40/49	37/47	34/44	30/42	27/39	24/36
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
79	96/78	91/76	87/75	83/73	79/72	75/70	71/69	68/67	64/66	60/64	57/62	53/60	50/59	46/57	43/55	40/53	37/50	34/48	31/46	28/43
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
84	96/83	92/81	88/80	84/79	80/77	76/76	73/74	69/73	65/71	62/70	59/68	56/66	52/65	49/63	46/61	43/59	40/57	37/55	35/53	32/51
85	96/84	92/82	88/81	84/80	80/78	76/77	73/75	70/74	66/72	62/71	59/69	56/68	52/66	49/64	46/62	43/61	41/59	38/57	35/54	32/52
86	96/85	92/83	88/82	84/81	81/79	77/78	73/76	70/75	66/73	63/72	60/70	57/69	53/67	50/65	47/64	44/62	42/60	39/58	36/56	33/54
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
89	96/88	92/86	88/85	85/84	81/82	77/81	74/80	71/78	67/77	64/75	61/74	58/72	54/71	51/69	48/67	46/66	43/64	40/62	38/60	36/58
90	96/89	92/87	89/86	85/85	81/83	78/82	74/81	71/79	68/78	65/76	61/75	58/73	55/72	52/70	49/69	47/67	44/65	41/63	39/61	36/59
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
93	96/92	93/90	89/89	85/88	82/87	78/85	75/84	72/83	68/81	66/80	62/78	60/77	56/75	53/74	50/72	48/71	45/69	43/67	40/65	37/63
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
95	96/95	93/94	89/92	85/91	82/90	79/88	75/87	72/86	69/84	66/83	63/82	60/80	57/79	54/77	51/76	49/73	46/71	43/70	42/68	38/66
96	96/95	93/94	89/92	86/91	82/90	79/88	76/87	73/86	69/84	66/83	63/82	61/80	58/79	55/77	52/76	50/74	47/72	44/71	42/69	39/67
97	96/96	93/95	89/93	86/92	82/91	79/89	76/88	73/87	69/85	67/84	64/83	61/81	58/80	55/78	52/77	50/75	47/74	44/72	43/70	39/69
98	96/97	93/96	89/94	86/93	83/92	79/90	76/89	73/88	70/87	67/85	64/84	61/82	58/81	56/79	53/78	50/76	48/75	45/73	43/72	40/70
99	96/98	93/97	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	93/98	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

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





Level 1

Chapter 2.9

Surface Preparation

**COMPARATIVE LISTING OF NACE, SSPC, AND ISO
SURFACE PREPARATION STANDARDS**

Note: This chart is comparative only, since many standards are not equivalent.

	NACE	SSPC	ISO 8501-1
NONABRASIVE CLEANING			
Solvent Cleaning		SSPC-SP 1	
Hand Tool Cleaning		SSPC-SP 2	St2 or St3 ¹
Power Tool Cleaning		SSPC-SP 3	St2 or St3 ¹
Power Tool Cleaning to Bare Metal		SSPC-SP 11	
Flame Cleaning		SSPC-SP 4 ²	F1
Pickling		SSPC-SP 8	
Waterjetting	NACE No. 5/SSPC-SP 12		
ABRASIVE BLAST CLEANING	JOINT SURFACE PREPARATION STANDARDS		
White Metal	NACE No. 1/SSPC-SP 5		Sa 3 ("Blast-Cleaning to Visually Clean Steel")
Near-White Metal	NACE No. 2/SSPC-SP 10		Sa 2 ½ ("Very Thorough Blast-Cleaning")
Commercial	NACE No. 3/SSPC-SP 6		Sa 2 ("Thorough Blast-Cleaning")
Brush-Off	NACE No. 4/SSPC-SP 7		Sa 1 ("Light Blast-Cleaning")
Industrial	NACE No. 8/SSPC-SP 14		

¹ ISO St is for hand and power tool cleaning. The two grades, St 2 and St 3 are shown as attainable with either hand or power tool cleaning.

² WITHDRAWN

³ NOTE: ISO 8501-1 has been widely adopted as a national standard in a similar way to B.S. 7079 in various countries, including Australia, New Zealand, Sweden, Japan.
BSI B.S. 7079 standards are equivalent to ISO 8501-1.

Surface Preparation

Blast Cleaning

Some of the methods of blast cleaning are:

Centrifugal blasting

- Sand-injected water blast
- Slurry blast
- Wet abrasive blast
- Dry abrasive blast

Dry Grit Blast Cleaning

The most generally established method of surface preparation for the application of coatings is by dry *grit blasting* as defined below. Indeed, when modern sophisticated coatings are applied for surface protection, there is no truly satisfactory or economically equivalent alternative process.

Dry grit blasting (using grit) is a highly concentrated stream of small abrasive particles projected at a surface removing rust, mill scale, or other contaminants creating a rough surface good for adhesion.

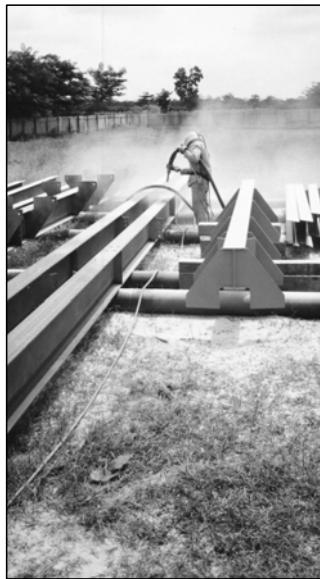


Figure 1 Dry Grit Blasting

The fundamental principle of the grit blasting process is the removal of rust, mill scale, or other surface contaminant (and obtaining a suitably roughened surface) by projecting a highly concentrated stream of relatively small abrasive particles at high velocity against the surface to be cleaned. The surface is abraded through the high-velocity impact of abrasive particles. In preparing steel surfaces for painting by blast cleaning, rust, mill scale, and old paint are removed along with some of the base metal.

Various degrees, or standards, of surface cleanliness achieved by abrasive blast have been defined. The abrasive blast cleaning standards for new steel most commonly used in abrasive blast cleaning applications are produced by NACE, SSPC, and ISO.

In October 1994, NACE and SSPC issued the following joint surface preparation standards for abrasive blast cleaning:

- 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”

These 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 system of standards represents a progressive scale of visual appearance only, the best grade being shown first in each case. The quality of blast cleaning is determined visually, and photographic standards are generally used 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 nonvisible salts). For these issues, other standards and measuring techniques must be used.

Blast Cleaning Equipment

Particles of abrasive may be projected by direct feed of the particles from a pressurized container into a high-pressure air stream (*pressure blasting*) or by centrifugal projection from rapidly rotating impellers (*centrifugal blasting* or *airless blasting*).

Direct-Pressure Unit

This is the most commonly used method of abrasive blasting. Abrasive is forced under pressure from the pressure vessel (blast pot) through the blast hose. It is a high-production method used for heavy-duty jobs, for example, in shipyards, refineries, and chemical plants and for cleaning railroad cars and buildings.



Figure 2 Blast Cleaning Equipment

Vacuum Unit

With this unit, material is blasted forward and recovered immediately by a vacuum. This method is used when no abrasive can fly around, for example, near sensitive equipment. This blasting method is expensive and is used only in special situations, such as in removal of lead-based paints.

Suction Unit

Air moves sand from hopper to nozzle; no pressure is applied to the blast hopper. Energy to move the abrasive out of the hopper comes from a reduction of air pressure through a Venturi. Because abrasive moves forward at a lower velocity, this method is used for light-duty jobs, such as frosting glass, blasting welds, and blasting car bodies and touch-up work.

Jet-Feed System

Abrasive is blown into a stand pipe and out through an elbow into the hose. This method is commonly used with fine abrasives.

A suitable type of blast unit must be chosen for the specific job. The most commonly used manual blast units are pressure vessels that can deliver abrasive into a compressed air stream by pressurizing the abrasive container. Other designs, such as gravity-fed pots or suction-fed units are not commonly used for surface preparation on an industrial scale.

When control of dust and debris is important, vacuum recovery systems are fitted to existing equipment, or specially designed units are used. The abrasive and waste are collected together, then generally separated and the abrasive recycled. The abrasive used in this case must be suitable for recycling.

The size of blast unit usually varies with the job. Blast units can range in size from those holding 1½ bags of abrasive (0.7 kilos, 150 lbs) for a small job to those holding over 40 tons of abrasive.

It is important to document the quantity, type, and size of equipment on the job. If the specification addresses certain equipment requirements and the equipment does not meet these requirements, the inspector should report the deficiency to the owner's representative.

Blast Cleaning Cabinets

It is sometimes desirable to blast clean individual items in an enclosed space so that other trades can continue to work in the immediate vicinity. If this is a regular requirement, many factories will buy or build a blast cleaning cabinet. The size of typical cabinets may vary from the very small *cupboard*—where blasting is done from outside the cabinet, with hands inserted through holes in the side—to the relatively large blasting room. The more sophisticated blast rooms may have a rail system to transport large items into the blasting area and will have grit recovery and recycling systems. In general, the blast cleaning apparatus is similar to that used for on-site blasting.



Figure 3 Blast Cleaning Booth

Centrifugal Blast

The most complex of the blast cleaning cabinets are designed for large quantities of steel to be blast cleaned 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 conveying system that will 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 from which the term *wheelabrator* has been adapted for general use. These cabinets too 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 would include shipyards or steel structure fabrication facilities, such as those used for building oil production platforms and their ancillary equipment.



Figure 4 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 wheel-blast 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 setup including air/blast hoses, abrasive pot, and an attendant
- For lower production cost

Centrifugal blasting may be used on such work pieces 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.

Manual Blasting Technique

Manual blasting should systematically cover the entire surface to be cleaned by moving the nozzle at fairly constant speeds in straight paths, each succeeding pass overlapping the preceding one and exposing clean metal without any discolored patches. The standard of blast cleaning should be no more, and certainly no less, than is required by the specification. The nozzle should be held at close to a right angle (90°) to the surface, but at a slight angle so that the abrasive does not bounce back at the operator.

Some surfaces, such as those with heavy mill scale layers or with coatings such as thermal-sprayed zinc or aluminum, are best blasted initially at a shallower angle (e.g., 45°). The operator must be aware that this technique, while efficiently removing the existing coating layer, produces a reduced surface profile due to the angle of impact. Final blasting at right angles to the surface is required if the correct surface profile is to be achieved.

Speed of nozzle travel is dictated by the rate of cleaning and should be as fast as will clean thoroughly without unnecessary dwell.

Hoses

Hoses are an important part of the blast cleaning process. Two different hoses are used:

- air supply hose
- blast abrasive hose

Air Supply Hose

This hose carries air from the compressor to the abrasive blast unit. Generally the larger the air line, the better; no smaller than 31-mm (1.25-in.) internal diameter (ID) is recommended. The recommended size should be three to four times the nozzle orifice. On lines longer than 30 m (100 ft), the hose ID should be four times the blast nozzle orifice size. The large size eliminates loss of air pressure through the air hose because of friction.

Blast Abrasive Hose

There are two types of abrasive supply hose:

- Four-ply, for 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 that is preferred by some blasters because of its greater flexibility

All hoses should have capped ends to allow for coupling and to prevent any moisture or compressed air from working its way through the braid or ply of the hose. Air inside the hose can cause the hose cover to bubble; water can cause rotting away of the wrapping on the hose. Inspection for these defects should be performed (at least by the blast operator) at the start of and periodically throughout a project.

The size and length of abrasive blast hoses are related to their efficiency. Hoses, generally, cannot be too large. Seventy-five percent of hoses used today have an ID of 31 to 38 mm (1.25 to 1.5 in.). A rule of thumb is that the hose ID should be three to four times the size of the nozzle orifice.

A *whip length* of 3 to 4.5 m (10 to 15 ft) with only a 19-mm (0.75-in.) ID is sometimes added to the end of the hose for ease of handling. The smaller ID causes a considerable drop in pressure, and it is recommended that operators use a whip attachment only when necessary.

Most blast hoses are now manufactured with an internal ground, often achieved by loading the rubber material of the hose with carbon black to allow static electricity to drain to earth. In some situations, an additional external ground may be necessary. Only grounded hoses should be used to ensure operator safety.

Couplings

Only externally fitted couplings should be used. Internally fitted couplings reduce hose ID and the air-carrying capacity significantly. In addition, a turbulent condition may be set up at the point where the air and abrasives hit the leading edge of the nipple inside the hose. Pressure drop and heavy wear can occur at that point.



Figure 5 Coupling

All joint seals should be carefully maintained to be fully pressure tight and any leaks quickly rectified.

Quick couplings are held in place with external screws penetrating into the wall of the hose. The screws should not penetrate the tube or air leaks can occur. Couplings are made of both brass (which lasts longer) and aluminum (which is lighter and easier to handle when the hose must be lifted into the air).

Couplings should be wired shut or otherwise properly coupled both to ensure safe connections and to prevent the coupling from opening if caught on irregular surfaces. Grounding should be maintained through the coupling.

Because of the inevitable pressure drop within air lines, pressure hoses should be kept as short as possible, the blast hose (i.e., distance from pot to blast nozzle) preferably not more than 6 m (20 ft). When greater distances must be used, the hose should be kept in straight runs, and any bends should be wide and have a smooth radius.

Blast Pot Care and Safety

Efficient use of the blast pot can save money in both man-hours and abrasives. The blast pot should be emptied daily, if practical, and kept dry to avoid contamination of the abrasive. Maintenance should be performed to eliminate leaks and pressure losses. The vessel should be inspected annually and hydro tested to 1-1/2 times the design pressure to ensure effective functioning.

Blast cleaning is a potentially hazardous operation. With abrasives and equipment under pressure, safety is very important. Remember that abrasives and air leave the nozzle at great speed (at a rate close to 720 kph [450 mph], or 660 ft/s, or about half the speed of a shotgun charge) and can impact on surfaces or other workers a considerable distance from the operation.

The entire system, including hoses, operator, and work piece, must be grounded 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.



Air Compressors and Equipment Used for Surface Preparation

In the blast cleaning operation, the air compressor must be capable of delivering sufficient air volume to maintain the required pressure at the nozzle. Related equipment, including the following, must be of sufficient size and type to match the compressor output:

Air and abrasive hoses

- Hose couplings
- Blast nozzles



Figure 6 Air Compressor

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 being performed, it is critical that the breathing air be fresh and pure. This is the responsibility of the applicator. Second, it is important that the blast air be clean to ensure that the blast cleaning operation does not add contaminants to the surface being cleaned.

The blasting contractor is responsible for complying with all requirements of the specifications, such as size of hose, type of nozzle, and air volume, when these are detailed in the specifications. 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 blasting machinery, paint spray equipment, power tools, etc. It is favored on site because it is relatively safe, being less dangerous than electrical power. To produce quantities of compressed air, it is necessary to use a compressor. Normally driven by a diesel motor (although electric compressors are common in fixed workshops), a compressor draws in atmospheric air, pressurizes it, and feeds the air into a pressure vessel (known as a receiver). The air is then held in the receiver until demanded by the equipment in use.

The production of compressed air presents two problems to the surface preparation process. These are:

- Any change in atmospheric pressure may result in the release of water vapor from the air.
- Because compressed air in the receiver is stored by pressurizing an oil reservoir, there is a possibility of oil vapor being retained by the air as it is released.

Both of these factors require that adequate vapor traps are fitted to blast cleaning equipment to remove the contaminating oil and water.

Compressors are rated for both air pressure and capacity.

Air pressure is measured in Pascals (Pa), pounds per square inch (psi), or bar. Air pressure is normally set a little above the intended working pressure, normally a maximum of 690 kPa (100 psi, 7 bar) for portable compressors. This pressure, if successfully maintained, produces efficient blast cleaning. Newer compressors can maintain pressures up to 1,034 kPa (150 psi, 10.5 bar). Air pressure used should be no more than safety considerations and regulations allow. This figure may vary in different countries.

Adequate pressure is critical to an effective blast process. If the abrasive is not propelled at sufficient pressure, extra time is required to accomplish the job. The compressor pressure control should be set to compensate for pressure lost in the blast hose. Pressure at the nozzle can be

measured using the hypodermic needle gauge, which we will describe later.

Capacity is measured in cubic feet per minute (cfm) or liters per minute (L/min.). The capacity of a compressor will determine the quantity of air it can deliver at its working pressure. For blast cleaning purposes, it is better to have a large capacity compressor working below its maximum level than a smaller compressor working at or near its maximum level. The compressor selected should be able to supply more air than is required to allow for reserve capacity for peak loads or for the addition of equipment.

For blast cleaning, using an 11-mm (7/16-in.) diameter nozzle operating from one blast pot, it is generally recommended that a compressor with a minimum capacity of 9,900 L/min (350 cfm) be used. For extended use, a compressor with greater capacity, perhaps 17,000 L/min (600 cfm), will operate with less strain and greater efficiency.

The same compressor used for blasting is often used to drive air-operated spray guns and other equipment. No other equipment requires such large quantities of compressed air as the blast cleaning operation.

It is estimated that with one 9.5-mm (3/8-in.) nozzle operating, there will be a 35-kPa (5-lb) drop in pressure for each 15 m (50 ft) of hose in use. This pressure drop will be compounded according to the number of operating nozzles, the nozzle sizes, and the lengths of hose being used.

Undersized compressors create inefficiencies that directly impact cost and schedule. They may lead to:

- Time wasted waiting for the compressor to build up to the required pressure when its capacity is not great enough
- Undue strain placed on the compressor during peak loads
- Loss of time caused by air-starved equipment operating inefficiently
- Inability to add new tools to the system



- Greater possibilities of breakdowns or shutdowns
- Excessive running to supply the quantity of air needed
- Excessive heat and condensation

Another consideration is the size of compressor manifold valve. The compressor should be equipped with outlets of 38 to 50 mm (1.5 to 2 in.) to match the air supply hose.

Essential Compressor Accessories

Water and Oil Separator

It is essential that surface cleanliness not be impaired during the blast cleaning process. This can arise from oil vapor or droplets carried over in the air from the compressor, from moisture entrapped in the high-pressure air, or from residual dust arising during blast cleaning.

Precautions should be taken to ensure that compressed air supplies are oil- and moisture-free. The installation of suitable oil and moisture traps, together with after-coolers and filters in the air lines is required, and these must be given adequate maintenance. Most oil and moisture traps are operated with drain plugs in a part-open position, allowing accumulated moisture to disperse.

Moist air can also cause abrasive to clog the abrasive lines or blast pot and may cause rusting of the blast cleaned surface.

Filters

These units contain charcoal and supply purified air to the blast hood. They are also equipped with a monitor to detect the presence of carbon monoxide (CO).

Driers

The units remove water from the compressed air to prevent the abrasive from becoming wet.



Absorbent

A filter absorbs moisture in compressed air to prevent condensation on the work piece.

Refrigerant

Removes water by cooling air and extracting moisture from the air stream, thereby preventing condensation on the work piece. Cooler air holds less water than warmer air.

Centrifugal Separator

Removes water through centrifugal force.

Water-Cooled Heat Exchange

Cools hot air from the compressor so moisture may be removed from the air stream.

Auxiliary Receiver

An auxiliary receiver or storage tank is sometimes used. It acts as a reservoir of compressed air. The compressed air is fed into the auxiliary tank from one or more compressors until it is needed to power the tools and operations connected to the tank.

Blotter Test

Compressed air for the blast cleaning operation can be checked for the presence of oil or water by a simple test, involving the use of white absorbent paper held in the air stream discharging from the compressor.

ASTM D 4285, “Standard Test Method for Indicating Oil or Water in Compressed Air,” requires the use of an absorbent collector, such as white absorbent paper or cloth on a rigid backing, or, alternatively, a nonabsorbent collector such as 6-mm (1/4-in.) transparent plastic. The collector is centered in the discharging air stream within 61 cm (24 in.) of the discharge point for a period of one

minute. The test should be conducted on the discharging air as close to the use point as possible and after the in-line oil and water separators.

The blotter test is used to check visually for any trace of oil or water in compressed air to be used in abrasive blasting or spray application of coatings. In 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.

Hydrocarbon oils usually can be distinguished from water using an ultraviolet (UV) light or by detecting the characteristic odor of oil. The surface being cleaned should also be thoroughly inspected for any sign of oil or water.

Blast Cleaning Nozzles and Nozzle Pressure

Nozzle Size

Other factors being constant, the speed of blasting is directly related to the size of the nozzle used. So also is the air consumption. Accordingly, the maximum nozzle size that can be used must depend upon the capacity of the compressor feeding it. The following table shows the volume of air required at various pressures to feed different sizes of nozzles.

Blast Nozzle Orifice Size		Volume of air required (ft ³ /min)				
		60 psi	70 psi	80 psi	90 psi	100 psi
1/4 inch	#4	67	76	85	94	103
3/8 inch	#6	151	171	191	211	232
1/2 inch	#8	268	304	340	376	413

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

Nozzle Qualities

Maintenance of nozzle size is of considerable importance and can be a problem if normal cast iron nozzles are employed, as these wear quite rapidly. More efficient blasting can be obtained using nozzles produced in special wear-resisting alloys or in such materials as tungsten carbide or ceramics. Although of higher initial cost, these nozzles are more economical in practice.

Nozzle Design

The internal profile of the blast nozzle is also an important factor. Venturi nozzles are generally preferred to the parallel-bore nozzles formerly used. They last longer, give higher grit velocity at more economic air consumption, and result in an overall increase in blasting efficiency.

Nozzle Designs: Venturi vs. Straight Bore

For many years, all nozzles had a straight internal bore with a small throat opening. The straight nozzles have an outlet abrasive velocity of about 349 kph (217 mph), 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.

In 1954, the Venturi shape was developed. The new shape 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 allows for abrasive velocity up to 720 kph (450 mph), or 660 ft/s and an almost equal impact over the entire surface. Venturi is the most effective nozzle shape for tough cleaning jobs.

Periodically the user should:

- Check nozzle type. The Venturi type provides a higher abrasive velocity than a straight-barrel type of the same size.
- Check for cracked and worn nozzles. Cracked nozzles should not be used because they can create a severe safety hazard. Worn nozzles decrease the effectiveness of the blasting operation.

A nozzle orifice gauge is used to measure wear. Some users specify that wear of the nozzle should not exceed one nozzle number (in the United States, 1.6 mm [1/16 in.]); other users may require that a nozzle be replaced when wear reaches 50% of the original size. The nozzle aperture test is described on the following pages.

A test for nozzle pressure of the optimum 620 to 690 kPa (90 to 100 psi) should be made using a hypodermic needle pressure gauge during the blasting operation. With the blaster's agreement, the inspector or operator should measure the pressure by inserting the needle into the hose, as close as possible behind the blast nozzle, when the hose is in actual use, blasting with abrasive. The nozzle-air-pressure test (hypodermic-needle test) is described in detail on the following pages.

Materials Used for the Nozzle Lining

The materials described refer to the nozzle lining, which is the area in contact with the abrasive. This material must be tough and durable, and resist the abrasion which inevitably occurs.

Tungsten carbide

Nozzles lined with this material have a 300-hour life; however, life expectancy is shortened when this nozzle is used with aluminum oxide or silicon abrasives.

Silicon carbide

A silicon carbide nozzle weighs 42% less than a tungsten carbide nozzle, making it easier to hold for a long time. With a dependable abrasive, the silicon carbide nozzle lasts up to 500 hours, which is 50 to 60% longer than tungsten carbide.

Norbide (boron carbide)

This is the most durable lining, with a 750- to 1,000-hour life. It can be used with all abrasives. Although boron carbide nozzles are two to three times more expensive than silicon and tungsten, their long life makes them cost effective.

Nozzle Size Considerations

Choice of nozzle size is affected by:

- The type of work to be done
- The volume of compressed air available
- The amount of pressure available
- The type of blast unit being used

Longer nozzles result in more velocity and a more concentrated blast pattern, so they are preferable on tough cleaning jobs. However, use of a nozzle too large for the work may result in power being wasted by undue blasting.

Nozzle Care and Safety

Nozzles should not be used as hammers, used for tapping signals from inside tanks, or dropped to the ground. They should be checked regularly for cracks and wear.

Nozzle Aperture Test (Venturi Nozzle)

As the nozzle is used, abrasives wear down the lining, increasing the diameter of the throat of the nozzle and decreasing its efficiency. Nozzle aperture should be checked regularly with a nozzle gauge. When performing this test:

- First, a mark is made on the gauge using a grease pencil at the approximate size of the nozzle.
- Next, the gauge is inserted in the back of the nozzle and twisted one full turn (360°).
- Then, the gauge is withdrawn and the black mark examined. The ID of the nozzle is indicated by where the grease pencil mark is rubbed off.

At the orifice size measured, the gauge indicates the volume of air in cubic feet per minute (cfm) or cubic meters per minute (m^3/min) necessary to deliver 690 kPa (100 psi) at the nozzle.

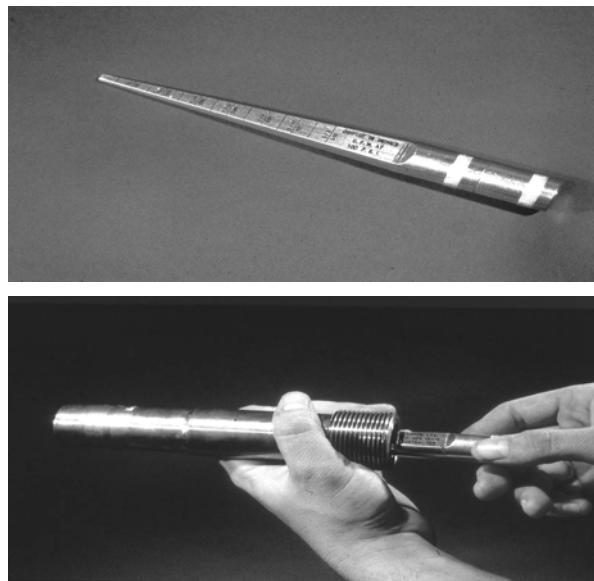


Figure 7 Nozzle Aperture Test

For example, a single #6 nozzle (9.5-mm [3/8-in.] ID) would require a compressor supplying $6.5 \text{ m}^3/\text{min}$ (232 cfm), or 6,500 L/min, to deliver and maintain 690 kPa (100 psi, 6.9 bar). If a larger diameter nozzle is used, or if the nozzle has worn to 12.5-mm (1/2-in.) ID, a larger compressor supplying $11.7 \text{ m}^3/\text{min}$ (413 cfm), or 11,700 L/min would be required to maintain 690 kPa (100 psi, 6.9 bar).

Nozzle Air Pressure (Needle Gauge)

The needle gauge is used to measure the air pressure at the nozzle. A hypodermic needle is inserted into the blast hose just behind the nozzle while the blast unit is in operation. If the pressure is less than expected or desired, the following items should be checked:

- Compressor size
- Size and length of air lines
- Couplings (for leaks, gaskets out of place)
- Size and type of nozzle
- Blast hose lining (for defects)
- Pipe on blast pot (for partial blockage)



Figure 8 Needle Pressure Gauge

Air and Abrasive Hoses

The inspector should:

- Check for evidence of damage or sharp bends in the lines. Heavy objects should never be allowed to rest on a hose.

- Ensure couplings are wired together or securely coupled for safe operations.
- Ensure abrasive hoses are properly grounded.

Productivity

Blasting Efficiency

The condition of the material to be blasted significantly influences both the rate at which blasting can be done and the quality of blast finish obtained.

Heavy rusted or corrosion-pitted steel is difficult to clean thoroughly because of the extra blasting time and attention necessary to remove deep-seated scale and injurious corrosion products. Somewhat heavier grades of grit and high blasting pressures are advantageous for such surfaces. Certain heat-treated alloy steels also acquire a particularly tenacious oxide scale, again requiring heavier grit and high blasting pressures for most efficient cleaning.

Air Pressure

In general, air pressure for grit blasting depends on such factors as grit quality and grade, type of material being blasted, and overall production requirements. Expendable abrasives are better used at high pressures—above 620 kPa (90 psi, 6.2 bar)—to obtain maximum cleaning rates, as grit breakdown after impact is of little consequence other than creating something of a dust problem.

Increased pressure materially increases rates of blast cleaning due to greater grit throughputs and higher particle velocities. Labor costs per areas blasted can therefore be considerably reduced, although grit losses tend to increase significantly above about 517 kPa (75 psi, 5.1 bar).

Also, at high blasting pressures—above 620 kPa (90 psi, 6.2 bar)—operator fatigue can limit productivity on long blasting *shifts*.

Nevertheless, it is usually recommended that blast pressure as measured at the nozzle be kept as high as is possible, with the provision that it cannot normally exceed 690 kPa (100 psi, 6.9 bar) to comply with safety regulations. The reasons are related to efficiency and production rates:

- Work done is considered to be directly proportional to the air pressure at the nozzle.
- 690 kPa (100 psi, 6.9 bar) at the nozzle gives 100% efficiency.
- 550 kPa (80 psi, 5.5 bar) at the nozzle gives 66% efficiency.
- 455 kPa (66 psi, 4.5 bar) at the nozzle gives 50% efficiency.

For example, at 455 kPa (66 psi, 4.5 bar) nozzle pressure only half as much area would be cleaned as at 690 kPa (100 psi, 6.9 bar), during the same time.

Note: Nozzle pressure may be measured by the operator or inspector using a hypodermic needle gauge.

The main reasons for inability to maintain high nozzle pressures are:

- Inadequate air supply. Theoretically, a #6 (9.4-mm, 3/8-in.) nozzle—one of the popular sizes—requires 6,570 L/min (232 cfm). To provide the necessary quantity of air, a compressor of at least 8,600 L/min (300 cfm) would normally be employed. For a larger nozzle, more air would be required and a proportionally bigger compressor would be needed.
- Too small air hoses; friction losses are expensive.
- Internal hose couplings can cause loss of efficiency, up to 15% of the working pressure. External couplings and nozzle holders are a must.
- Badly designed machines may have a significant pressure loss through the machine.
- 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.
- Air must be clean and dry.

Rates of cleaning cannot be quoted definitely. There are many variables affecting a blasting operation, including:

- 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 being used.

As a very general guide only, high cleaning rates can reach $30 \text{ m}^2/\text{h}$ ($300 \text{ ft}^2/\text{h}$). Low rates can fall to as low as $4 \text{ m}^2/\text{h}$ ($40 \text{ ft}^2/\text{h}$). It must be stressed that these production rates are indications only and cannot be assumed for any specific job. Similarly, the consumption of abrasive can be variable, and calculation of quantities used is very much a matter of trial or experience. As a general guide, an expendable abrasive consumption rate of 50 kg/m^2 (10 lbs/ft^2) is common for irregular structures.

Abrasives

The degree of surface roughness and the rate of cleaning depend primarily on the characteristics of the abrasive grit used. Although the blasting abrasives in general use 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 types of abrasive commonly used for preparation for painting. These are:



- Chilled iron grit or shot abrasives
- Crushed slag
- Naturally occurring mineral grit
- Ceramic grit

Note: 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 abrasive but increasingly cannot be used throughout the world (nor can any abrasive containing free silica) due to the very real health hazard of *silicosis*. Workers exposed to hazardous levels of free silica dust—such as that released during the blast cleaning process—may develop silicosis, a disease of the lung.

Some naturally occurring forms of sand are said to be *silica-free*, and these may still be found in common use, particularly in the United States. Silica-free sand does not release silica in a harmful form (i.e., free silica) when it breaks up under the impact of the blasting process.

Permission to use sand may occasionally be given for *site work* in the open air, but only when the operators and other personnel are carefully protected from the dust created and the site and blasting conditions are approved by the health authorities (e.g., factory inspector, OSHA). This is most likely to occur when the sand is to be used in conjunction with waterjetting equipment.

Chilled Iron Grit or Shot

This is by far the most widely used abrasive for surface preparation in a coatings application facility or any similar workshop environment. Chilled iron grit is available in a variety of grades and to a specific minimum hardness. It is an excellent general purpose abrasive due to its relatively high density, which gives high particle energy, and its slow but effective rate of breakdown which maintains cutting edges on the grit particles.



Figure 9 Chilled Iron Grit

While chilled iron grit is used extensively for grit blast preparation in works or on site where grit reclamation and recirculation can be achieved, it is too expensive an abrasive to be used where grit reclamation is not possible, as on many site jobs.

Crushed Slags

Crushed slags from metallurgical processes or combustion are relatively cheap abrasives. Copper slag, coal slag, and aluminum slag are common. While quite effective grits for *once only* use, because of their rapid breakdown to dust, they are not generally suitable for grit reclamation and reuse. These materials are often called *expendable abrasives*.

Chemical Analysis of Typical Copper-Slag Abrasive

A typical analysis of copper-slag abrasive may show the chemical content to be similar to the following table:

SiO ₂	38.40%	Silicon Oxide
Al ₂ O ₃	3.35%	Aluminum Oxide
TiO ₂	0.35%	Titanium Oxide
FeO	41.55%	Iron Oxide (II)
Fe ₂ O ₃	3.15%	Iron Oxide (III)
MnO	0.27%	Manganese Oxide
CaO	5.86%	Calcium Oxide
MgO	2.15%	Magnesium Oxide
K ₂ O	0.53%	Potassium Oxide
Na ₂ O	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. Notice also that most of the contents are oxides of one metal or another.

Ceramic Grit (Aluminum Oxides and Silicon Carbides)

These are relatively expensive abrasives, but their use can sometimes be justified by their special properties.

Due to the retention of sharp cutting edges on the particles in use, their cutting action can be particularly effective, especially on hard-base materials which may resist effective blasting by chilled cast iron grit.

Additionally, the effective cutting action can be achieved at blasting pressures lower than normally employed for other abrasives. These ceramic grits are particularly well suited to blast preparation of thin metal surfaces, which show *buckling* or distortion 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 safely used to grit blast stainless steel or nonferrous material surfaces, without causing rust staining, discoloration, or bimetallic corrosion.

Shot

Blasting abrasives that are rounded in shape are known as *shot*. Their common use during the development of blast cleaning techniques leads to the common misuse of the term *shot blasting*.

Shot used for blast cleaning has less cutting effect and hence will prolong the life of blasting equipment and machinery (e.g., wheelabrators and other automated equipment). The disadvantage is that less cutting effect gives a more-rounded, less-rough surface, often below the adhesion requirements of today's high-performance coatings. It is still widely used in blast cleaning machines used to prepare steel prior to fabrication. The prefabrication primers used must be carefully selected and must be compatible with the surface produced by shot blast cleaning and with the subsequent coatings if they are to remain on the steel surface and become part of the coating system.

In addition to blast cleaning, shot blasting may usefully *work-harden* a metal surface by *peening*, a process which can reduce the incidence of stress corrosion cracking.

Abrasives Checks

The inspector and the operator should ensure that:

- Both the type and size of abrasive being used are as specified.
- The appropriate specified recycling procedure is followed. Most metallic abrasives, such as iron and steel shot and grit, and expensive abrasives, such as glass beads, may be recycled. Contaminants, including fines, dust, paint, and mill scale, must be removed from the abrasive materials if they are to be recycled.

- Abrasives are clean and free of moisture and oil.
- They are stored off the ground, away from moisture and the elements.

Abrasive Cleanliness Test

Abrasives can be tested for cleanliness through the use of a simple test known as the *vial test*. Some of the abrasive is dropped into a small vial of water of known pH (preferably distilled or deionized water with a pH of 7) and shaken. Typically, the ratio should be one volume of abrasive to two volumes of water. The top of the water is inspected for a film of grease or oil. The water can be visually checked for turbidity (cloudiness due to sediment), which is usually a sign of excess dirt, dust, or clay in the abrasive.

A litmus or pH paper test of the water in the vial will tell whether the abrasive is acid or alkaline. pH paper will indicate the actual value of acidity or alkalinity. If the abrasive is dirty, or is acid or alkaline, the coating inspector should document these results and immediately report this to the owner's representative.

Litmus and pH papers indicate the presence of those chemical salts dissolved in water, which form an acidic or basic solution. (Note: Litmus and pH papers will NOT detect the presence of chlorides). If the red litmus paper changes to a blue color, the solution is basic. If the blue litmus paper changes to red, the solution is acidic. If, however, the litmus paper does not change, it indicates the solution is neutral. However, 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.

Abrasive Sieve Analysis

ASTM C 136 is the test method for sieve analysis of fine and coarse aggregates.

Typically a 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.

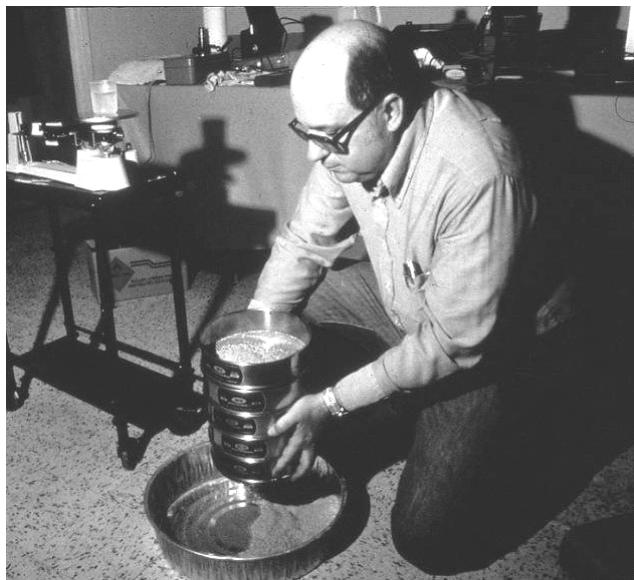


Figure 10 Abrasive Sieve Analysis

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.

When in doubt about whether a given abrasive is the correct size, a mesh or sieve test may be performed. Equipment required for the test includes:

- An accurate balance
- A set of United States National Bureau of Standards (NBS) screens

A convenient quantity of abrasive is weighed (1,000 g [about 2.2. lbs] is a very handy weight) and then poured into the top of the nested screens. The screens are nested so that the screen with the largest openings is on top,

graded down through the screen with the smallest openings on the bottom, for example: from top to bottom, #8, # 15, # 16, #40, #50, etc.

The screens are shaken over a retaining pan; the abrasive particles are retained on the screens whose sizes are 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 which remain on each screen and calculate the percentage retained. This is why using 1,000 g of abrasives to start with is convenient. If, for example, 238 g of abrasive is retained at a given level, we know that 23.8% of the abrasive was retained at that level without doing a lot of extensive arithmetic.

In addition to the specific size of abrasive, hardness is also a significant factor. Harder abrasives have a greater cutting effect but may also shatter on impact, limiting their ability to be recycled. Softer abrasives have less cutting effect and may become rounded as they are used, but recycling is an economic advantage of such materials. Hardness is commonly measured on the Rockwell scale (e.g., metallic chilled iron grit, HRC range 50 to 55) or on the Mohs scale (e.g., Copper slag abrasive, hardness range 6 to 7 Mohs). These two scales may be correlated, but manufacturers typically quote one scale or the other, not both.

- Metallic
- Hard nonmetallic (oxides)
- Slag
- Free silica-containing
- Agricultural



Types of Abrasives

Metallic Abrasives

Some examples of metallic abrasives include:

- **Cast steel:** This is a hard metallic abrasive used for removing scale and other hard surface deposits.
- **Steel grit:** Steel grits are abrasives with irregular shapes. They 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.
- **Steel shot:** Shot is spherical in shape; 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. Shot may cause stretching of light materials, driving mill scale and other impurities into the surface.
- **Cast iron:** Hardest metallic abrasive; used for removing 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 be used in no corrosive environments; it has a high initial cost, but can be recycled.
- **Malleable iron:** A relatively hard metallic abrasive, used for removing 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 to 65 HRC (HRC = Hardness, Rockwell C)—are often used for etching, but they break down rapidly. Softer abrasives—35 to 40 HRC—may be used for easier cleaning jobs. These materials may round up after use.

The average hardness of metal abrasives is 45 to 50 HRC, which works well as an air blast abrasive.



Hard Nonmetallic Abrasives (Oxides, Natural, or Manufactured)

Hard nonmetallic abrasives can be used indoors and outdoors, under various atmospheric conditions. Hard nonmetallic abrasives have a breakdown rate greater than any of the metallic abrasives. Low initial cost may compensate for the high loss during blasting.

Garnet (oxide): Garnet is fast cutting, has long life, is good for cabinets and blasting rooms, and is both sharp and angular.

Silicon carbide (oxide): This abrasive is expensive and fast-cutting; it is also used for grinding wheels.

Aluminum oxide: The mineral corundum is natural aluminum oxide, and emery, ruby, and sapphire are impure crystalline varieties. It can be manufactured from bauxite. It is fast-cutting, durable, uniform, and expensive.

Reclaiming is critical to economic use of silicon carbide and aluminum oxide. The hard nonmetallic abrasives are free of the silica hazard present with siliceous abrasives.

Slag Abrasives

Refractory Slag: This type of slag is manufactured from byproducts of burning coal, refining copper, and nickel. It is fast-cutting with medium durability.

Mineral Slag: SSPC-AB 1, “Mineral and Slag Abrasives,” is a specification that defines the requirements for selecting and evaluating mineral and slag abrasives used for blast cleaning steel and other surfaces for painting and other purposes. This specification mainly covers abrasives intended for one-time use without recycling; reclaimed materials must be retested before reuse.

Abrasives Containing Free Silica

Siliceous abrasives, like the synthetics, can be used indoors and out, under various atmospheric conditions. The potential to release free silica is a limiting factor

because of the health hazards associated with breathing dust containing free silica.

Because of their greater breakdown into dust, free-silica-containing abrasives should not be used where dust will present a hazard to workers or machinery. In the United States, all persons working near the operation, including coating inspectors, are required by OSHA to wear protective clothing, goggles, and breathing equipment.

Sand: This was once the most commonly used abrasive in heavy-duty situations such as cleaning old rusty surfaces. Sand is available in many sizes. Sands differ in breakdown rate, but generally become significantly finer after the first use. Many operators do not allow reuse of sand abrasive.

Flint/Chert: Flint (sometimes called *chert*) is a crystalline form of native silica or quartz. The color varies from smoky gray to brownish-black to dull yellow. These materials are products of hard rock mining. They are hard and break to very sharp edges.

Quartz (SiO): Quartz is sharp, fast-cutting, and expensive.

Sand is still used in the United States because it is cheap. The high breakdown rate of sand may tend to counter its original low cost. Usually, no attempt is made to reclaim sand. However, it is often considered (particularly in the United States) 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.

Agricultural Abrasives

In addition to the other abrasives we have discussed, the agricultural abrasives are commonly used in a variety of situations where abrasive dust associated with other abrasives may be harmful to sensitive equipment. When stainless steel or other high-purity alloys are blasted, it is important that the abrasive cannot embed metallic particles in the surface. Crushed walnut shells have been used, for example, to blast clean components of the space



shuttle to preserve the integrity of the special alloy materials.

Specialty Abrasives

These include such abrasives as dry ice, plastic beads, sponge, bicarbonate of soda, and ice.

Dry ice (carbon dioxide): This is frozen (solid) carbon dioxide. It may be produced on site by the cooling of liquid carbon dioxide and compression of the resulting flakes into pellets. This abrasive may also be produced by grinding and screening blocks of dry ice.

Caution: Dry ice generates very low temperatures (boiling point is -79°C, -110°F) and can cause immediate frostbite if it comes in direct contact with exposed skin.

Dry ice has been used successfully to remove certain types of surface contaminants and existing organic coatings. It does not change the surface roughness of metal surfaces. It produces little or no dust and usually leaves the substrate dry and cold. Dry ice is a single-use abrasive, because it evaporates immediately after use. The pellets of CO₂ are produced in close proximity to the site of blasting (within a few meters) and are used immediately.

Ice (Water): Produced by freezing water, either on site or off site. The ice is crushed and sieved to produce the blast abrasive. It is used for removal of certain types of surface contaminants and existing organic coatings. It will not change substrate roughness and does not produce dust, but will leave substrate wet with water. Ice is a single-use abrasive.

Plastic Beads: These are small plastic beads (about the size of the holes in a plastic button) used to remove coatings with a minimum of roughness change to the substrate. Plastic beads are almost always used in recovery (recycle) systems. They are extensively used to strip coatings from aircraft. The dust produced may be combustible.

Plastic bead blasting requires extensive training of the blast operator, because the abrasive flow, work-to-nozzle distance, and blast air pressure will be different for



different coating types. These variables are usually determined by the blast operator. This abrasive leaves the surface dry, but it may be dusty.

Baking Soda (sodium bicarbonate): Baking soda usually is used in a water slurry driven by compressed air. It is useful to remove surface contamination and existing coatings with minimum substrate change. It produces little or no dust, but the substrate must be rinsed with fresh water as a final step. The operator requires special training; abrasive cannot be recycled.

Sponge: Sponge particles (synthetic) are used to remove surface contaminants and create a surface profile suitable for recoating. The sponge particles are propelled by compressed air 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 particle. 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.

Other Abrasives

This class of abrasives includes water slurries of abrasives that have low hardness and are soluble in water. It has been reported that sodium chloride (salt) and other products of that type have been used.



Abrasive Selection

Some or all of the following should be taken into account 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

Abrasive Recycling

Recycling is usually done so that expensive abrasives, such as high-grade metallics, can be reused. It may also be used to reclaim less expensive abrasives, like sand, if shipping costs are a factor.

In centrifugal blasting, reclamation (or recycling) is a standard operation. The process is more difficult in nozzle blast operations which are not confined. In small cabinets and blast rooms, recycling is fairly simple; it is more complex in larger rooms.

There are four major methods of reclamation:

- **Screen method:** In this method, the abrasive runs over a series of screens; the top, large-size screen eliminates oversized materials; the remaining abrasive falls down to a smaller screen. Dust and fines pass through, leaving only usable abrasive in the screen. The method can be done by hand or mechanically.
- **Air-screen wash:** In this separating system, the oversized abrasives are removed by mechanical screens. The abrasive is distributed over a wide sloping plate, which causes it to fall over the edge. As it falls, the abrasive passes through an air stream at a

predetermined velocity. The usable heavy abrasive is carried a short distance and then falls into a chute. This method is considered less precise than the screen method.

- **Water method:** Because it uses water, this method is used with noncorrodible materials only, never with iron and steel. In this method, abrasives are passed through a water wash, which separates the dust and fines from coarse particles. The upward velocity of the water is reduced, which causes the heavier abrasives to be deposited in the bottom of the reclaimer. The remaining abrasives are dried in a kiln before being reused. The water method is inexpensive and is helpful in reducing dust but can require large amounts of water that should be filtered and purified before being released into drains or rivers.
- **Cyclone method:** In this separating method, the abrasive is drawn through a hose into a cylinder similar to a high-powered vacuum sweeper. Rapidly moving air in the cylinder sends the dust and fines out the top of the cylinder; the heavier, reusable materials fall through a screen at the bottom.

Abrasive Test Summary

Testing should be conducted if:

- Abrasives are being recycled
- Abrasives such as river or beach sand are being used
- There is some reason to suspect incorrect sizing or contamination of the abrasives
- There is much variation in profile depth
- There is an unexplained difference in color of the blasted steel



Table 1 General Types of Abrasives

Metallic	Nonmetallic	Siliceous	Agricultural	Specialty Abrasives
Chilled Cast Iron	Silicon Carbide	Quartz	Coconut Shells	Dry Ice
Cast Steel	Aluminum Oxide	Flint	Black Walnut	Ice
Malleable Iron	Garnet	Sand	Pecan Shells	Plastic Beads
Crushed Steel		Silica	Peach Pit Shells	Soda
Cut steel wire	Refractory slag Mineral slag		Filbert shells	Sponge
			Cherry pit Almond Shells Apricot pit Shells Rice Hulls Ground Corn Cobs Sugar	Glass beads

Table 1 shows the five major classifications of abrasives and some of the types of abrasives found in each category:

Abrasives should be certified as being checked for and free of soluble chemical salts, particularly if used in a wet blast operation.

Safety Note: All abrasives may present a health hazard and require the use of proper respiratory safeguards.



Table 2 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
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

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. The following chart, however, shows some abrasives that may be used to attain a given anchor pattern.

Table 3 Choosing Abrasives for a Given Anchor Pattern

Anchor Pattern		Pressure Blast or Centrifugal Wheel
Mils	Micrometers (µm)	
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:

1. Pressure blast: normally around 620 kPa (90 psi) nozzle pressure 60 cm (2 ft) from surface
2. Steel shot is not normally recommended when a sharp anchor pattern is required; its round shot peens the surface.
3. It should be remembered 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.
4. These recommended abrasive sizes apply only to mild steel. As the hardness and type of metals vary, so will the anchor pattern.



Table 4 SAE Shot Specifications

SAE Shot Number	Max. Percent Retained	Screen Number and Aperture	Max. Percent Retained	Screen Number and Aperture	Min. Percent Retained	Screen Number and Aperture	Max. Percent Retained	Screen Number and Aperture	Max. Percent 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

S.A.E.	MAX. LIMIT SCREEN		NOMINAL SCREEN		MIN. LIMIT SCREEN	
Grit Number	Maximum Grit Retained Percent	Screen Number and Aperture	Minimum Grit Retained Percent	Screen Number and Aperture	Maximum Grit to Pass, Percent	Screen Number 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)	-	

Safety

Operator Clothing and Air Supply

For the safety and comfort of the blast cleaning operator, it is essential that good quality working clothes are used. Typically these would include:

- 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 11 Blast Operator Safety

It is important that the operator has a good supply of clean, fresh air for breathing. Two common ways of achieving this are:

- A supply of air at low pressure is delivered from the blast pot via a filter. This method has the disadvantage of the air being the same quality (often poor) as that used for blasting.
- A separate supply of air, also at relatively low pressure, is fed from a remote air-driven pump well away from any contaminated or dust laden atmosphere.

Operator Safety for On-Site Blasting

Abrasive blast cleaning at high pressure is a dangerous operation. It is essential that steps are taken to protect both the operators and any spectators or other site personnel. Some considerations would be:

- No one but the operator should be allowed within the vicinity of the blast cleaning operation.
- Warning notices should be displayed.
- A look-out (or *pot-man*) should be on the alert.
- All equipment should be tested for safety in operation.
- A *Deadman's Handle* cut-out device should be fitted and used. A deadman (remote control) valve, which allows the machine to be controlled at the nozzle by the operator should be part of this unit. The inspector should ensure that this safety feature is always operable and is in use during blast operations.

Blast Pot and Accessories

Several accessories are commonly used with the blast pressure pot, including:

- Abrasive metering valve, which meters the proper balance of abrasive to the air flow and nozzle size
- Remote control (deadman) valve

The remote control valve (*deadman valve*) must be held 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 or 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 12 Deadman Valve

The deadman valve could be considered to be cost effective because it can eliminate the need for a pot tender (or blaster's helper). Figure 12 shows an operator holding the blast nozzle with his hand under the deadman.

Remote control valves may be operated 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 and are not intrinsically safe, so they cannot be used in a hazardous environment.

Filtered and regulated air-supplied respirators are required for all dry abrasive blast cleaning.

Not only the operator but all personnel in the contaminated area must wear approved breathing apparatus. In addition, all equipment must be grounded to prevent electrical shock.

Safety Summary

All participants in the surface preparation process, including coating inspectors, should use common sense in detecting potential hazards. Any lighting, scaffolding, or equipment malfunctions presenting safety hazards should be reported to the appropriate person. Knowledgeable and responsible workers will always assure themselves of 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 be traveling as fast as 450 mph, having the effect of a shotgun blast.

The coating inspector must follow all safety and health rules as established by the safety engineer or the person responsible for safety on the contract.

The coating inspector 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

The operators may be required to ground equipment, and the coating inspector may be required to verify that the equipment is properly grounded.

Site safety must conform to applicable worker protection rules and regulations. In the United States, OSHA (Occupational Safety and Health Administration) regulations provide the necessary guidelines. In other countries, similar governmental bodies have developed similar regulations that must be observed. A more detailed appraisal of appropriate regulations is provided in the safety module of this program.



Masking

When blast cleaning is taking place, it is common for some areas not to be blasted, for a variety of reasons. Typical examples include surfaces that are already painted or sensitive equipment such as valves or instruments. Where such surfaces have to be left unblasted, these can be *masked off* using suitable templates of metal or rubber or suitably tough masking tapes firmly secured to the surface requiring protection from the blast stream.

Masking materials should be fixed in place before any blast cleaning begins in the immediate area. They should be checked on a regular basis to ensure that they are providing adequate protection and should be carefully removed at the completion of the blasting and painting operation.

Blowdown

On completion of blast cleaning, the blasted surface should be cleaned to remove residual dust and abrasive. It may be blown down with a high-pressure jet of clean dry air, vacuum cleaned, or brushed with a clean dry brush until there are no traces of residual dust or grit. The surface at this point in time should closely resemble the visual standard of surface finish specified (e.g., NACE No. 2/SSPC-SP 10, Sa 2½, etc.).

When dust or grit is not completely removed, it often remains hidden in crevices or corners. It can be disturbed by the high pressures of the paint spray stream and distributed into the paint film, causing a poorly adherent paint layer or an incomplete film.

Surface 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*.



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 37 to 87 μm (1.5 to 3.5 mils).

Surface profile is important in that it increases the surface area and roughness (anchor tooth) to which the coating can adhere.

Too shallow a surface profile may result in premature coating failure due to lack of adhesion seen as peeling, blistering, or delamination.

Too high a profile may have peaks that are inadequately covered, resulting in *rust rashing* or rust spots. This effect is most likely when primers are applied but left exposed (without topcoats) for some period of time. Good practice suggests that at least two coats of a coating system should be applied 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 67 μm (2.5 mils). This effect may be caused—in part—by attempts to increase the thickness to achieve coverage of the profile peaks. Inorganic zinc silicate primers are well known to be sensitive to excess thickness. The guidelines provided by the coating manufacturer on technical data sheets should be followed.

Depth of surface profile can be evaluated by several methods:

- Comparator and coupons
- Replica tape
- Dial gauge depth micrometer (profilometer)

Surface Profile Coupons

Surface profile coupons are available in 12- μm (0.5-mil) increments from 12 to 75 μm (1/2 to 3 mils). The coupons allow for determination of surface profile through comparison (ASTM D 4417, Method A).

Other examples of surface profile coupons are the ISO 8503 comparators for grit and shot.



Figure 13 Surface Profile Coupons

According to ISO 8503, there are two types, Type G for grit abrasives and Type S for shot. With the assistance of a 5X (and not to exceed 7X) lighted magnifier, the profile reference comparator is placed on the blasted surface to assess the profiles on the comparator that are nearest the profile of the blasted surface and determine grade.

Five grades may be recorded:

- Finer-than-Fine Grade
- Fine Grade
- Medium Grade
- Coarse Grade
- Coarser-than-Coarse Grade

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

The comparators are accompanied by a card stating the parameters of ISO 8503 Part 1 and Part 2. The assessment of the comparators is to be reported by the user as being one of the five grades, not a segment number. It is also suggested that the user review the cards for additional information.

Keane-Tator Surface Profile Comparator

The Keane-Tator surface profile comparator consists of a reference disc and a 5X illuminated magnifier. The disc has five separate leaves, each of which is assigned a number representative of the profile depth of the leaf. The reference disc is compared with the surface through the 5X magnifier. The leaf that most closely approximates the roughness of the surface is considered to be the pattern of that surface. Reference discs are available for sand, grit/steel, or shot abrasives.

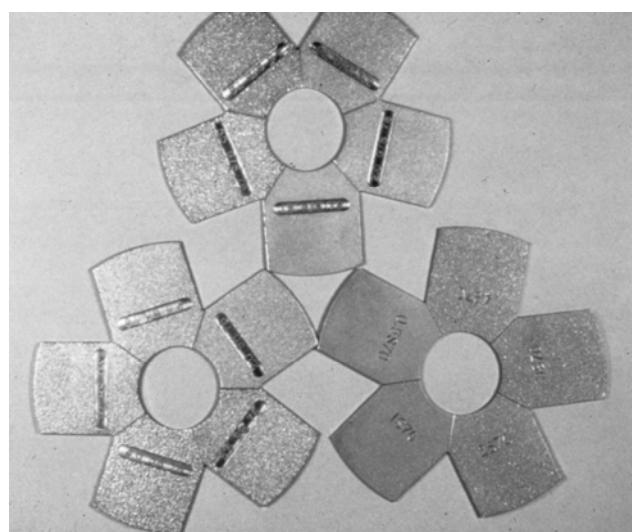


Figure 14 Keane-Tator Surface Profile Coupons

Replica Tape

Surface profile may be measured with replica tape, a proprietary product produced by the Testex® Corporation. Two types of tape are commonly used: coarse—for 20- to 50- μm (0.8- to 2.0-mil) surface profile and extra coarse—for 37- to 112- μm (1.5- to 4.5-mil) surface profile.



Figure 15 Replica Tape and Anvil Micrometer

A piece of tape with a small square of compressible foam plastic attached to a noncompressible plastic (Mylar) film is applied to the blast cleaned surface, dull side down. A hard, rounded object (burnishing tool), such as a swizzle stick, is then used to crush the foam to the blast cleaned surface, causing the foam to form an exact reverse impression (replica) of the actual surface profile.





Figure 16 Replica Tape Procedure

The tape is removed from the surface and an anvil micrometer is used to measure the thickness of the foam and the plastic. The thickness of the Mylar film (50 μm [2 mils]) is subtracted from the micrometer reading, and the result is the depth of the surface profile.

Note: Two standards are used to describe the working method for using replica tape: NACE Standard RP0287 and ASTM D 4417, Method C.

Dial Gauge Depth Micrometer

The instrument base rests on the tops of the surface profile peaks, while the spring loaded tip projects into the valleys. The method of use is according to ASTM D 4417, Method B. This is a very sensitive test and, although it can be used in the field, its best application is in the laboratory.

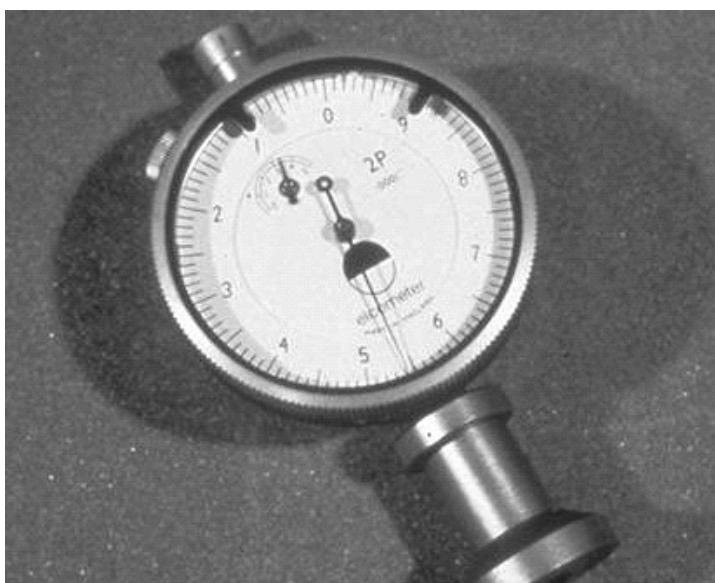


Figure 17 Dial Gauge Depth Micrometer

If the surface profile (anchor pattern) is found by measuring to be less than was specified, a deeper profile can be achieved by reblasting with a more aggressive or bigger abrasive and possibly at greater air pressure. If the surface profile (anchor pattern) is found to be greater than specified, remedial work may not be possible.

Digital Surface Profile Gauge

This gauge works like the dial gauge depth micrometer in that it measures peak-to-valley distances, but it has the following added capabilities:

- Can store readings in instrument memory
- Can statistically analyze reading sets
- Can print hardcopies of instrument readings

The instrument has an accuracy of $5 \mu\text{m}$ (0.20 mil) $\pm 5\%$. It has a replaceable tip.

The instrument should be calibrated in accordance with ASTM D 4417, Method B.

To use, first adjust the gauge to zero. Take readings by firmly holding the instrument on the prepared surface. Do not drag the instrument across the surface between readings as this may damage the stylus and affect gauge accuracy. The number of readings taken should be sufficient to characterize the surface, or as specified or agreed upon by all parties.

Other Profile Measuring Techniques

Other surface profile instruments, such as a depth measuring microscope or diamond-point tracking stylus gauges, are sophisticated laboratory methods not commonly used in the field (on site) or blast shop.

Surface Cleanliness

- Surfaces must be free of oil and grease before blast cleaning. Blast cleaning will not remove oil and grease.

- All surfaces should be inspected after cleaning for compliance with the specification.
- Cleanliness after preparation is important. Residual traces of abrasive must be blown off, vacuumed, or swept away before primer coating. (Note: If lead is present in the paint waste or blast debris, the surface cannot be blown off. The contractor must follow all regulations regarding lead removal.) Any scaffolding, staging, or support steel above the surface must also be cleaned to prevent abrasive from dropping onto the freshly cleaned surface or onto the newly primed surface.

Surface Condition at Time of Painting

Surfaces prepared for coating should not be allowed to deteriorate or to be contaminated in any way between completion of the preparation phase and coating application.

Clean grit-blasted surfaces should not be handled or touched unless hands are protected with clean gloves. They should also not be exposed for prolonged periods or exposed at all to atmospheric or storage conditions of high humidity. Under such conditions oxidation and rusting may proceed very rapidly.

As far as practicable, any storage after blast cleaning should be in a warm, dry environment and, ideally, spraying should follow blasting as quickly as possible. Commonly applied rules indicate a maximum delay of four hours and require that *If visible deterioration has occurred, the surface preparation shall be repeated.*

Surface Cleanliness Standards

There are many standards related to surface preparation, issued by many standards writing organizations. Those that will be described in some detail in CIP Level 1 are produced by:

- NACE International
- SSPC—The Society for Protective Coatings



- ISO—International Organization for Standardization

Effect of Environment on Abrasive Blasting Operations

Ambient conditions may have an effect on the abrasive blasting process as well as on the blast cleaned surface before painting. Ambient conditions include:

- Air temperature (and substrate temperature)
- Relative humidity
- Dew point temperature
- Environmental exposure (e.g., marine and industrial)

Air Temperature

It is unwise to abrasive blast if the steel surface is much colder than the surrounding air. Moisture may condense on the blasted surface causing the surface to flash rust. The substrate temperature may be checked using a steel surface thermometer.

Relative Humidity

When blast cleaning, high humidity (moisture) can result in the rapid deterioration of the cleaned surface. Final dry abrasive blasting should not be performed 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 and a surplus would appear as condensation. For that reason, most coating specifications require that coating not be carried out if RH exceeds a certain limit, usually 85 or 90%.

In addition, if air is saturated with water vapor, the evaporation of solvents is inhibited, causing problems with coating film formation.



Relative humidity is calculated by making temperature measurements with a hygrometer.

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 will not achieve adequate adhesion to the substrate.

If abrasive blasting is performed when environmental conditions are close to the dew point temperature, condensation is likely and flash rusting may occur.

For this reason, coating specifications normally have a requirement that coatings should not be applied if the temperature of the steel or the surrounding air is less than 3°C (5°F) above the dew point. Dew point, like RH, is calculated by making temperature measurements with a hygrometer.

Time Limits Before Coating

To reduce the risk of a prepared surface deteriorating before coating, specifications often impose a time limit. Typical wording may be:

Coatings shall be applied to surfaces prepared for painting within 4 (four) hours of completion of the preparation activity.

Clearly, the risk of deterioration depends to a large extent on prevailing ambient conditions (temperature, relative humidity, etc.), so the four-hour period allowed may appear to be arbitrary. It is imposed as a helpful safeguard and should be observed when specified. Other typical time allowances may be 2 hours for the most critical applications or in changeable weather zones, or 6 hours or even 8 hours when stable, positive weather conditions are anticipated. The specification statement may be developed by the addition of:

...or before any visible deterioration of the surface, whichever is the sooner.

In this case the time limit still applies. If surface discoloration is seen, the discoloration should be removed by further preparation and the surface coated, regardless of how much time has passed since preparation was completed.

Dehumidifiers

One way to ensure that ambient conditions are suitable for painting is to dehumidify the air. This is naturally only possible in an enclosed space.

The most commonly used dehumidifiers work by drawing ambient air across a desiccant, such as silica gel, and delivering the air at a lower RH to the desired space. A separate stream of air is heated and passed over the desiccant to remove the moisture and revitalize it. This second stream of air is vented to the atmosphere. The attainment of very low humidity is possible in large spaces. This technique is commonly used in ship tanks and crude oil storage tanks.

Other types of dehumidification equipment are available, and these are discussed in the advanced surface preparation module of this program.

Environmental Exposure (Atmosphere)

In marine and industrial environments where the air contains particles of chemical salts, the possibility exists 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 reblast the surface.

The presence of certain chemical salt deposits, such as ferrous sulfate, or ferrous hydroxides may be determined by means of test papers or chemical test kits.



Chemical Contamination of Corroded Steel

Generally, corroded steel is more difficult to clean than new steel. The surface is less smooth than new steel, and it often contains chemical contaminants bonded to the steel in the corrosion process. These contaminants are known as *soluble salts*, and are not easily removed in the surface preparation process.

Soluble Salts

Steel that has been exposed to 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 *nonvisible* 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 completion of the blast cleaning process, particularly when humidity is relatively high—it is a clear indication that the surface is contaminated.

To remedy the problem, the surface should be cleaned more thoroughly. Further blast cleaning may be effective in some cases, but better success may be achieved by washing using high-pressure wash equipment. Waterjetting may also be effective to remove heavy contamination. Surface preparation in these cases should be followed by testing for soluble iron (ferrous) salts and/or chlorides, to ensure that remaining contamination is below critical levels.





Figure 18 pH Indicator Paper

Inspection of Surface Cleanliness

The rust that forms on steel surfaces exposed to either industrial or marine atmospheres may contain significant quantities of sulfate and chlorides. If these compounds are not removed, they can give rise to premature paint failure. Spot tests have been developed to detect the presence of soluble iron, sulfates, and chlorides on blast cleaned steel.

In these spot tests, color reactions are used to indicate the sites of contaminated rust. Each method employs pieces of chemically treated filter paper which can be dried after use to provide permanent records. The papers are pressed against the steel surface which has been wetted with distilled water. After a short time in contact with the surface the papers are removed and examined for color changes.

Qualitative Test for Acid or Alkaline Conditions

The use of litmus paper to determine acidic or alkaline conditions has already been discussed. To perform a simple test on a cleaned surface, a swabbed sample should be collected using distilled water and cotton swabs.

Because the test is not quantitative, the volumes of distilled water and the area swabbed are not critical, but

for the sake of consistency a regular swabbing technique should be followed. The method described for quantitative measurement of soluble iron salts (see below) could be used, or a litmus test made on the same sample.

A positive reaction (alkaline when red litmus paper turns blue, acidic when blue litmus paper turns red) indicates the surface is not neutral and further cleaning is required.

Quantitative Test for Acid or Alkaline Conditions

The use of pH indicator paper allows a measure of the degree of acidity or alkalinity (pH) on a surface. Once again, the surface must be washed or swabbed to collect a representative sample, and it is good practice to follow a standard method. When the sample has been collected, immersion of pH paper for 2 seconds, followed by observation of the color change, allows measurement of the pH. The color is compared to a color chart provided with the pH paper, and a pH number between 1 and 14 can be recorded.

Electronic pH testers are available to provide digital measurements. Once again, a liquid wash or swab sample must be collected, and the tip of the pH tester is immersed in the solution long enough to provide a stable measurement. Coatings should not be applied to surfaces with pH less than 6 or greater than 8 without the specific technical approval of the manufacturer.



Qualitative Test for Soluble Iron

A filter paper is saturated with potassium ferricyanide solution (orange) and dried. When pressed against a wet steel surface it will show a blue color wherever soluble iron salts have been dissolved by the water.

Qualitative Test for Soluble Sulfates

Test papers are prepared by being soaked in a barium chloride dehydrate (6%-by-weight) solution and dried. The dry paper is then pressed against the test surface, backed by a second paper soaked in saturated potassium permanganate. *Contamination* is absorbed and held in the barium sulfate lattice, imparting a pink color to those parts of the paper that contacted sulfates.

Qualitative Test for Soluble Chlorides

For this test, a filter paper is wetted with silver nitrate (2%-by-weight) solution and then pressed against the steel surface for about 20 seconds. It is then peeled off and thoroughly washed with chloride-free water. Any silver chlorides formed remain in the paper and can be detected by immersion in photographic developer. Chloride sites show as brown-black areas. The paper can be washed and dried for record purposes.

Qualitative Test for Mill Scale

An acidic solution of copper sulfate, applied to a blast-cleaned surface, will deposit bright copper on clean steel, but will show a black color on mill scale.

Quantitative Test for Soluble Iron

The Merckoquant test provides an indicator paper that reacts to the quantity of dissolved iron in water. To relate to the quantitative nature of this procedure, a controlled washing or swabbing technique must be used.



This test does not determine the quantity of chlorides, sulfates, or any other specific salt. It measures the quantity of soluble iron in the form of Fe^{++} or Fe^{+++} ions.

Test for Oil Contamination

Oil present in small quantities on blast cleaned surfaces may be detected by:

- Shining an ultraviolet light source on the surface, causing the oil to fluoresce.
- Pouring solvent across the surface. The solvent should form a continuous flow and not *break* into droplets.

Ultraviolet Light

An ultraviolet light can be used to illuminate a surface to reveal traces of certain hydrocarbon oils and grease, fingerprints, etc. Ultraviolet light also may reveal other materials on the surface, which may or may not be detrimental to the coating.

Safety Note: Only approved ultraviolet lamps should be used. Looking directly into unshielded ultraviolet lamps, may cause severe eye damage, including blindness. Consult the safety engineer or other knowledgeable person about any ultraviolet lamp you may consider using.

Water Blast Cleaning

Surface preparation for coating application using water as a principle ingredient is a relatively recent development. It was developed for two principle reasons.

First, the presence of water damps down dust emissions and allows the use of abrasive blast cleaning techniques in places where the dust is considered a nuisance or hazardous.

Second, the water can have the effect of washing away soluble contamination, which dry blast cleaning cannot easily remove. 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.



Figure 19 Water Blasting

Two forms of water blast cleaning have been developed. Those that use abrasive combined with water and those that use water alone.

Waterjetting and Water Blasting

For a number of years, industry has used water under high pressure as a means of surface preparation of steel and other hard surfaces where abrasive blasting was not feasible. Certain surface preparation standards, such as NACE Standard RP0172, incorporated the term *water blast* in the title and body of the document. The use of this term has been confusing to many users, since it seems to imply that some type of abrasive in the water is always necessary.

Currently, when preparing surface preparation standards, NACE, SSPC, and other societies have agreed to use the term *waterjetting* to describe the cleaning process where water alone is the cleaning medium. The term *water blast* is used to describe any cleaning process where abrasive of

some type is incorporated with water to form the cleaning medium.

In the advanced CIP courses, waterjetting and water blasting are discussed in more detail, but for now, we will take a brief look at this cleaning process as an alternative to abrasive blast cleaning.

Inhibitors

In waterjetting and other similar cleaning operations using water, an inhibitor is sometimes added to the water to help prevent rusting of the cleaned surface before a coating can be applied. This only applies, of course, when preparing steel (ferrous) surfaces.

Potential problems associated with the addition of inhibitors include:

- Quantity of inhibitors must be carefully controlled. The deposition of excess quantities of inhibitor on a surface will probably successfully prevent rust formation, but is also likely to interfere with coating adhesion. Equally, the deposition of too little inhibitor on a surface will fail to provide protection against rust formation.
- Inhibitor deposits are likely to interfere with long-term coating performance. The introduction of a chemical layer between the coating system and the prepared surface is controversial and has been criticized by experts as *weakening* the protection given by the coating system.

Inhibitors are generally added to the water in the form of soluble solids added to the water container or in liquid concentrate form added to the blast stream by metering through an injector. Successful use of inhibitors depends on the consistency of whichever method is chosen.

Waterjetting

Waterjetting has been categorized by the standards-producing bodies (NACE, SSPC, etc.) for the sake of consistency. The current categories defined by NACE and SSPC are:

- Low-Pressure Water Cleaning (LP WC): Cleaning performed at pressures below 34 MPa (5,000 psi)
- High-Pressure Water Cleaning (HP WC): Cleaning performed at pressures of 34 to 70 MPa (5,000 to 10,000 psi)
- High-Pressure Waterjetting (HP WJ): Cleaning performed at pressures of 70 to 210 MPa (10,000 to 30,000 psi)
- Ultrahigh-Pressure Waterjetting (UHP WJ): Cleaning performed at pressures above 210 MPa (30,000 psi)

The advantages of high-pressure waterjetting include:

- Use of water as a cleaning material, since water suitable for water cleaning is generally available in inexpensive large quantities
- Lack of contamination of surrounding areas because there are no abrasive particles
- Lack of dust and spark hazards

Waterjetting equipment used for surface preparation generally includes:

- High-pressure water pump attached to a motor of suitable size
- High-pressure hose
- Special design nozzle



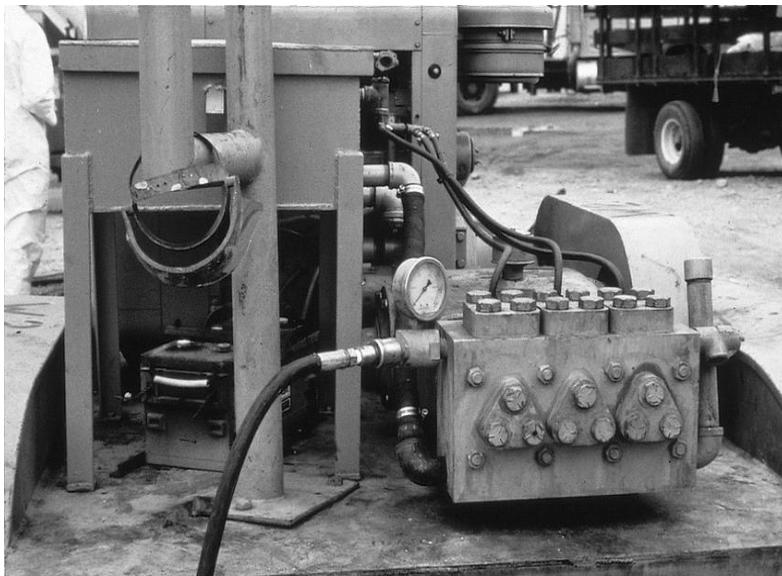


Figure 20 Waterjetting Equipment

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 (deadman valve)

In addition, the use of a regulator to gradually increase pressure at start-up will help the operator adjust to the back pressure of the spray nozzle.

Low-Pressure Water Cleaning

Low-pressure water cleaning (LP WC) used for surface preparation is primarily a washing technique. At pressures below 34 MPa (5,000 psi), water removes soluble contamination and some loosely adherent surface contaminants. It will reliably remove chalking of aged coatings, leaving the coating surface intact.

Low-pressure water cleaning is often used to wash the underside of ships in dry dock, removing the marine

growth and some deteriorated antifouling coatings prior to recoating.

High-Pressure Water Cleaning

High-pressure water cleaning (HP WC) is commonly used for surface preparation of concrete surfaces prior to coating application.

Using properly focused water nozzles, HP WC equipment is capable of cutting through steel plate or concrete blocks, so the technique can be both efficient and dangerous. When used for surface preparation for coatings, the production rate is relatively low. In addition, only loose contamination can be successfully removed.

High-Pressure Waterjetting

High-pressure waterjetting (HP WJ) equipment is seldom used for surface preparation for coatings. The cleaning effect is not better than equipment operating at lower pressure, and the production rate is not cost effective.

Ultrahigh-Pressure Waterjetting

This method uses water at very high pressure—210 MPa (30,000 psi) and above (up to 340 MPa [50,000 psi]). 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 UP 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 8 L (2 gal) per minute.

The nozzle must be held close to the surface being cleaned, as the cleaning effect decreases rapidly at some distance from the nozzle. The water stream has almost no effect on the surface if the nozzle-to-surface distance is increased to more than 50 cm (18 in.). The most effective cleaning effect is achieved at a spray distance of



approximately 50 mm (2 in.), though the blast pattern is then very narrow, and production rates may decrease.

Water used at this pressure removes most contaminants, such as chemical salts, dirt, grease, and rust scale. It will not produce a surface profile but is capable of restoring the prior surface profile wherever it previously existed, provided the equipment is designed to clean the surface to a high standard. This is typically achieved only by operating at the highest pressures (240 MPa [35,000 psi] and above).

One incidental benefit of the very high pressures used is a heating effect on the surface being blasted. In the case of steel, this heat has the effect of limiting the deterioration through rusting, and the surface remains relatively clean (though with some *ginger* discoloration).

Waterjetting in Immersion Conditions

Pure waterjetting is seldom used at pressures below 48 MPa (7,000 psi) for surface preparation prior to painting, except as a wash technique. It is, however, in common use under water for the removal of marine growth on ships and oil-related structures.

The cleaning of marine growth from a ship's hull or offshore structure is normally achieved at pressures between 20 and 50 MPa (2,900 and 7,200 psi, 200 and 500 bar).

The performance depends upon two main factors:

- The maneuverability of the diver and the 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 200 m²/h (2,000 ft²/h) can be achieved with high-pressure waterjetting. However, many other factors must be taken into consideration under water and the performance is usually reduced as a result. To give an indication of underwater jetting rates, the legs of a drilling platform in the North Sea covered with weed and mussel growth up to 600 mm (24 in.) thick were cleaned at the rate of 20 m²/h (200 ft²/h). This was exceptionally heavy fouling.



However, as there is no reaction force with an underwater blast unit (since the design compensates for reverse thrust), the operation is performed with considerably less physical effort when compared with similar work above the surface.

Underwater concrete cutting is another application for waterjetting, and equipment has been employed for this purpose at depths up to 140 m (450 ft). A section of damaged concrete coating on a 760-mm (30-in.) 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 76 MPa (11,000 psi, 760 bar) were employed on this occasion, and one diver at a time from the team was employed to handle the gun and perform the cutting.

Where steel must be brought to a white metal finish, special underwater equipment has been developed that uses abrasives injected into the water stream.

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 takes place in a relatively public environment, as when city buildings are blast cleaned, for example. For this reason, equipment was developed to provide a shroud of water around a normal flow of abrasive carried in compressed air.

Other advantages of this modified dry blasting system include the ability to remove soluble contaminants from the surface 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 the problem of removing the used abrasive (in its wet form) and the necessity of using an inhibitor in the water to prevent surface rusting when used to clean steel.

The 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.

In use, the water stream wets the abrasive stream outside and in front of the nozzle discharge, which helps keep dust to a minimum. This cleaning process may be used where dust would be objectionable. The surface profile is similar to that achieved with dry abrasive blasting but, of course, the surface is wet after blasting.

Blasting pressures are much the same as for dry blasting, up to 690 kPa (100 psi, 6.9 bar), and production rates are similar. Clean up time is probably more, because of the difficulty of removing wet abrasive sludge.

Sand-Injected Water Blast

This method uses the same basic equipment required for 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 possible to create a desired surface profile on the cleaned surface. As with dry blasting, the surface profile created depends largely on a combination of abrasive size and pressure used. In general, the abrasive will be less effective when mixed with water, and the surface profile will be less than that produced by the same abrasive used dry.

Production cleaning rate is much better with abrasive injected into the water stream, and up to 90% of the dry blasting production rate can be achieved with this type of equipment. Typical water usage is in the range of 8 to 60 L/min (2 to 15 gal/min). The production rate is around 50% of that achieved by dry blast cleaning.



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 then is pumped through a single hose to the blast nozzle.

Many of the comments made above also relate to the use of slurry blasting equipment, although these specialized units have certain extra advantages. Because the abrasive/water mix is pumped as slurry, the pressure can be easily controlled. 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.

Moisture-Tolerant Coatings

A disadvantage of water blasting or waterjetting of any kind is that the quantity of water used creates a damp environment and a wet surface. In general, the surface must be allowed to dry before coatings are applied, or special moisture-tolerant coatings must be used.

Some coating manufacturers have developed coatings, often based on epoxy technology that can be applied directly to a wet surface. The use of such coatings greatly increases the convenience of using this method of surface preparation.

Some of these specialty coatings are designated as being tolerant of *damp* conditions, others as being tolerant of *wet* conditions. Care should be taken to determine how wet the surface will be at the time of application.

Waterjetting Summary

The use of water blasting has created a great deal of controversy. There is no doubt that the control of the system (with its ability to reduce pressure, etc.) is valuable and that reduction of contamination of the surface is important. On the other hand, the need to use inhibitors, thereby setting deposits on the steel surface, and the

problems of disposal of the spent abrasive may be matters that require considerable justification.

There is also, as yet, some doubt about the long-term performance capabilities of the new (moisture tolerant) coatings that have been developed for application to wet surfaces.





Item No. 21065

Joint Surface Preparation Standard

NACE No. 1/SSPC-SP 5 White Metal 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 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 10¹).

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

Contents

1. General	1
2. Definitions	1
3. Associated Documents	1
4. Procedures Before Cleaning	1
5. Blast Cleaning Methods and Operation	2
6. Blast Cleaning Abrasives	2
7. Procedures Following Blast Cleaning and Immediately Prior to Coating	2
8. Inspection	3
9. Safety and Environmental Requirements	3
10. Comments (Nonmandatory).....	3
References.....	3
Appendix A: Explanatory Notes (Nonmandatory).....	4

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 1² 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 abrasives.

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 abrasives.

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).

NACE No. 1/SSPC-SP 5

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 4⁸ 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, G₁ SP 5, G₂ SP 5, and G₃ 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 RP0287¹¹ 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 2¹³ 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.



Item No. 21066

Joint Surface Preparation Standard

NACE No. 2/SSPC-SP 10 Near-White Metal 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 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 6¹) but less than white metal blast cleaning (NACE No. 1/SSPC-SP 5²).

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

Contents

1. General	1
2. Definitions	1
3. Associated Documents	1
4. Procedures Before Cleaning	1
5. Blast Cleaning Methods and Operation	2
6. Blast Cleaning Abrasives	2
7. Procedures Following Blast Cleaning and Immediately Prior to Coating	2
8. Inspection	3
9. Safety and Environmental Requirements	3
10. Comments (Nonmandatory).....	3
References.....	3
Appendix A: Explanatory Notes (Nonmandatory).....	4

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 mm² [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 1³ 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).

NACE No. 2/SSPC-SP 10

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-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: 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 4⁹ 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, G₁ SP 10, G₂ SP 10, and G₃ 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 SP0178¹⁰ 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.

⁽¹⁾ ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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 RP0287¹¹ 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 2¹³ 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.



Item No. 21067

Joint Surface Preparation Standard

NACE No. 3/SSPC-SP 6 Commercial 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 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 14¹) but less than near-white metal blast cleaning (NACE No. 2/SSPC-SP 10²).

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

Contents

1. General	1
2. Definitions	1
3. Associated Documents	1
4. Procedures Before Cleaning	1
5. Blast Cleaning Methods and Operation	2
6. Blast Cleaning Abrasives	2
7. Procedures Following Blast Cleaning and Immediately Prior to Coating	2
8. Inspection	3
9. Safety and Environmental Requirements	3
10. Comments (Nonmandatory).....	3
References.....	3
Appendix A: Explanatory Notes (Nonmandatory).....	4

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 mm² [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 1³ 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
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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.

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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.

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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.

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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.

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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.

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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.

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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.

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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.

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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).
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).

NACE No. 3/SSPC-SP 6

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-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: 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 4⁹ 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, G₁ SP 6, G₂ SP 6, and G₃ SP 6 depict surfaces cleaned to commercial 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 SP0178¹⁰ 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

⁽¹⁾ ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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 RP0287¹¹ 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 2¹³ 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.



Item No. 21068

Joint Surface Preparation Standard

NACE No. 4/SSPC-SP 7 Brush-Off 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 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 14¹). 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

Contents

1. General	1
2. Definition	1
3. Associated Documents	1
4. Procedures Before Cleaning	1
5. Blast Cleaning Methods and Operation	2
6. Blast Cleaning Abrasives	2
7. Procedures Following Blast Cleaning and Immediately Prior to Coating	2
8. Inspection	3
9. Safety and Environmental Requirements	3
10. Comments (Nonmandatory).....	3
References.....	4
Appendix A: Explanatory Notes (Nonmandatory).....	4

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 1² 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-off 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.

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. 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).

NACE No. 4/SSPC-SP 7

11. ASTM⁽¹⁾ D 4417 (latest revision), "Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel" (West Conshohocken, PA: ASTM).
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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.

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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, G₁ SP 7, G₂ SP 7, and G₃ 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.

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ensure that coating thicknesses are properly measured, the procedures in SSPC-PA 2¹² 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.



Item No. 21076

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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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

Contents

1. General	1
2. Definitions	1
3. Surface Cleanliness Requirements	1
4. Flash Rusted Surface Requirements	3
5. Occupational and Environmental Requirements	3
6. Cautionary Notes	3
References.....	4
Bibliography	5
Appendix A: Surface Cleanliness Conditions of Nonvisible Contaminants and Procedures for Extracting and Analyzing Soluble Salts	6
Appendix B: Waterjetting Equipment	7
Appendix C: Principles of Waterjetting	7
Table 1: Visual Surface Preparation Definitions	2
Table 2: Flash Rusted Surface Definitions	3
Table A1: Description of Nonvisible Surface Cleanliness Definitions (NV)	6
Table C1: Typical Pressurized Water Systems	8

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.

NACE No. 5/SSPC-SP 12

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 7⁷).

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.

NACE No. 5/SSPC-SP 12

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⁾ 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, $\mu\text{g}/\text{cm}^2$ (grains/in.²) or mg/m^2 (grains/yd²) ($1 \mu\text{g}/\text{cm}^2 = 10 \text{ mg}/\text{m}^2 = 0.0001 \text{ grains}/\text{in.}^2 = 0.13 \text{ grains}/\text{yd}^2$).

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 $\mu\text{g}/\text{cm}^2$ (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 $\mu\text{g}/\text{cm}^2$ (0.0007 grains/in. ²) of chloride contaminants, less than 10 $\mu\text{g}/\text{cm}^2$ (0.001 grains/in. ²) of soluble ferrous ion levels, or less than 17 $\mu\text{g}/\text{cm}^2$ (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 $\mu\text{g}/\text{cm}^2$ (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 Method⁹
- (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 Method¹¹
- (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 Strips⁹
- (b) Chloride Chemical Titration Kit⁹
- (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 Water¹⁴

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 Ions⁸
- (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 handheld 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).

$$\text{Kinetic Energy} = \frac{1}{2}mv^2 \quad (\text{C1})$$

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



Item No. 21082

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.

Joint Surface Preparation Standard

NACE No. 6/SSPC-SP 13 Surface Preparation of Concrete

Contents

1. General	1
2. Definitions	1
3. Inspection Procedures Prior to Surface Preparation	2
4. Surface Preparation	3
5. Inspection and Classification of Prepared Concrete Surfaces	5
6. Acceptance Criteria.....	6
7. Safety and Environmental Requirements	6
References.....	6
Appendix A: Comments	8
Table 1: Suggested Acceptance Criteria for Concrete Surfaces After Surface Preparation	6
Table A1: Typical Surface Properties of Finished Concrete.....	9
Table A2: Surface Preparation Methods	14

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-

NACE No. 6/SSPC-SP 13

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 301⁷ 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 6G191⁸ 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 515.1R⁹ 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 6G191⁸ 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 6G191⁸ 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 samp-

ling 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 4258¹¹ 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 4258¹¹ 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.

NACE No. 6/SSPC-SP 13

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 12,¹² 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 4260¹⁴ 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. 03732¹⁷ (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 4262¹⁸ 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 2170²¹ 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.

References

1. ACI 116R (latest revision), "Cement and Concrete Terminology" (Farmington Hills, MI: ACI).
2. SSPC-Guide 11 (latest revision), "Guide for Coating Concrete" (Pittsburgh, PA: SSPC).
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).
4. ACI 308 (latest revision), "Standard Practice for Curing Concrete" (Farmington Hills, MI: ACI).
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NACE No. 6/SSPC-SP 13

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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 2²⁷ 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 Characteristics²³

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 Cure²⁹

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 308⁴ 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 308⁴ 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 Damage³⁰

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 RP0390⁵ and ICRI 03730⁶ describe removal and repair procedures for concrete

NACE No. 6/SSPC-SP 13

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 6G191⁸ 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 Testing³⁶

The two commonly used methods for testing adhesion of coatings to concrete substrates are ASTM D 4541³⁷ (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 4541³⁷ 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 503R³⁸ 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. 03732¹⁷ (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 method¹⁹

ASTM F 1869, Calcium chloride test²⁰

ASTM F 2170, Relative humidity test²¹

ASTM E 1907, Conductivity test⁴³

ASTM E 1907, Calcium carbide method⁴³

ASTM E 1907, Capacitance-impedance method⁴³

A1.8.5 Use and Interpretation of Moisture Test Methods

A1.8.5.1 The plastic sheet method¹⁹ 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 method¹⁹ 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/m² (3 lb/24 hr/1,000 ft²) 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 cre-

ated, 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 RP0892¹⁵ and ACI 515.1R⁹ 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 7¹) but less than commercial blast cleaning (NACE No. 3/SSPC SP-6²).

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

1. General	1
2. Definitions	1
3. Associated Documents	1
4. Procedures Before Cleaning	1
5. Blast Cleaning Methods and Operation	2
6. Blast Cleaning Abrasives	2
7. Procedures Following Blast Cleaning and Immediately Prior to Coating	2
8. Inspection	3
9. Safety and Environmental Requirements	3
10. Comments (Nonmandatory).....	3
References.....	4
Appendix A: Explanatory Notes (Nonmandatory).....	4

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 mm² [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 1³, ISO⁽¹⁾ 8501-1⁴ (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.

Additional information on surface imperfections is in Paragraph A4 of Appendix A.

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).

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.

blast nozzle, and abrasive, with or without vacuum for dust and abrasive recovery.

5.2 Any of the following methods of surface preparation may be used to achieve an industrial blast cleaned surface:

5.2.3 Dry abrasive blasting using a closed-cycle, recirculating abrasive system with centrifugal wheels and abrasive.

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,

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.

6.3 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.

6.2 The cleanliness and size of recycled abrasives shall be maintained to ensure compliance with this standard.

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 be considered requirements of the standard. The sections

NACE No. 8/SSPC-SP 14

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 4¹⁰ 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 G₁ SP 14, G₂ SP 14, and G₃ 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 SP0178¹¹ 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 RP0287¹² or ASTM D 4417.¹³

NACE No. 8/SSPC-SP 14

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 2¹⁴ 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.



Level 1

Chapter 2.10

Self-Study Questions

Chapter 2.4—Documentation

1. The inspector is generally required to provide the client with _____ of inspection work.
2. The type of reporting to be done by the inspector should be identified in the _____ or developed during the pre-_____.
3. An alternative to the logbook/notebook may be a portable _____.
4. Entries in the inspector's logbook/notebook should be in _____ and not in _____.
5. Daily reporting is important because:
 - a. inspector may _____
 - b. it may be an aid in _____
 - c. it is valuable in _____
6. Routine reports may include:
 - a. _____
 - b. _____ history

Chapter 2.5—Pre-Job Conference

1. True or False - A pre-job conference is just as useful if held later, after the job has begun, as it is if held before the job starts.
2. One of the most important things an inspector can do in a pre-job meeting is to _____ his _____.
3. The inspector's job is part of a _____.
4. One way an inspector can help the contractor is by ensuring fair and _____ of the specification.
5. There are at least three ways to handle conflict, but perhaps the best way is to _____ it.

Chapter 2.6—Surface Preparation Overview

1. Inspection for contamination should take place:
 - a. before any _____
 - b. after _____ and before coating
 - c. _____ each coating application
2. Condition of steel surfaces:
 - a. True or False - In condition A, the steel is essentially new steel covered with mill scale, with little or no rust.
 - b. True or False - In condition B, the steel is covered with rust but has no mill scale.
 - c. True or False - In condition C, the steel is covered with rust and some pitting is visible.
 - d. True or False - In condition D, the steel is covered with rust and pitting is visible.
3. The inspector should examine the steel for design and _____ defects.
4. True or False Some solvents, such as xylol or toluol, dissolve oil and grease, and can dissolve the vehicle of some coatings and cause them to lift off the surface.
5. Detergents should be the _____ type.
6. True or False - Alkaline cleaners can leave a slightly soapy film on the surface.
7. True or False - Acidic cleaners work by chemically attacking and then dissolving the reaction products.
8. Water is sometimes called the _____ solvent.

Chapter 2.9—Surface Preparation

1. True or False - SSPC-SP 3 is the standard for hand tool cleaning.
2. SSPC-SP 3 is the method of preparing the steel surface by the use of _____ hand tools.
3. True or False - Rotary power wire brushes provide a good surface profile.
4. True or False - Scaling or chipping hammers can cut the metal surface and leave sharp burrs.
5. True or False - Rotary scaler can be used to remove mill scale and rust from the surface.
6. SSPC- SP 11 is the standard for power tool cleaning to _____.
7. In preparing steel surfaces according to SSPC-SP 11 for painting, the surface must be roughened enough to produce a profile not less than _____ mil (_____ μm).



Level 1

Chapter 3.1

Coating Application by Brush, Roller and Mitt

Coating Application by Brush, Roller, and Mitt

Coating application is one of the important factors in the performance of any coating system. The quality and physical properties of a coating material are determined by the manufacturer, but the potential performance can only be reached if the coating is properly applied. Other factors, such as surface preparation and the choice of coating for a specific service environment, are also important.

To become a successful protective coating, the material must be transferred from its primary container to the surface to be protected and must then form a cohesive film with desired properties. The film must be dense, resistant to the passage of moisture and other potentially damaging or corrosive materials, and must dry or cure to its solid state. The application process plays a significant role in film formation.

Application Methods

There are many methods used to apply protective coatings for industrial use, including:

- Brush
- Mitt
- Roller (hand or power)
- Spray (including conventional air spray, airless spray, or some modification of these)

Of these, spray application is probably the most widely used for industrial protective coatings.

(Note: Other specialized methods, including trowel or hand application and complex spray equipment, are discussed in the advanced CIP courses. Dip coating,



roller coating, spin coating, and other similar techniques are also discussed in the advanced CIP courses.)

One or more of the following may influence the choice of the method used:

- Size and type of job. Bigger jobs are more likely to use more equipment and more sophisticated equipment. The type of job (defined by the specification) will determine what application method is required or most suitable.
- Accessibility of areas to be coated. Some projects (e.g., elevated water tanks, radio/TV masts) will place restrictions on the type of application equipment used for practical reasons.
- Configuration of areas to be coated. More complex areas may be difficult to coat adequately with spray equipment. Large flat areas (e.g., ships, tanks, etc.) are mostly suited for spray application.
- Presence of critical areas or surrounding environment that could be damaged by overspray (from spray application). Increasingly there is public resistance to debris, such as overspray, drifting off the job site. Full containment of the work area may be possible, but the use of brushes and rollers rather than spray equipment may be a more economical solution to the problem.
- Type of coating. Many modern coatings, particularly high-solids, high-build coatings, are designed for application by spray techniques. Brush or roller application is not recommended and should only be used when spray application is not possible or for small areas such as repair areas.
- Availability of skilled workers. More sophisticated coatings and equipment require significant expertise by the individual applicators. In many geographical areas the level of skill is simply not available to allow specification or use of such materials.

- Budget constraints. If money is not available to pay for the more expensive coatings or application equipment, choice may be limited to simple materials and simple application techniques.

Application method depends very much on the type of coating being used. Some specialized coatings, in particular, may be restricted to a specific application method. Some coatings that are 100%-solids, for example, can only be applied using special equipment such as heated plural-component airless spray pumps or by mechanical methods, such as by trowel or by hand.

Conventional liquid coatings—applied by brush, roller, or spray—should generally be applied in multiple passes, thin enough to allow proper evaporation of the solvents as the coating dries and cures. Some high-build coatings, particularly those with thixotropic qualities, dry too fast to allow reworking that would occur with brush application, and must be sprayed. Other high-build coatings cannot tolerate the thinning that would be necessary to make them pass through conventional spray equipment, and airless spray equipment must be used.

Coatings used on porous surfaces should be able to penetrate and fill the surface voids in the substrate, and should be thinned if necessary to ensure penetration.

Brush Application

Application of paint by brush is the traditional method, although, in industrial terms, it has been largely superseded by spray application techniques. Brush application of coatings is slower than other methods and generally is used:

- For smaller jobs (new construction and maintenance) where application by roller or spray may not be feasible and for repair or *touch-up* of damaged areas
- For *cutting in* corners or edges

- To achieve good penetration into crevices or pits
- In critical areas where spray application, if used, may cause damage because of overspray on surrounding surfaces, such as around sensitive machinery, motors, instruments, and glass faces on gauges
- For stripe coating of welds, rivets, bolts, nuts, edges, flanges, corners, etc.

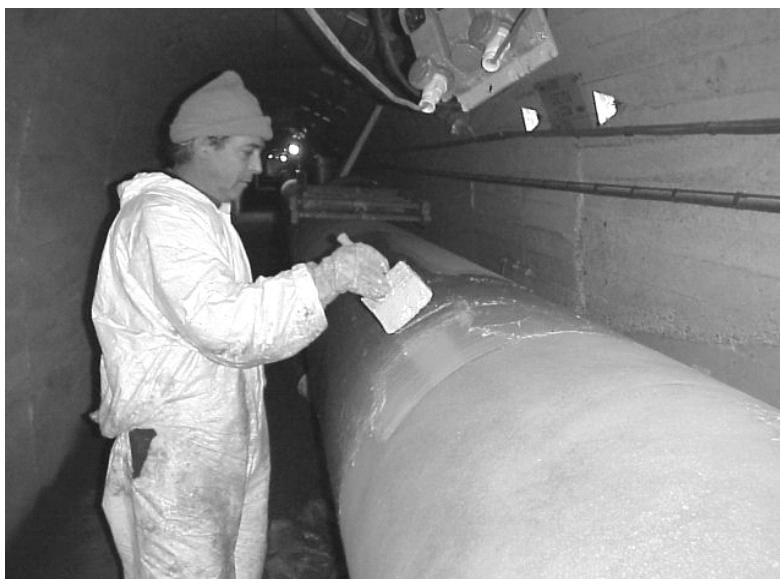


Figure 1 Brush Application

However, there is no doubt that the rubbing action of a brush can be an additional aid to good adhesion. For this reason, brushing is often preferred for application of primers and is also recommended for the general application of underwater compositions. Brush application can be advantageous for application of coatings on surfaces that cannot be fully and properly cleaned. The superior *wetting* action achieves better contact between the coating and the surface. This is especially useful on rusted steel, where spray application may leave the coating sitting on top of the corrosion layer with little or no penetration—and therefore little or no adhesion.

Even when repainting old paintwork (for maintenance), it may be helpful to brush-apply the first coat.

A brush of suitable size for the work in hand should always be selected; using a small brush on a large area makes it difficult to apply an even coating and slows down the rate of working, while using a large brush on a narrow area makes accurate work impossible.

In practice, the brush is dipped into the coating and the excess material removed, by wiping or tapping the brush on the edge of the container as it is withdrawn. The brush is used to flow the coating on the surface in smooth, even strokes without undue pressure that could leave streaks or valleys in the coating on the surface.

Subsequent applications should be made at right angles to the previous coat in a cross-hatch style. This procedure helps ensure complete, even coverage and helps seal any pinholes from the previous coat.

The applicator should maintain a *wet edge* and brush the coating out from a newly coated area towards the previous wet edge. This practice minimizes the visual appearance of brush marks and overlapped work areas.

For application of industrial protective coatings, there are three major points to be considered:

- Brush painting is said to achieve superior *wetting*.
- Brush marks (i.e., peaks and troughs) lead to areas of low film build.
- Consistently high film build is difficult to achieve and lower film build should be specified. To achieve higher film build, it may be necessary to apply multiple coats.

Application using a brush is slow. This can be both positive and negative:

- Positive—slows operator down, makes him/her look carefully at what he/she is doing

- Negative—slows operator down and therefore is more time consuming, less economical

Brush Construction

Brushes are made by embedding bristles in a setting compound, then attaching a wooden or plastic handle. The flat end of the handle and the setting compound are then joined together with a ferrule.

Filler strips are inserted inside at the bottom of the bristles, which makes a cavity to hold more coating. This process reduces the number of bristles required and makes it easier to spread coatings.

Longer bristles are installed in the center part of the brush and lengths are tapered toward the outer bristles. This tapered effect makes coating application easier than if all the bristles were the same length.

Two types of bristles are used:

- Natural bristles
- Synthetic filaments

The traditional *china* bristles come from the china hog; the ends of these bristles are naturally split or *flagged*. This feature makes the china bristle an excellent bristle because it can hold more coating and wears well under continued use. China bristles are not practical for water thinned coatings because they absorb moisture, swell, and lose their efficient shape.

Other natural bristles, such as ox hair, mohair, camel hair, and horsehair, are used in brush manufacture. Generally, these bristles are somewhat inferior to china bristles, but they are more economical and easier to obtain.

Nylon and polyester are the synthetic filaments used in making brushes. The ends of the filaments are artificially split to produce flagged ends. Both nylon and polyester are more resistant to water than the hog bristles, with polyester being the most water resistant.



Both nylon and polyester are softened by prolonged use, but polyester filaments hold up better than nylon. Both types lose their stiffness in alcohol and lacquer solvents, with polyester less affected than nylon, but neither material should be used in coatings containing these solvents.

Paint Mitts

Mitts are generally made of lambskin and are lined with solvent-resistant material. They have limited use in the application of coatings for industrial use. Generally, they are used on small projects, such as for coating handrails, small-diameter piping in racks, etc., where roller or spray application is not feasible. They are also used for the application of maintenance coatings to electric transmission towers.



Figure 2 Mitt Application

In practice, the mitt is dipped into the coating and used to wipe the coating onto the surface. The coating film achieved is not of reliable quality, so the use of this type of equipment should be restricted to areas where appearance is more important than long-term protection.

Roller Application

Roller application is of particular value on broad, flat areas. Although not as quick as spraying, it is usually quicker than brush application. Another advantage is that it enables the semi-skilled painter to obtain a reasonable and consistent standard of finish.

There are no particular difficulties in roller application and the technique is soon acquired. For large jobs it is more convenient to work from a bucket than a tray. A perforated grid is placed inside the bucket. The roller is dipped into the paint and then rolled over the grid to remove surplus material and distribute it evenly. With the tray, a reservoir at one end holds the paint; after charging the roller, it is rolled out on the platform of the tray.

The covering material for the rollers may be short-haired *carpet-pile* fabric, long-haired lambs wool, or sponge plastic. Selection of the correct length of roller pile for the particular coating is critical to successful application. If necessary, the advice of the coating manufacturer should be sought to determine the best type of roller material.

In use, the roller is rolled over the surface in criss-cross strokes, working the material out evenly. Often, material is applied in this way and left, but if necessary, it may be *laid-off* (i.e., smoothed) by passing the roller vertically or horizontally over the surface. As with brush application, many modern, high-build coatings are not suited to this method of application, and the application of a consistent coating film is not easily achieved.

The quality of the coating film produced is also dependant on the *nap* of the roller. This term refers to the make-up of the fabric covering (e.g., length and density) and affects the quantity of paint applied and the texture of the applied film.

Rollers must always be cleaned immediately after use. Problems with the use of rollers generally arise from

carelessness with the handling technique and maintenance of equipment. Rollers are not effective in forcing paint into pitted areas or displacing residual traces of loose dust and dirt from the surface. There is also a tendency for operators to apply a heavy coat at the beginning of a patch, thinning out to an inadequate thickness before a roller is recharged with paint.



Figure 3 Roller Application

The application of thick, high-build coatings is difficult with rollers on all surfaces except the floor, because it is more difficult for the operator to apply consistent pressure to walls and ceilings.

Pressure Rollers

Pressure-feed rollers allow for the application of a continuous coating film by supplying materials from a pressurized tank directly into the roller. The roller core is made with a perforated metal case that allows the coating to flow from inside the roller to the outer surface of the roller, where it is readily available for application. A valve on the handle or the tank controls the fluid pressure and moderates the flow of coating to the roller surface.

Pressure-feed rollers are generally used on projects where large flat surfaces can be coated at the same time.

Operator efficiency can be increased significantly with such automated equipment.

Finish-Coat Appearance

It should be noted that there may be a significant difference in appearance of coatings, depending on the application method. Brush, roller, and spray application techniques all bring their own characteristic appearance to the finished coating film. Special paint rollers are often used to achieve a specific finish appearance.

Some coating types, including those pigmented with flake materials (e.g., aluminum flake, [micaceous iron oxide] MIO), may be especially sensitive to appearance change. This is reflected in the choice of application method and technique. For best results and the most even appearance, the applicator should use consistent strokes of the spray gun, roller, or brush, and should apply the finish coat with strokes in the same direction whenever possible. This aspect is most likely to be significant on highly visible structures such as elevated water tanks, cruise ships, and public buildings.



Level 1

Chapter 3.2

Coating Application by Conventional Spray

Coating Application by Conventional Spray

Generally, spray application is the best method to use for the rapid application of coatings to large surface areas and for the uniform application of most coatings in nearly all situations.

There are two major types of spray application equipment:

- Conventional air spray: The coating is atomized by a stream of compressed air and is carried to the surface on a current of air. Both air and coating enter the gun through separate passages (channels), are mixed, and are driven through the air cap in a controlled spray pattern.
- Airless spray: The coating is atomized without the use of compressed air and is carried to the surface by the power of the fluid pressure passing through the spray gun. The coating is pumped under high pressure to the airless spray gun where it is forced through a precisely shaped and sized opening called the *orifice* or spray tip, as it is being driven to the surface.

Both conventional air spray and airless spray equipment may form the basis for modified equipment for special use situations, including:

- Plural-component spray
- Hot spray
- Electrostatic spray
- Centrifugal spray
- HVLP (high-volume low-pressure) spray
- Air-assisted airless spray



We will study these more complex systems and equipment in the advanced module on Coating Application. We will also study other methods of coating application, including:

- Powder coating
- Flame spray
- Spray metallizing
- Dipping, barrel coating, flow coating, and roller coating
- Electrophoresis

Conventional Air Spray

Advantages

- Spray pattern is easily adjusted to almost any desired fan width.
- High-quality finishes, such as for automobiles and furniture, can be produced.

Disadvantages

- High loss of coating is caused by overspray.
- Bellowing and air turbulence are created by the compressed air required.
- Reduction of coatings with solvent is often necessary for proper atomization, resulting in lowered DFT per application.

Note: When spraying intricate or irregular surfaces, the greater control and lower throughput of conventional spray equipment may produce less overspray than airless spray.



Airless Spray

Advantages

- Overspray and bounce back are reduced, resulting in material savings
- Heavier film builds are possible with most coatings
- Compressed air is not required to atomize coating
- Pressure pot is not required
- Equipment can also be powered by air, electricity, or hydraulics
- Production rate is much faster
- Coating may be driven into crevices, cracks, and corners

Disadvantages

- The fan width of an individual spray tip is fixed, not variable
- There is little control over quantity of coating applied, except by changing tips
- Because of the speed of the fluid flow, it is difficult to coat small, intricate items

Conventional spray is widely used for high-quality finishes (e.g., car spraying) but it is relatively slow and provides a low film build. High-build coatings can be sprayed using conventional spray equipment, but the material generally requires thinning to pass through the gun at the relatively low pressures.

Conventional spray is widely used in some parts of the world for a broad range of coating applications. Some users continue to use conventional spray equipment because it is safer and less hazardous for the applicator.



For the industrial user, however, only the high-pressure (conventional) equipment is of interest and then only for particular uses (e.g., application of zinc silicate on intricate shapes) where control of the spray pattern is important. In general, the use of conventional spray equipment has largely been replaced by airless spray for application of most industrial protective coatings. In Europe, conventional spray is rarely used. In the United States, and some other countries, conventional spray is more widely used, particularly for coatings such as inorganic zinc or where finish appearance is important.

Spray Safety Overview

The purpose of this overview is to discuss safety hazards found in all spray operations, regardless of the specific types of spray equipment used. Specific cautions for each piece of spray equipment will be addressed.

Fire and Explosion Hazards

The danger from toxic or fire hazards should always be in the minds of coating inspectors as well as supervisors and workers. Most workers are usually aware of the hazards from mechanical equipment, cranes, ladders, staging, etc.; however, they may not realize the tremendous damage that can result from a small quantity of vaporized volatile solvent (an explosion hazard), and they must be made aware of the dangers to health inherent in fume and dust exposure.

Workers have been killed by explosions due to painting in confined places. One accident occurred when the workers were being supplied with fresh air through proper masks because of the toxic hazard, but the concentration of vapor in the air space was in the explosive range. An extension light bulb broke and ignited the vapor, killing several men.



Flash point is an indication of the fire or explosion hazard of a flammable solvent. A surface may be hot enough to volatilize sufficient solvent to cause a localized danger. Sprays and mists can be very dangerous; even finely atomized metals or dusts may explode when dispersed in air.

Coatings and their solvents are sometimes categorized according to their flash-point temperature. Low-flash-point solvents are those with a flash point below typical storage temperatures (23°C, 73°F), and are the most hazardous to store and/or use.

Adequate ventilation is essential to keep the solvent content of the air below the lower explosive limit (LEL) and also to facilitate curing of the coating.

Static electricity may discharge with the potential to ignite solvent vapors. The hazard may be reduced by grounding the spray equipment and ensuring that connections are electrically continuous.

Breathing Apparatus

Spray finishing 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. Anyone who is around a spray finishing operation should consider some type of respirator or breathing apparatus.

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:

- First, some sort of respiratory protection is dictated by regulations, such as those formulated in the United States by the Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH).

- Second, even without regulations, common sense determines that inhaling paint overspray and solvent fumes is not healthy.

Even though the concentration of flammable gas or vapor may be below the LEL, it may be far above the safe limit for breathing. The maximum allowable concentration (MAC) is the amount that must not be exceeded when a worker is exposed to the hazard for an eight-hour workday. This concentration pertains to vapors, gases, mists, and solids. MACs are published annually (in the United States) in the *Archives of Industrial Hygiene*. These same MACs are often adopted in other countries.

In general, the aromatic solvents, such as xylene and toluene, are more hazardous than the aliphatic solvents, such as mineral spirits. Unfortunately, mineral spirits are rarely used in high-performance coatings, and 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 air space may be considered safe from fire or explosion, it might be extremely dangerous to personnel. Exposed workers should be supplied with fresh air masks connected to a source of clean, cool, filtered air.

The common practice of using low-flash-point solvents such as MEK or acetone as *universal thinners* can be extremely hazardous, particularly in enclosed spaces.

Spray painters, in particular, should be protected against breathing dangerous concentrations of paints containing lead or chromate; brush painters are also exposed to these hazards. In addition to being supplied with adequate

ventilation, spray removal, respirators, and air filters, workers should clean themselves thoroughly before eating and before leaving the job. Contaminated clothing should not be reused until thoroughly cleaned.

When air-supplied respirators are used, it is critical that the air supplied is fresh and pure. The common practice of using plant air (i.e., air taken from a factory supply) can be dangerous if the air is contaminated by the compressor or an operation elsewhere in the plant. Filters and warning monitors should always be fitted in line before the air is used by the sprayer.

There are four primary types of respirators available to protect the operator:

- Air-supplied hood
- Air-supplied mask
- Organic vapor (cartridge) respirator
- Dust respirator

Air-Supplied Hood Respirator

Hood respirators are designed to cover the entire head and neck area and supply the wearer with clean, dry air at low pressure through a filtered air supply. They protect the wearer from heavy concentrations of vapor, fumes, dust, and dirt that might prove harmful to respiratory organs, eyes, ears, and exposed skin.

They are used where other types of respirators are impractical and do not provide sufficient protection. The hood respirator provides the most complete means of protection because it offers eye, ear, and skin protection. The continuous supply of dry fresh air prevents misting or fogging in the hood.

Air-supplied 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 Respirator

The air-supplied mask respirator may cover the nose and mouth only or may be full face, and operates from an external supply of air. It does not provide the degree of protection against splashes, etc., that can be achieved with a hood respirator. If a full-face respirator is not used, eye protection, such as goggles, must also be worn.

Organic-Vapor-Cartridge Respirator

The organic-vapor respirator covers the nose and mouth and is equipped with a replacement cartridge designed to remove the organic vapors by chemical absorption. The correct cartridges must be used.

Some of these are also designed to remove solid particles from the air before the air passes through the chemical cartridge. They are usually used in a finishing operation with standard materials and are not recommended for use in commercial coating operations. To be effective, there must be a complete seal between the mask and the face. Separate safety goggles or other eye protection must be worn when required.

Because the cartridges have a limited life and must be replaced, records of respirator use should be maintained.

Dust Respirator

Dust respirators are sometimes used by sprayers or helpers, but in most applications they are not effective and are probably illegal. These respirators are equipped with a cartridge to remove only solid particles from the air, such as in preliminary surface preparation operations like sanding, grinding, or buffing, and are not designed to remove vapors. Separate safety goggles or other eye protection must also be worn when required.

Personal Protective Equipment

Safety recommendations for proper personal protection equipment (PPE) can be found on the coating manufacturer's material safety data sheets (MSDS). Specified clothing such as gloves, masks, and long-sleeve shirts should always be worn. Further information on these issues can be found in the basic safety module of this course.

Conventional Spray Equipment

Conventional Air Spray—Air-Control Equipment

Air-control equipment is any piece of equipment installed between the air compressor and the point of use that modifies the nature of the air stream.

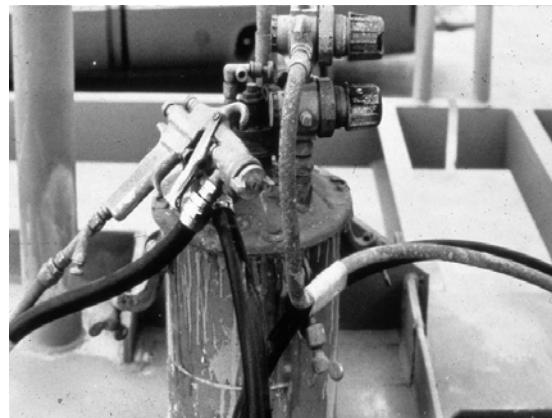


Figure 1 Conventional Air Spray Equipment

Air-control equipment can modify, or control, the:

- Volume of air
- Air pressure
- Cleanliness of air to the spray gun
- Distribution of air to multiple pieces of equipment

Air-control equipment is often collectively known as the *air transformer* (also called a *filter* or *regulator*). This multi-purpose device:

- Removes oil, dirt, and moisture from compressed air
- Regulates, and indicates by gauge, the regulated air pressure
- Provides multiple air outlets for spray guns and other air-operated tools

The principal parts of an air transformer are:

- **Air condenser**—a filter installed in the air line between the compressor and the point of use. It separates out such solid particles as oil, water, and dirt and cools the compressed air. The air condenser is not capable of regulating air pressure.
- **Air regulator**—This device reduces the main line air pressure as it comes from the compressor. It automatically maintains the desired air pressure with minimum fluctuations. Regulators should be used in lines already equipped with an air condenser or other filtration device.

Air regulators are available in a wide range of air volumes and pressures, with or without pressure gauges, and in different degrees of sensitivity and accuracy. They have main air inlets and regulated air outlets.

- **Air-pressure gauge**—indicates the air pressure
- **Outlet valves**—provide shut-off of individual lines
- **Drain**—used to vent the accumulated water, oil, and dirt from the condenser
- **Lubricator**—Some air-powered tools require a very small amount of oil mixed in the air supply that powers them. Lubricators are often combined

with air filters and regulators in a single unit. The operator should ensure that the air supply for conventional air spray equipment does not contain a lubricator.

When air-powered tools are being used, oil allowed to fall on the prepared surface would clearly be a problem. Both the operator and the coating inspector must check to see that oil is not applied to the surface.

Good practice recommends that lubricators for air-powered tools should be on a branch line separate from lines supplying air to spray applications.

Troubleshooting and Maintenance

The air transformer (filter or regulator) and condenser should be drained or cleaned at least twice daily, depending on the humidity and system usage. In humid areas or where the system is used heavily, more frequent cleaning (draining) is required.

Moisture or oil in the spray atomization air will ruin a coating job. The air must be clean and dry and oil and water removed from the air supply. Condensation is often likely due to pressure changes as the compressed air is released to the atmosphere. As with blast cleaning equipment, air lines are likely to contain moisture from the previous day's work and should be dried at the start of work each day. The compressor should run long enough to warm up and reach operating temperature and the air checked for oil and water using the blotter test (e.g., ASTM D 4285).

If moisture passes through the air transformer or air condenser, the operator should check the following and see that corrections are made as necessary:

- Drain filter/regulator, air receiver, and air line of any accumulated moisture.



- Make certain the filter or regulator is located at least 8 m (25 ft) from the compressor.
- See that the main air line does not run adjacent to any steam or hot-water piping.
- Ensure that the compressor air intake is not located near steam outlets or other moisture-producing areas.
- See that the outlet on the air receiver is located near the top of the tank.
- If the compressor is water-cooled, check for a damaged cylinder head or leaking head gasket. Intake air should be as cool as possible.
- Check pressure gauges to ensure they are readable and accurate. Most equipment that can be calibrated should carry a calibration sticker, particularly if an ISO 9000 quality system is operated by the applicator.

Conventional Air Spray Equipment Overview

Conventional air spray equipment used for application of industrial protective coatings generally contains all the following components:

- Air compressor, which provides a continuous supply of compressed air to the material container and spray gun
- Air control equipment, which helps provide a steady supply of clean, dry air
- Hoses, which transport air and coatings between compressor, spray pot, and spray gun
- Spray pot, which contains and holds the coating to be applied



- Conventional air spray gun, which mixes air and coating and applies the mixture to the work piece in a controlled spray pattern

Conventional Air Spray Hoses

Air Hose

The air hose is usually red, although in a small low-pressure system it may be covered with a black and orange fabric. The air hose transfers compressed air from the air regulator to the gun. Air hoses should **not** be used for coatings.

The internal diameter (ID) of the hose from the regulator to the spray gun should be a minimum 8 mm (5/16 in.), although larger sizes are not uncommon. If the air hose ID is too small, the spray gun is *starved* for air because of excessive pressure drop, which can result in a variety of spray defects.

Fluid Hose

The fluid hose is usually black or brown rubber and is electrically conductive so the system can be grounded. Since solvents in coatings can readily attack and destroy ordinary rubber compounds, the fluid hose is lined with special solvent-resistant material impervious to common solvents. Some fluid hoses made of clear plastic are now available.

For normal finishing, 10-mm (3/8-in.) ID hose is suitable. Guns used in maintenance finishing work may require 12.5-mm (1/2-in.) ID hose. High-viscosity materials could require 20- to 25-mm (3/4- to 1-in.) ID material hose.

Note: Coatings or solvents should never be applied through an air hose, since the air hose does not have the essential protective liner. If so used, the air hose may be

attacked by the coating or solvent, causing the hose to rupture or contaminate the spray air with particles of deteriorated hose.

Cleaning and Maintenance

Fluid hoses are generally cleaned by running appropriate cleaning solvent through the line at the end of the work shift. Sufficient solvent should be used to remove all the coating material. The operator will generally judge the effectiveness of cleaning by the color of solvent as it is cycled through the line.

The fluid hose can be cleaned using a hose cleaner, which forces a mixture of solvent and air through the fluid hose and guns, ridding them of coating residue. A valve stops the flow of solvent and allows air to dry the equipment.

If cleaning is not adequate, coatings which cure in the line will either lead to blockage (or reduced ID) of the line or more likely will be softened by other solvent used subsequently and contaminate other coatings or block the lines and tips.

The outside of both air and fluid hoses should be wiped down with the appropriate solvent or cleaner at the end of each working day.

Hoses should be:

- Stored by hanging in neat coils
- Cleaned properly and regularly

Hoses should not be:

- Dragged across floor
- Pulled around sharp objects
- Run over with a vehicle



- Kinked or bent
- Used as a rope for lowering persons or equipment from scaffolding

Coatings Supply

Coating materials must be delivered to the spray gun. In this course we will discuss only:

- Pressure-feed material supply
- Pressure-feed air spray guns

Other types, including suction feed and gravity feed, are rarely encountered in industrial coating operations. Common types of material containers include:

- Remote pressurized tanks located away from the gun
- Cups that attach to the gun itself (cup guns). Cups fitted directly to spray guns are necessarily small and must be refilled frequently. They are more likely to be used for small operations and for fine finishes on small components. They are infrequently used for the application of industrial coatings.

Cups may be pressurized or may be used to provide material for suction-feed or for gravity-feed equipment.

Remote pressurized tanks



Cups attached to the gun



Figure 2 Coating Containers During Application

Pressure-Feed Tanks (Spray Pot)

Pressure-feed tanks are closed containers, ranging in size from about 7.5 to 450 L (2 to 120 U.S. gal). They provide a constant flow of coating material at uniform pressure to the spray gun.

The tank is pressurized with compressed air and fluid is forced out of the tank through the fluid hose to the gun.

Increasing or decreasing the air pressure in the tank controls the rate of fluid flow. Pressure-feed tanks provide a practical, economical method of feeding material to the gun over extended periods of time and are generally used where continuous production is to be maintained. The flow of material is positive and uniform.

Relatively high-viscosity and high-solids coatings can be applied in this way, but generally not 100%-solids coatings. Tanks can be equipped with agitators that keep the material mixed and in suspension. (Note: There are some—modern—100%-solids coatings that are very low in viscosity and can be applied by conventional spray.)

A typical pressure-feed tank consists of:

- The shell
- Clamp-on lid
- Fluid tube
- Fluid header
- Regulator(s) with gauge(s)
- Safety-relief valve
- Agitator





Figure 3 Pressurized Tank Containers

The construction of pressure-feed tanks varies according to the service for which they will be used. Light-duty tanks are usually made of welded steel and have inlet air pressure restriction. Heavy-duty tanks are ASME coded and made of drawn steel. When abrasive or corrosive materials are to be sprayed, the tank shell used should be coated or lined with some special material; an insert container can also be used.

Pressure-Feed Tank Regulator

Pressure-feed tanks should be equipped with regulators, for three primary reasons:

- Regulators allow material flow to be accurately adjusted until constant.
- Regulators provide adjustment capability to accommodate a wide range of material viscosity and permit pressure increases when added hose lengths demand it.
- Regulators allow more adjustment of the balance between the material flow and the atomization air pressure.

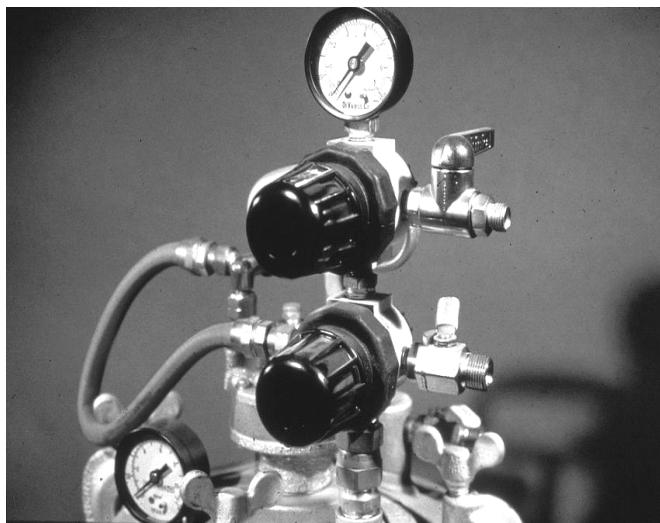


Figure 4 Pressure-Feed Tank Regulator

Pressure-feed tanks may be fitted with a single-regulator or a double-regulator. The double-regulator should always be used in industrial spray applications.

One regulator controls the air pressure on the material in the tank, thereby controlling fluid flow. The other controls atomization air pressure to the spray gun.

Both controls are at the tank near the operator and can be adjusted for any operating condition. The fluid pressure may be higher or lower than the atomization air pressure, depending on:

- Height at which the gun is operated above the tank
- Degree of atomization required
- Size and length of hose
- Speed of operation
- Type of material being sprayed

In this connection, inspectors should be aware that the single-pressure regulator and gauge found on many conventional spray pressure pots controls only the pressure within the container and not the pressure of the air that atomizes the coating. With a single-regulator, the

atomizing pressure will be equal to that at the receiver of the compressor (minus the pressure drop in the hose lines); if the receiver pressure cannot be controlled to suit spraying operations, an additional pressure regulator must be inserted in the line between receiver and spray pot or between gun and spray pot.

Pressure-Feed Equipment Maintenance

Pressure-feed material tanks and insert containers should be completely cleaned inside and out with an appropriate solvent after every use. Cleaning while the paint is still wet is obviously the most efficient method. When cleaning a pressure-feed container, clean and inspect the sealing surfaces, gaskets, and clamps.

Conventional Air Spray Gun

The piece of equipment that delivers the coating to the work piece is the spray gun. There are two very broad classes of spray gun:

- Automatic
- Manual

Automatic guns are generally identical, in operation, to the manual guns and have identical specifications. They are mounted on a fixed or moving apparatus to paint objects that are usually carried past them on a conveyor.

Automatic guns are triggered by remote control through an attached air cylinder and are pre-adjusted to spray the correct mixture for a good finish. The specific uses and details of automatic spray application are covered in the advanced module of this program.

It should be noted, however, that many manual spray concepts and tools are very similar to those used in automatic spray applications. The spray pattern and density are adjusted using various valves and control devices on the gun.

A manual gun is held by an operator who triggers the flow of air and material. The material is applied when the operator aims the gun and pulls the trigger. Operator technique is important to produce a fine finish.

Conventional Air Spray Gun Parts Overview

The principal components of a typical manual air spray gun fall into three main categories:

- Control of air flow
- Control of fluid flow
- Gun body

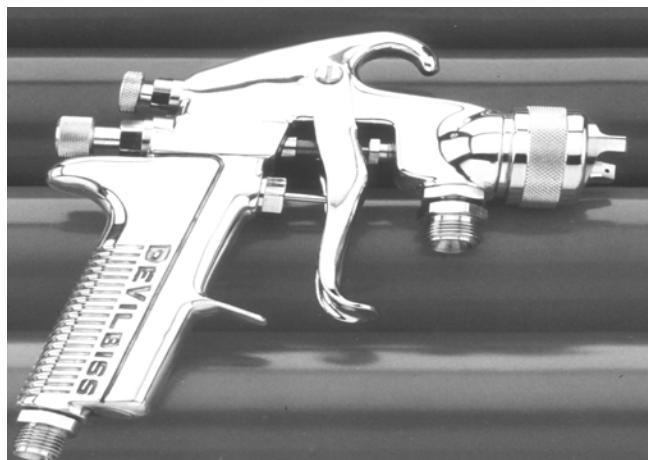


Figure 5 Air Spray Gun

Air Flow

Some of the major air flow parts are:

- Air-control valve
- Air-adjusting valve
- Pattern-adjusting valve
- Air cap

Air-Control Valve

The air-control valve is located in the gun's handle, directly behind the trigger. When the trigger is pulled, the air-control valve opens, allowing air to pass through the gun. A positive return spring in the stem of the air-control valve keeps the valve closed until the trigger is pulled.



Figure 6 Air Control Valve

The air-control valve provides no air pressure regulation. When the air valve is closed, no air enters the gun. When the valve is opened, the full air pressure is admitted.

The air pressure is entirely controlled by a pressure regulator located between the compressor and the gun. The air pressure should be adjusted according to the viscosity of the material being sprayed and the desired density of the spray (light or heavy coverage).

Air-Adjusting Valve

An air-adjusting valve (or screw) is provided on some low- and medium-volume guns and is included as an option on high-volume guns. When the valve is built into the gun, it is located adjacent to the air inlet at the base of the handle. When included as an option, the valve is placed at the air inlet connection, in line with the air hose.

The air-adjusting valve controls only the flow of air (L/min, cfm), and has no effect on air pressure (MPa, psi).

Pattern-Adjusting Valve

The pattern-adjusting valve (or screw) is located at the back of the gun. It is the top of two knurled knobs found there. The stem of the valve seats in the front of the gun, in either an air baffle or air port.

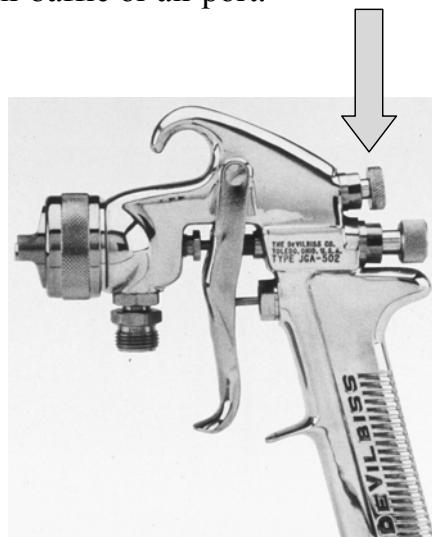


Figure 7 Pattern-Adjusting Valve

The pattern-adjusting valve regulates air supply to the horns of the air cap. The horn air controls the shape of the spray pattern. When the valve is closed (turned completely clockwise) a round spray pattern results. As the valve is opened (turned counterclockwise) an increasingly narrow fan pattern develops.

Air Cap

The air cap directs pressurized air into the coating for atomization, and onto the coating via air horns to control the shape of the spray pattern.

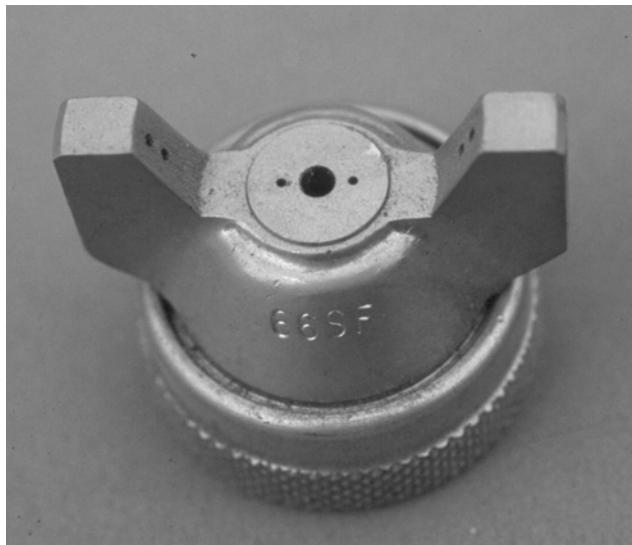


Figure 8 Air Cap

Internal vs. External Mix

Industrial air spray guns are commonly referred to as either internal or external mix. Both types may be used in manual or automatic operations.

Internal-Mix Guns

Internal-mix guns combine air and coating material inside the air cap. The material is atomized prior to leaving the gun. Internal-mix guns must be used with a pressure supply (i.e., suction-feed or gravity-feed are not possible). They are generally used when a coarse finish is required, such as ceiling texture spray and mastic roof coatings.

Atomization air and material pressure must be approximately equal at the gun. The fan pattern is determined by the shape of the air cap opening.

Internal-mix guns (also known as *low-pressure guns*) are generally used when only a low-pressure compressor is available or when slow-drying or viscous materials are used. Fast-drying materials would tend to plug the gun's cap hole.

External-Mix Guns

External-mix guns combine air and coating material just beyond (or outside) the fluid tip. Air atomizes the material as it leaves the gun.

External-mix guns may be supplied by either pressure-feed or suction-feed sources. They are used when a fine painted finish or versatility is required. They are a widely used type of gun because they provide better atomization and more control than internal-mix guns.

Some of the advantages and limitations of each type include:

External-Mix Advantages

- Produces fine atomization
- Provides control of spray pattern size
- Saves on air cap, no wear
- Available with suction and pressure feed

External-Mix Limitations

- Requires more air volume (L/min, cfm)
- Requires high air pressure (MPa, psi)
- Can produce maximum overspray
- Yields minimum film build per pass
- Yields minimum size spray pattern

Internal-Mix Advantages

- Requires less air volume (L/min, cfm)
- Requires less air pressure (MPa, psi)
- Provides minimum overspray
- Yields maximum film build per pass
- Yields maximum size spray pattern

Internal-Mix Limitations

- Provides coarse atomization
- Spray pattern size is fixed
- Air cap and fluid tip will wear
- Only pressure feed is available

Adjusting the Gun for Spraying

Once the equipment is hooked up, the pressure-feed gun must be adjusted. The basic steps are:

- Open spreader adjustment valve for maximum pattern size
- Open fluid-adjustment screw until the thread is visible
- Set fluid flow rate
- Turn on atomization air and adjust to establish spray pattern
- Test pattern, adjust as necessary

Once the gun is balanced and ready to spray, good spray technique is required to produce an acceptable coating application.

Conventional Air Spray Cleanup

After the coating operation is finished, correct cleanup is necessary to ensure that the equipment will be in good working order for the next job. Air caps, spray tips, and the pressure pot should be thoroughly washed in cleaning solvents, and cleaning solvent should be run through the fluid lines until clear fluid is circulating. Lines and pressure pots should then be emptied and dried before storage.



The following sections describe procedures for cleaning and troubleshooting guidelines to remedy spray application defects.

Pressure-Feed Guns

To clean a pressure-feed gun, hold a cloth over the air cap and pull the trigger to force material back into the open container. Clean the container and add solvent. Pressurize the system and run solvent until clean. (**Note:** Atomization air should be turned off during this procedure.) Dry the hose by again loosening the cap and container lid and forcing air back through the gun and hose. Clean the air cap and fluid tip. Clean out the tank and reassemble for future use.

Safety Note: Use this method of cleaning with air spray guns **only**. Operators should **never** put their hand in front of an airless spray gun.

Removable Spray Head

If the spray gun being used has a removable spray head, the spray head may be detached for cleaning as follows:

Loosen the locking bolt, which holds the spray head and the gun body together, and unscrew it from the head. Push the trigger forward as far as possible with the back of the fingers. Pull the spray head forward. To replace, push the trigger forward and insert the spray head. Pull back on the trigger and tighten the locking bolt.

Lubricating the Spray Gun

Lubricate the fluid-needle packing, air-valve packing, and trigger-bearing screw. A drop or two of oil should be put on the fluid-needle packing occasionally to keep it soft. The fluid-needle spring should be coated with petrolatum.

Note: Never clean a spray gun by soaking the entire gun in solvent. The solvent will remove the natural oils found in the gun's leather seals, causing the seals to dry out and the gun to malfunction.

Cleaning the Air Cap

The air cap should be cleaned by immersing it in clean solvent and drying it by blowing it off with compressed air. If small holes become clogged, soak the cap in solvent. If reaming is necessary, use a match stick, broom straw, or any other soft implement. Digging out holes with wire or a nail may permanently damage the cap.

Paint Application Problems

Conventional Air Spray Troubleshooting

Some of the more common air spray problems and the causes and corrections are listed in the table below:

Table 1 Common Paint Application Problems

PROBLEM	CAUSE	CORRECTION
Fluid leakage from fluid-packing unit	A loose packing nut, worn packing, or dry fluid-needle packing	Lubricate packing with a few drops of light oil. Tighten packing nut to prevent leakage, but not so tight as to grip the fluid needle. Replace the packing when it is worn. Tighten the packing nut until it grabs and holds the needle, then back off the packing nut until the needle is free to travel into the fluid tip.
Air leakage from front of gun	<ul style="list-style-type: none"> a. Foreign matter on valve or seat b. Worn or damaged valve or seat c. Broken air-valve spring d. Sticking valve stem due to lack of lubrication e. Bent valve stem f. Packing nut too tight g. Gasket damaged or omitted 	Inspect and correct
Fluid leakage from the front of the gun (pressure feed)	<ul style="list-style-type: none"> a. Worn or damaged fluid tip or needle b. Lumps of dirt lodged in fluid tip c. Packing nut too tight d. Broken fluid-needle spring e. Wrong size needle or tip 	Inspect and correct

PROBLEM	CAUSE	CORRECTION
Jerky or fluttering spray	Applying to both suction and pressure feed: a. Lack of sufficient material in container b. Tipping container at excessive angle c. Obstructed fluid passageway d. High-viscosity coatings, requiring addition of thinner e. Loose or cracked fluid pick-up tube in cup or tank f. Loose fluid tip or damaged tip seat	Inspect and correct
Top-heavy pattern	1. Horn holes partially plugged 2. Obstruction on bottom of fluid tip 3. Dirt on air cap seat or fluid tip seat	To remedy the defects shown on this page or the next, determine if obstruction is on air cap or fluid tip. This is done by making a solid test spray pattern, then rotating the cap one-half turn and spraying another pattern.
Bottom-heavy pattern	1. Horn holes partially plugged 2. Obstruction on bottom side of fluid tip 3. Dirt on air cap seat or fluid tip seat	If the defect is inverted, obstruction is on the air cap. Clean the air cap. If not inverted, it is on the fluid tip. Check for fine burr on the edge of the fluid tip (remove with 600 wet or dry sand paper) or for dried paint just inside the opening (remove by washing).
Heavy right-side pattern	1. Right-side horn holes partially clogged 2. Dirt on right side of fluid tip	Inspect and correct.
Heavy left-side pattern	1. Left-side horn holes partially clogged 2. Dirt on left side of fluid tip	Inspect and correct.
Heavy center pattern	1. Too low a setting of the spreader adjustment valve 2. Too low an atomizing pressure or material too thick 3. With pressure feed, too high a fluid pressure for the atomization air being used or material flow in excess of the cap's normal capacity 4. Too large or too small a tip for the material used	To correct the defects shown on this page, readjust atomizing pressure, fluid pressure, and spray width adjustment until the desired spray is obtained.
Split spray pattern	Air and fluid not properly balanced	Reduce width of spray pattern by means of the spreader adjustment valve or increase fluid pressure. This latter adjustment increases speed and the gun must be handled much faster.

PROBLEM	CAUSE	CORRECTION
Dry spray	Sprayed coat is short of liquid material because: <ol style="list-style-type: none"> 1. Air pressure is too high 2. Material is not reduced or thinned correctly (suction feed only) 3. Gun is too far from work or out of adjustment 	<ol style="list-style-type: none"> 1. Decrease air pressure 2. Reduce or thin according to directions; use proper thinner or reducer 3. Adjust distance to work; clean and adjust gun fluid and spray pattern controls
Starved pattern	Spotty, uneven pattern, slow to build due to: <ol style="list-style-type: none"> 1. Inadequate material flow 2. Low atomization air pressure (suction feed only) 3. Gun motion too fast 	<ol style="list-style-type: none"> 1. Back fluid adjusting screw out to first thread 2. Increase air pressure; rebalance gun 3. Move at moderate pace, parallel to work surface.
Unable to get round spray	Fan adjustment stem not sealing properly	Clean or replace
Will not spray	<ol style="list-style-type: none"> 1. No air pressure at gun 2. Internal-mix air cap used with suction feed 3. Fluid pressure too low with internal-mix cap and pressure tank 4. Fluid tip not open enough 5. Fluid too heavy for suction feed or viscosity too great 	<ol style="list-style-type: none"> 1. Check air lines 2. Change external air cap 3. Increase fluid pressure at tank 4. Open fluid-adjusting screw 5. Change to pressure feed or reduce fluid (i.e., add thinner).
Dripping from fluid tip	<ol style="list-style-type: none"> 1. Dry packing 2. Sluggish needle 3. Tight packing nut 4. Spray head misaligned on type-MBC guns, causing needle to bind 	<ol style="list-style-type: none"> 1. Lubricate packing 2. Lubricate 3. Adjust 4. Tap all around spray head with wood and rawhide mallet and retighten locking bolt
Excessive overspray	<ol style="list-style-type: none"> 1. Too much atomization air pressure 2. Gun too far from surface 3. Improper stroking, i.e., arcing, moving too fast 	<ol style="list-style-type: none"> 1. Reduce air pressure 2. Check distance 3. Move at moderate pace, parallel to work surface.
Excessive fog	<ol style="list-style-type: none"> 1. Too much or quick drying thinner 2. Too much atomization air pressure. 	<ol style="list-style-type: none"> 1. Remix 2. Reduce air pressure
Fluid leakage from packing nut	<ol style="list-style-type: none"> 1. Packing nut loose 2. Packing work or dry 	<ol style="list-style-type: none"> 1. Tighten, but not so tight as to grip needle 2. Replace packing or lubricate

PROBLEM	CAUSE	CORRECTION
Thin, sandy, coarse finish drying before it flows out	1. Gun too far from surface 2. Too much air pressure 3. Quick drying thinner	1. Check distance 2. Reduce air pressure 3. Remix
Tails in spray fan	Inadequate fluid delivery Fluid not atomizing	a. Increase fluid pressure b. Change to larger tip orifice size c. Reduce fluid viscosity d. Clean gun and filter(s) e. Reduce number of guns using pump f. Install sapphire insert
Pattern expanding and contracting (surge)	Pulsating fluid delivery Suction leak	a. Change to a smaller tip orifice size b. Install pulsation chamber in system or drain existing one c. Reduce number of guns using pump d. Increase air supply to air motor e. Remove restrictions in system, clean tip screen or filter if used f. Inspect for siphon hose leak
Hour glass fan shape	Inadequate fluid delivery	a. Same as a through e above





Level 1

Chapter 3.3

Coating Application by Airless Spray

Coating Application by Airless Spray

Airless spray differs from conventional air spray because it does not use compressed air to atomize the paint. Instead, paint is pumped from a container—usually the manufacturer's original cans but sometimes bulk supply drums (200 L [55 U.S. gal])—through a supply line to the airless spray gun.

Airless spray operates by forcing paint at high pressure through an accurately designed small hole or orifice. As the paint leaves the gun and meets the atmosphere it expands rapidly. These two factors cause the paint to break up into an extremely fine, very even spray pattern. Air is not used to atomize the paint, hence the description *airless*.

In airless spray equipment, the material is under high pressure between the pump and the gun, but unlike pressure-feed air spray, the material is not under pressure in the material container. Thus, the material may be drawn directly from the original container by suction from the pump.

Advantages of airless spray include:

- Production rates are increased (faster application). Airless spray applies most types of paint faster than any other manually operated method of paint application.
- Because the paint container is not under pressure, the pump can operate from the manufacturer's container.
- Because air is not used for atomization, overspray is much reduced. A degree of paint *drop-out* may occur but this can be reduced by pressure control.
- Blowback is minimized.

- A uniform thick coating is produced, reducing the number of coats required.
- A very *wet* coating is applied, ensuring good adhesion and flow-out.
- Most coatings can be sprayed with very little added thinner. With less solvent the material dries faster and is less harmful to the environment.
- Coating penetrates better into pits, crevices, recessed areas, and hard-to-reach areas, such as corners.
- The single hose connection to the gun makes it easier to handle.

To create the extremely high fluid pressures required, airless spray pumps are highly engineered. They are most often one of two types:

- **Air Motor**—Compressed air is supplied from an independent air compressor. Pressures between 415 and 690 kPa (60 and 100 psi [4 and 7 bar]) are required with a minimum consumption of 1.7 L/min (3.5 cfm). The pumps have a fixed ratio, ranging from 20:1 to 65:1 according to type and make. The pump multiplies every kilopascal, pound, or bar of air pressure delivered to the pump by the ratio number. A 30:1 ratio pump with an air intake pressure of 690 kPa (100 psi [7 bar]) will produce spraying pressures of up to 20 MPa (3,000 psi [210 bar]). To reduce the spraying pressure, it is only necessary to restrict the inlet air pressure driving the pump, e.g., 30:1 ratio pump, 412 kPa (60 psi [4 bar]) inlet pressure, 12 MPa (1,800 psi [120 bar]) paint pressure.
- **Electrically Driven Hydraulic Pump**—Hydraulic fluid pressure is used to drive the fluid pump. This is more efficient and requires no air pressure, having only to be plugged into the main electricity supply. It is capable of producing spraying

pressures up to 20 MPa (3,000 psi [210 bar]). There may, however, be difficulties with a suitable electricity supply on many job sites. In addition, the pressure an electrically driven pump can provide is limited. The equipment is incapable of spraying some heavy-duty paints and therefore less versatile.

Air Motor



Electric

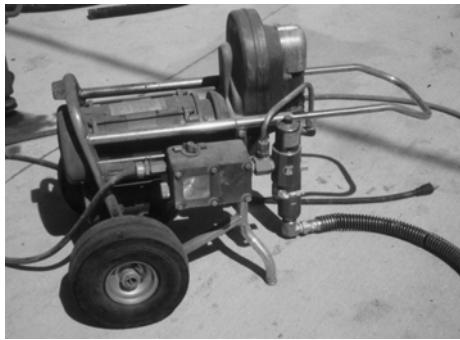


Figure 1 Airless Spray Pumps

The following equipment is also used with airless spray equipment:

- **Fluid Lines**—are special high-pressure, solvent-resistant small bore hoses reinforced with wire mesh.
- **Fluid Tips**—The orifice size controls the quantity of paint passing through. The angle of the tip controls the size of the fan pattern. Tips have to be changed when adjustments are required. A range of shapes and sizes is available. The airless spray gun has a trigger but no other controls. Fan pattern and material flow is controlled by the fluid tip. A safety catch is fitted to prevent accidental spraying. The needle, tip, and seating are made of tungsten carbide to withstand the high pressures and abrasive action of some paints.
- **Reversible Tip**—Because the orifice size of the fluid tip is so small, it can easily be blocked by small particles of paint or other contamination. To avoid removing, cleaning, and replacing the tip each

time this occurs, special heads have been designed to allow the tip to be reversed so that the dirt can be blown out and the tip then returned into its working position.

- **Filters**—Fine-gauge mesh filters are fitted within the system, generally at the pressure pump as the coating enters the fluid line. These filters can become clogged and are often neglected.

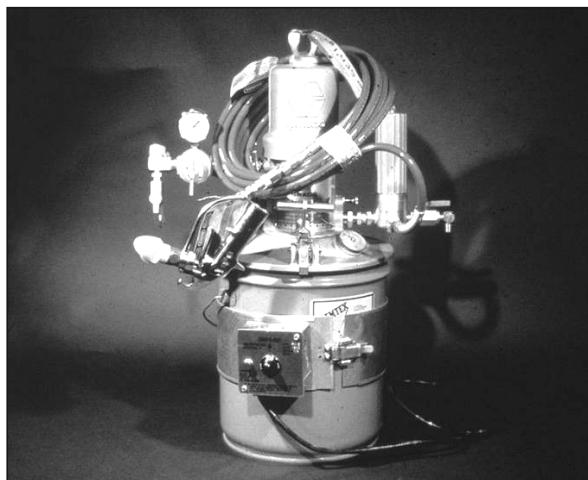


Figure 2 Airless Spray Equipment

Airless Spray Safety

The safety precautions for airless spray are essentially those for 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 achieved is so effective that liquids may be passed through a membrane (e.g., human skin) without breaking it.

This is exactly the same principle used in the high-pressure devices the military uses instead of hypodermic needles to give military personnel their medical shots.

Thus, the hazard of accidental injection of coating materials is a very real and present danger. Accidental injection—if untreated—may result in loss of a limb or may even be fatal. It is advisable, when working with or

near airless spray equipment, to treat an airless spray gun as though it were a loaded weapon.

Safety authorities (e.g., OSHA in the United States) recognize the danger and require that airless spray guns carry a safety warning and that they be fitted with a safety spacer at the tip (i.e., the point where coatings leave the gun). The intention of the spacer is to reduce the possibility of injecting paints or solvents through skin without breaking the surface.



Figure 3 Airless Spray Gun with Spacer

Injection of solvents or other fluids through the skin damages local tissue and may introduce the fluid into the blood stream. Localized swelling occurs and continues to occur until the pressure is relieved. Proper treatment involves release of pressure and toxic chemicals, generally by cutting open the skin areas affected. The resulting wound may be very significant.

All equipment used should conform to OSHA (United States), Health and Safety at Work Act (United Kingdom), or other required standards.

An accidental injection is highly unlikely if all safety precautions are observed. However, should a person be accidentally injected, he or she should be taken to a

doctor **immediately**, even if the injury seems minor. Delay may cause loss of a finger, an arm or a leg, or even death.

Some additional rules for airless spray safety are:

- A pressurized unit should never be left unattended. The unit should be shut off, the pressure relieved, the spray gun's trigger safety engaged, and the power shut off before leaving.
- All fluid connections should be high-pressure-rated airless spray fittings, tightened securely and checked before each use.
- The fluid hose should be electrically grounded to reduce the hazard of static electricity sparking.
- The coating and solvent manufacturers' safety precautions and warnings should be followed.
- Any unsafe condition or practice should be reported to the safety supervisor immediately.

Airless Spray Equipment

The most commonly used airless spray system is the direct-supply type. In this system, the pump operates only during spraying. It starts when the spray gun is triggered, and stalls out against pressure and stops when the trigger is released. A typical direct system contains:

- Paint supply
- Pump
- Filter
- Hose
- Spray gun



Airless Spray Pumps

An airless spray pump is a piece of equipment that draws the coating from the coating container and supplies it under pressure to the rest of the airless spray system. Most pumps are reciprocating, positive-displacement types that deliver coating under pressure on both the up stroke and down stroke.

Pump volume is rated in liters per minute (L/min) or gallons per minute (gpm) and depends on the coating pump displacement and the number of cycles per minute at which it operates. Pumps used in coating applications deliver from 10 to 60 L/min (2.5 to 15 gpm).

Fluid pressure can vary, depending on pump design, from about 5.5 to 45 MPa (800 to 6,500 psi). The most commonly used airless spray pumps deliver paint at pressures in the range of 10 to 24 MPa (1,500 to 3,500 psi) and are powered by compressed air.

Although the pumps may be driven by compressed air, the air does not come into contact with the paint and is not used to atomize the paint; hence, the principle is still that of the airless spray.

Pumps can be also be powered by electricity or hydraulics.

Pump output pressure is rated in kilopascals (kPa) or pounds per square inch (psi) and, in the case of air-powered pumps, is dependent on the ratio of air:motor piston area to paint:pump piston area and the incoming air pressure. In other words, these pumps work on a fixed ratio multiplication principle providing a fluid paint pressure that is a multiple of the incoming air pressure.

For example, in a 30:1 ratio pump, 550 kPa (80 psi [5.5 bar]) incoming air pressure results in approximately 17 MPa (2,400 psi) outgoing fluid pressure. Typical ratios are 25:1, 30:1, 45:1, and 65:1. The higher ratio pumps are preferred for spraying high-solids materials and are

essential if more than one spray gun is operated from the one pump.

Cold-weather operation and the use of longer hoses also requires additional pressure for successful atomization.

Airless Spray Material Containers

In an airless spray system, the material container is not pressurized. The coating is drawn from the container by the pump, which then pressurizes the coating.

Since the material is drawn by suction through the inlet hose, the hose should be armored to prevent its collapse and any subsequent restriction of paint flow.

Airless Spray Hose and Fittings

The fluid hose, depending on its size and the fittings used with airless equipment, must be designed to safely withstand the high pressures (up to 52 MPa [7,500 psi]) produced by these systems. They must also be resistant to the materials and solvents that will pass through them. The most common materials used in airless fluid hose are nylon, Teflon®, and polyurethane.

All airless hose should be **electrically grounded** to prevent static electricity buildup. The airless unit itself should be electrically grounded in hazardous environments, such as in a live gas plant or an enclosed space.

Only fittings, swivels, connections, and other parts designed for high-pressure airless applications should be used when working with airless spray equipment.

Hose Safety

Improper use or handling of hose could result in hose failure and possible personal injury. The hose should be carefully handled and routed (laid out) to avoid kinking, abrasion, cutting, or exposure to temperatures above 82°C (180°F) or below -18°C (0°F).

Before each use, the entire hose should be checked for cuts, leaks, abrasion, bulging of cover, or damage or movement of couplings. If any of these conditions exist, the hose should be replaced immediately. Neither tape nor any other device should be used in an attempt to mend the hose.

Chemicals or agents that are not compatible with the hose material should not be used in the airless hose, for cleaning or any other purpose.

Fluid connections should be tightened securely before each use. When the system is under pressure no attempt should be made to uncouple or disconnect the hose.

The hose should not be used to pull the airless unit. Only conductive or grounded fluid and air hoses should be used for airless applications. The gun should be electrically grounded through hose connections.

Overall, the combined hose length should not exceed 150 m (500 ft).

Airless Spray Guns

The airless spray gun forces the coating through a small orifice at its tip at high pressure, thus atomizing the coating and shaping the coating into an oval pattern for application to the work piece.

The two basic types of airless guns are:

- Internally ported: The pressurized coating passes through the gun body before being forced through the orifice.
- Externally ported: The coating is carried to the orifice through a tube on the outside of the gun.

- Internally ported



- Externally ported



Figure 4 Airless Spray Guns

The major components of an airless spray gun include:

- Inlet: Usually 6-mm (1/4-in.) threaded nipple to which the grounded fluid hose is attached.
- Material port: Carries pressurized coating from inlet to diffuser.
- Safety tip guard: Required by safety regulations, the safety tip is generally colored bright safety orange or red. The safety tip is designed to prevent anyone from getting part of his or her body close enough to the orifice to receive an injection of coating.
- Orifice (or spray tip)
- Gasket: Ensures a tight seal between the fluid tip and the diffuser, thus preventing high-pressure leaks.
- Diffuser: Helps the efficiency of atomization. The diffuser has a 2.28-mm (0.09-in.) orifice with a bar inside which splits the high-pressure stream of material. The diffuser is also a built-in safety device, designed to break up the high-pressure coating stream should the gun be triggered without a spray tip in position to atomize it.
- Trigger safety: When in the **On** position, as shown in Figure 5, the trigger safety prevents the gun from being triggered, just as a safety on a firearm can

prevent accidental discharge. When in the **Off** position, as shown in Figure 5, the gun may be triggered and used.

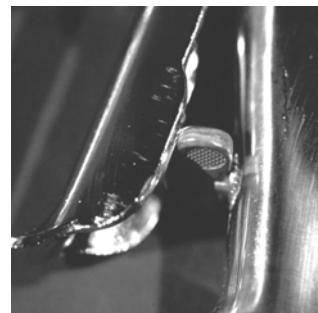
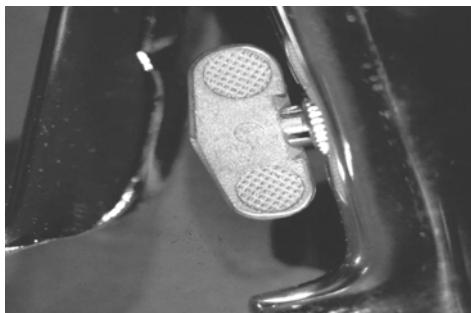


Figure 5 Airless Spray Gun Trigger in On/Off Position

Selection of Airless Spray Tips

Airless spray tips are available in a wide variety of sizes. They are generally constructed of a tungsten carbide alloy. Since an airless spray gun acts as an on/off switch and does not have the air and fluid controls found on air spray guns, the airless spray fan width and spray pattern are adjusted solely by the tip chosen.

The following chart shows tip sizes commonly used for various materials.

AIRLESS SPRAY COMPARATIVE TIP CHART		
Material	Approximate Orifice Size	Typical Available Fan Width (30 cm, [12 in.] from spray tip)
Low-viscosity coatings	0.28 mm (0.011 in.)	15, 20 or 25 cm (6, 8 or 10 in.)
Wash primers, shop primers	0.17 to 0.27 mm (0.007 to 0.011 in.)	15, 20 or 25 cm (6, 8 or 10 in.)
Lacquer, varnish, enamel, finish coatings	0.28 to 0.38 mm (0.011 to 0.015 in.)	15, 20, 25, 30 cm (6, 8, 10, 12 in.)
Industrial primers	0.38 to 0.53 mm (0.015 to 0.021 in.)	15, 20, 25, 30 cm (6, 8, 10, 12 in.)
Note: 100-mesh filter screens should be used with the above tips.		
Medium, or heavy viscosity vinyls; acrylics, latex, alkyds	approx. 0.43 mm (0.017 in.)	15, 20, 25, 30 cm (6, 8, 10, 12 in.)
High-build coatings	0.48 to 0.63 mm (0.019 to 0.025 in.)	20, 25, 30, 35 cm (8, 10, 12, 14 in.)
Glass-flake coatings	0.63 to 1.0 mm (0.025 to 0.040 in.)	25, 30, 35 cm (10, 12, 14 in.)
Note: 60-mesh filter screens should be used with above tips.		

Various fan widths are obtained with different shaped orifices of the same size. For example a 0.013-in. orifice can produce a 6- to 8-in., 8- to 10-in., or 10- to 12-in. fan width depending on the shape of the orifice. Conversely, a 6- to 8-in. fan width can be obtained with either a 0.011-, 0.013-, 0.015-, 0.017-, or 0.019-in. orifice. (In metric terms: a 0.33-mm orifice can produce a 15- to 20-cm, 20- to 25-cm, or 25- to 30-cm fan width; conversely, a 15- to 20-cm fan width can be obtained with either a 0.28-, 0.33-, 0.38-, 0.43-, or 0.48-mm orifice.)

High-viscosity, high-particle size coatings generally require larger orifice sizes.

As stated earlier, pumps are rated by the quantity of paint they will deliver per minute when operating at maximum speed. Spray tips are rated by how many liters (gallons) per minute they will pass. A pump should be capable of delivering paint at a faster rate than the tip can atomize it, to ensure consistent working.

Though a 2.83-L/min (0.75-gpm) pump rarely delivers 2.83 L (0.75 gal) in a minute because of gun triggering, and a 0.75-L/min (0.20-gpm) tip will rarely spray 0.75 L (0.20 gal) in a minute for the same reason, it must be

remembered that the flow rate is the important factor, and this must be matched between the tip and the pump. For example, a 0.53-mm (0.021-in.) orifice tip has a flow rate of 1.6 L/min (0.42 gpm) and requires at least a 2.5 L/min (0.67 gpm) or larger pump.

It should also be noted that a 0.1-L/min (0.021-gpm) tip will never pass more than 1.6 L/min (0.42 gpm), whether a 1.24-L/min (0.33-gpm) pump or a large 26-L/min (7-gpm) pump is supplying it.

The advantage of using a pump rated higher than the tip is that the pump can run slower, lasts longer, and has a capacity reserve for use with a larger tip, with more than one tip, or with a longer hose.

When using multiple guns from a single pump, the user must add the flow rates of the tips to determine the required pump rate. For example, a 0.53-mm (0.021-in.) orifice tip has a flow rate of 1.6 L/min (0.42 gpm); therefore, two such tips have a combined flow rate of 3.21 L/min (0.84 gpm) and would require at least a 6.32 L/min (1.67 gpm) pump or larger.

Several tip configurations are available:

- **Standard tip**—provides a single fan width and a single orifice size. If it plugs, the system must be shut down and depressurized and the safety tip removed before the orifice can be taken out and cleaned. [Note: Never attempt to remove the tip of an airless spray gun when the system is under pressure.]
- **Adjustable tip**—This tip has a large orifice and a screw-threaded tungsten-carbide rod that adjusts the orifice size as it moves in or out. A range of tip sizes can be achieved.

- Reversible tips:
 - Ball tips have a tapered spray orifice and can be reversed by turning a lever. The gun is then triggered and the obstruction is blown out of the tip. The lever is reversed to its operating position, and the sprayer can go back to work.
 - Cylinder tips have the orifice contained in a cylinder. Operation is identical to the reversible ball tip. If the tip plugs, the cylinder can be reversed, the gun triggered, and the obstruction blown out.

The following is a brief description of airless spray technique and some troubleshooting points for reference.

Airless Spray Application Technique

Good airless spray technique is much like air spray, except:

- the gun is held further from the work surface
- coating thickness is greater, which requires less pattern overlapping
- there is a more positive action when triggering the gun
- The spray gun should be held 350 to 450 mm (14 to 18 in.) from the work. The distance varies with the covering ability of the paint, type of surface to be sprayed, and desired spray pattern. Also, the gun should be nearly perpendicular to the surface.
- The operator should try to maintain a 200 to 300 mm (8 to 12 in.) fan width (width of spray pattern). This makes a good wet spray pattern. If the gun is not perpendicular to the surface and within 350 mm (14 in.), a spray tip with a narrower fan angle should be used to keep the proper fan width.

- Runs, sags, or thin coating can result from poor operator technique but are more often caused by improper tip size. Remember, too, that as the tip wears, the fan angle narrows, giving a wetter coat. Generally, a tip should be replaced after spraying a maximum of 380 to 520 L (100 to 150 gal) of coating.
- Have the gun in motion off the work before triggering the gun open and release the trigger after the pattern has left the work, if possible. Move the gun at a constant speed through the entire stroke.
- For a wider spray pattern, hold the gun farther from the work or use a tip with a wider fan angle. However, this will apply a thinner coating, so to maintain the same coat thickness, also use a larger spray tip and/or move the gun more slowly.
- For a heavier coating, make slower strokes with the gun or hold the gun closer to the work. However, this will give you a narrower spray pattern; to maintain the same pattern width, the tip must be changed to one with a greater fan angle. Otherwise, use a larger tip for a heavier coat.
- When spraying complex shapes or objects with critical areas, work out the best combination of spray gun movements to get good coverage without excess paint buildup or sags.

The following chart describes some troubleshooting issues that may be used to remedy application defects.

Airless Spray Troubleshooting		
Spray Pattern Problem	Cause	Correction
Tails, fingering	Inadequate fluid delivery Fluid not atomizing	Increase fluid pressure Change to larger tip orifice Reduce fluid viscosity Clean gun and filter(s) Reduce number of guns using pump Install sapphire insert
Pattern expanding and contracting (surge)	Pulsating fluid delivery Suction leak	a. Change to a smaller tip orifice b. Install pulsation chamber in system or drain existing one c. Reduce number of guns using pump d. Increase air supply (volume) to air motor e. Remove restrictions in system; clean tip screen or filter, if used f. Inspect for siphon hose leak
Hour glass	Inadequate fluid delivery	a. Same as a through e, above
Uneven spray pattern	Worn spray tip	Replace tip

Spray Techniques

Faster application is the main purpose of using spray techniques to apply industrial protective coatings rather than brush or roller. This advantage may not apply if the area to be painted is relatively small or complex.

The main point to remember about spray technique is that both the material and the equipment are designed to function adequately with the paint traveling through a fixed distance (approx. 45 cm [18 in.]) before hitting the surface being painted. This overriding consideration rules many aspects of practical spraying, such as:

- The spray gun should move parallel to the surface being painted and not arced.
- Excess solvents should not be added to paint materials, thereby changing the atomization and flow characteristics.



- Extra care should be taken when dealing with complex shapes, corners, etc.

In general, conventional spray equipment is not commonly used on site for industrial painting; airless spray equipment is used instead. A comparison of the two types of spraying shows that, in operation, the airless method has the following advantages:

- Because of the wider fan obtained and much higher throughput of paint, the higher film thickness necessary for modern high durability can be obtained comparatively rapidly. Specifically designed paints of high viscosity and high solids are generally available to take advantage of the application method, although conventional materials can be successfully used with correct selection of tip size and fan.
- There is less spray *fog*, because of the absence of a blast of air. This means that not only is the airless method more economical because less of the paint is wasted as fog, but the equipment can be used in confined space such as deep tanks or rudder trunks, because the reduced spray fog makes working conditions in enclosed areas more acceptable.
- Paints for airless spraying generally do not need to be thinned. This leads to savings both in materials and time.

Operation

The airless unit is very simple to operate. Only one adjustment is necessary to control the flow of paint to the gun and no critical balancing of air and fluid pressure is required to obtain perfect atomizing action. The size of the spray pattern cannot be altered by fluid pressure adjustment but is governed by the type of tip fitted and by the viscosity of the material used.

Spraying technique differs slightly from conventional spraying. The spray gun must be held at right angles to the surface throughout the stroke, but the distance between the gun and surface should be about 350 to 450 mm (14 to 18 in.). Strokes may be overlapped by 50% to obtain coverage, but the speed of stroke is faster than with normal spraying.

Feathering is not possible with the airless method; the trigger must be compressed firmly and completely at the beginning of each stroke and released abruptly and fully at the end of it. The movement of a stroke should commence before the trigger is pulled and carried on after it has been released to ensure that the operative part of the stroke is at a constant speed.

Airless Spray Guns: Selection of Tips

Tip Orifice		Spray Angle (°)	Fan Width		Fluid Flow Rate	
(0.001 in.)	(mm)		(0.001 in.)	(mm)	U.S. gals/min	L/min
9	0.23	10 to 50	2.75 to 9	70 to 230	0.1	0.39
11	0.28	10 to 80	2.75 to 14	70 to 350	0.15	0.57
13	0.33	10 to 80	2.75 to 14	70 to 350	0.2	0.76
15	0.38	10 to 80	3.5 to 14	90 to 350	0.35	1.3
18	0.45	20 to 80	5 to 14	140 to 350	0.42	1.6
23	0.58	20 to 80	5 to 14	140 to 350	0.6	2.3

Use the following guidelines when selecting tips:

- Thin materials require small orifice size; thick materials require large orifice size.
- The larger the tip-orifice diameter, the greater the fluid flow and the faster the coverage.
- Select the smallest orifice suitable for the material.
- The greater the tip angle, the wider the fan pattern.

- The larger the orifice, the larger the pump and air-supply volume required (to drive the pump).
- If the paint is too thin for the size of the orifice being used, excess volume of fluid flow will result and the pump will cycle too rapidly.

Adjustable Spray Tips

These are available in four sizes and can be fitted to most guns. By rotating the adjustment knob, both the spray fan width and the volume of paint being applied can be varied.

Tip Cleaners

When the control on top of the attachment is turned, the paint tip is reversed. Operating the spray gun in this position blasts out the particle blocking the orifice. The tip can then be reversed to its normal operating position. These attachments are often known by the trade name *Reversa-Clean*[®].

Paint Mixing

In most coatings, especially heavily pigmented materials such as zinc-rich primers and micaceous iron oxide (MIO) coatings, settlement is likely to occur during storage. Unless the coating is thoroughly mixed before use it will not perform satisfactorily. Poor opacity, slow drying, poor gloss, and other problems often result from failure to mix the coating properly before use.

When coatings are mixed, a properly made stirrer should be used, long enough to reach the bottom of the container and with a broad, chisel-like edge and a comfortable handle. All settlement should be mixed by stirring, using a beating and lifting action. If large quantities of paint (20 L, 5 U.S. gal) are to be mixed, it is advisable to use a mechanical mixer, preferably of the type driven by compressed air.

For some high-solids (high-viscosity) coatings—including zinc-rich primers—the use of a mechanical mixer may be mandatory and required by the specification or by the manufacturer's technical data sheets. In these cases, hand mixing is not recommended and should not be allowed.

Many conventional spray pots are equipped with a built-in mechanical stirrer. Airless spray equipment is not generally fitted with automated stirrers.

Where the paints are to be applied by spray, a certain amount of thinning may be required. It will not normally be necessary to add more than 10% of the recommended thinner to bring the paint to a suitable consistency for application. Over thinning should be avoided because the thin coating that results has poor durability and a lower resistance to corrosion than one applied at the correct thickness.

In general, thinning of paints should be avoided unless necessary. If thinning of the paint is required, it should be done under supervision and with the correct solvent.

Another reason for not thinning coatings unless necessary is the need to comply with VOC regulations. Increasingly stringent regulations are aimed at reducing the emission of solvent vapors into the atmosphere. The addition of thinners to mixed paint materials significantly increases the VOC content of the coating over the designed VOC levels of that product.

In the case of two-pack (or multi-component) coatings, it is important that materials are mixed in the correct ratio. Manufacturer's instructions should be followed with respect to induction period of pot life requirements. It is generally not recommended that partial quantities of supplied materials are mixed (e.g., 2½ L from a 5-L kit or 1 gal from a 5-gal kit). Ideally, the applicator will order some coating materials in smaller containers to allow the mixing of small quantities.



If partial kits are to be mixed, it is important that the materials are stirred before being measured out and that the measuring is done accurately. Only the required amount of paint should be mixed and any mixed material remaining after the job is completed should be properly disposed. It cannot be returned to the original containers.

Brushes, spray equipment, or other application tools should be cleaned with the recommended solvent immediately after use and—in some cases—at work breaks, because the paint may quickly harden causing unnecessary damage and delays, especially to airless spray equipment.

Applying the Coating

The information in the remainder of this section may apply to both airless spray and conventional air spray methods.

Before beginning to apply a coating, the operator should check to ensure that the spray gun is delivering a normal spray pattern. The painter should adjust the gun to develop the optimum fan shape.

Hold the gun so the pattern is perpendicular to the surface at all times, keeping the gun at a uniform distance (about 25 to 30 cm [10 to 12 in.] for conventional spray) from the surface being sprayed.

The stroke is made with a free arm motion, keeping the gun at right angles to the surface at all points of the stroke. Triggering should begin just before the edge of the surface to be sprayed is in line with the gun nozzle. The trigger should be held fully depressed and the gun moved in one continuous motion until the other edge of the object is reached. The trigger is then released, shutting off the flow, but the motion is continued for a short distance until it is reversed for the return stroke. When the edge of the sprayed object is reached on this return stroke, the trigger is again fully depressed and the motion continued across the object.



Overlap each stroke 50% over the preceding one. Move the gun at a constant speed while the trigger is pulled, since the material flows at a constant rate. A 50% overlap will provide uniform coverage.

Arcing the gun results in uneven application and excessive overspray at each end of the stroke. When the gun is arced 45° away from the surface, up to 65% of the material is lost.

Some special techniques may be used to provide specific types of coating film, including:

- **Tack coat**—a light covering coat applied to the surface and allowed to flash until it is just tacky, which usually takes only a few minutes. The finish coats are then sprayed over the tack coat. This method allows the application of heavier wet coats without sagging or runs.
- **Full wet coat**—a heavy, glossy coat applied to full thickness, almost—but not quite—heavy enough to run. It requires skill and practice to spray such a coat.
- **Mist coat**—an incomplete spatter coat applied with a very fast gun motion. The idea is to partially displace the air in porous coatings, like inorganic zinc primer, before over coating.
- **Stripe coat**—a separate coat applied to edges, corners, welds, and other vulnerable areas to provide extra thickness at those locations. The stripe coat may be applied by brush (recommended for primer coats especially) and may be applied once in a coating system or once for each coat in the coating system.

These techniques are not universally used, some being commonly used in certain geographical areas but not elsewhere. For example, the application of a mist coat was developed primarily in the United States to eliminate the need for specialist intermediate coats when over

coating porous coatings. Some users still prefer to use a special penetrating tie coat rather than use the mist-coat technique.

Corners and Edges

Large, flat areas are relatively easier to coat than corners, edges, bolts, nuts, rivets, etc. It is important, then, for the coating inspector to pay particularly close attention to hard-to-coat areas.

Difficult areas, such as corners and edges, should be stripe coated if required, or allowed, by the specifications, and then sprayed before other areas. The stripe coat is often applied by brush, particularly in difficult areas. The spray painter should then aim directly at the edge or corner so that half of the spray covers each side equally and should hold the gun a little closer than normal. With conventional spray, the applicator may screw the spreader adjustment control in a few turns to reduce the width of the spray pattern.

Either technique will reduce the pattern size. If the gun is just held closer, the spray stroke will have to be faster to compensate for a normal amount of material being applied to the smaller areas.

Special attention should be given to spraying bolts, nuts, threads, and rivets. These are critical areas that should be properly coated to deposit paint uniformly to all exposed areas.

When spraying curved surfaces, the painter should try to keep the gun perpendicular to the surface at all times. This may not always be physically possible, but it is an ideal that the painter should strive for because it produces a better, more uniform finish.

After all the edges and corners have been sprayed, the flat or nearly flat surfaces should be sprayed.



Paint Application: Quality Control

Paint Testing on Site

The range of paint tests that may be successfully carried out on site at the time coatings are applied is limited by both the difficulty of handling complex laboratory equipment and by the lack of laboratory experience of most site personnel. In practice, the common tests which may be performed are:

- Viscosity Check—to check suitability of flow characteristics and quantity of added thinners



Figure 6 Viscosity Check

- Wet-Film Thickness Check—to ensure that the film will achieve the desired DFT
- Visual Checks—on condition of paint, batch numbers, storage time, condition of paint container, label details, etc. Further visual checks can be made on the drying coating film after application, looking for coating condition (gloss, misses, pinholes, etc.).

Wet-Film Thickness Checks

Measurement of wet paint film thickness provides a useful guide for inspectors or paint sprayers to ensure that a correct and even film thickness is being applied to the article being coated. Use of a wet-film comb at this stage of a paint application operation helps prevent *reject work* which in itself is time consuming and therefore costly.

The most common instrument for measuring wet-film thickness (WFT) is the comb gauge. WFT measurements should be made as soon as possible after coating application.

The gauge may leave marks in the coated surface that may adversely affect the integrity of the coating. Those marks should be immediately over coated with fresh coating to avoid pinholes. Guidance may be provided by the specification on the use of the WFT gauge.

Dry-Film Thickness Checks

DFT will normally be measured using an electronic or magnetic gauge. The instrument must be calibrated if accurate measurements are to be made. For best results:

- Calibrate the instrument on steel with a surface profile matching the profile of the painted surface being measured.
- Using shims of known thickness, calibrate the instrument in the expected range of DFT to be measured.
- When a particular standard or method is required by the coating specification, that method should be used.

Weather Conditions

Applying coatings during poor weather conditions is likely to result in a lesser-quality coating film and



reduced protection. Quality control on site should monitor relative humidity, dew point temperature, and the temperature of the surface being coated to avoid problems with:

- Coatings being applied to a damp surface
- Freshly applied coatings becoming affected by moisture soon after application
- Coatings being applied when the temperature is too low for the curing reaction to proceed
- Coatings being applied when the surface temperature is too high and the film-formation process is disturbed
- Coating solvents being unable to evaporate, due to high partial vapor pressure (i.e., large amounts of water vapor in the air)

In general, a specification is likely to require the following conditions:

- Air temperature greater than 5°C (40°F)
- Dry surface to be coated
- Relative humidity lower than 90%
- Steel surface temperature at least 3°C (5°F) above the dew-point temperature.

If any of these conditions is not met, coating application should not be performed unless formal dispensation is allowed.

Workmanship

Poor coating application is a major factor in coating failure. Typical problems resulting from faulty application techniques might include:

- Improper thickness
- Pinholes
- Overspray
- Holidays (discontinuities)
- Pinpoint rusting

Almost all application-related failures are due to poor workmanship, though this may sound like harsh judgment. Poor workmanship refers to such practical issues as holding the spray gun too close or too far away from the surface or at a significant angle to the surface being coated.

These matters are largely a question of training, or the lack of it, leading to a simple lack of understanding of what causes paint application problems. It is important that painters are trained in the skills of paint application, particularly those applying modern, high-performance coatings. Good workmanship cannot be guaranteed. The specification must require good workmanship, and the inspector must be trained to recognize an acceptable quality of work.

Improper Thickness

If a coating is too thin, pinpoint corrosion can occur; if too thick, the coating may crack. High film thickness is likely to be a bigger problem than low film thickness, due to the development of stress during the coating drying and curing cycle, and is more difficult to correct than low DFT.





Figure 7 Improper Thickness

Excessively thick coatings may retain solvent, leading to problems with cure and possibly to blistering in extreme cases. With polymerized coatings, particularly those intended to be applied at high DFT (500 μm [20 mils] per coat or more), there may be internal shrinkage due to the excessive thickness leading to cracking, flaking, or delamination (loss of adhesion). Care should be used to ensure the application stays within the recommended parameters, particularly film thickness.

Coatings should be applied in an even, uniform film, allowing coating to wet the surface. Use thin, multiple passes with 50% overlapping to achieve a uniform film and ultimately the proper final thickness.

Applying single-coat systems requires special care. Errors in coating film thickness applied cannot easily be corrected, and it is important to get the application *right the first time*.

Pinholes

Pinholes are small (visible) holes in a coating, often caused by application of a thicker organic coating over a porous surface (e.g., coating epoxy over concrete or over inorganic zinc). Coatings with the *wrong* solvent balance

may also suffer pinholing caused by the inability of solvent to escape from the rapidly curing coating. High ambient temperatures may also lead to pinholing, as the film *sets* more rapidly.

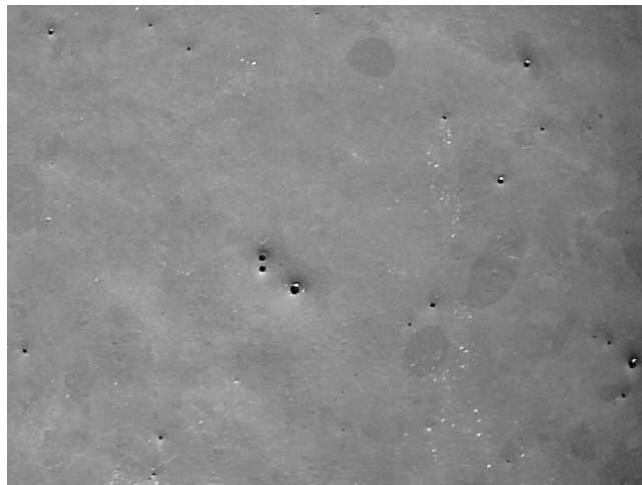


Figure 8 Pinholes

Fast-drying coatings such as vinyl or chlorinated rubber are most likely to suffer pinholing. The fast-drying surface does not allow the air (entrained in the paint as a result of spraying) or the solvents to escape. The name often given to this effect is *gassing*.

The effect can often be seen immediately after coating application in the form of bubbling, rather like the surface is boiling. The vapors may escape completely and the pinholes close up as the coatings flow together. Any interruption of this process is likely to solidify the coating film before the necessary flow has taken place. The result may be seen as bubbles or blisters at the surface, as craters where the blisters have broken, or as pinholes where the craters have filled but the pinhole has not.

The addition of extra thinners or the wrong thinners will increase the probability of pinhole formation.

To limit pinhole formation when coatings are applied to porous substrates, applicators may apply a thin coating, able to penetrate the substrate. These materials, when specially designed, are called *tie coats*. Alternatively,

thinning the coating with up to 50% thinner may help penetration of the substrate and achieve better adhesion.

Overspray/Dryspray

Overspray occurs when paint falls onto a surface that was not intended to be painted. This is most likely to occur when the applicator fails to trigger the gun, continuing to spray paint at the beginning or end of each stroke, applying coatings beyond the target areas. Overspray generally adheres to the surface it reaches, leaving a rough surface. The coating is likely to create a partial film, forming an ineffective barrier.

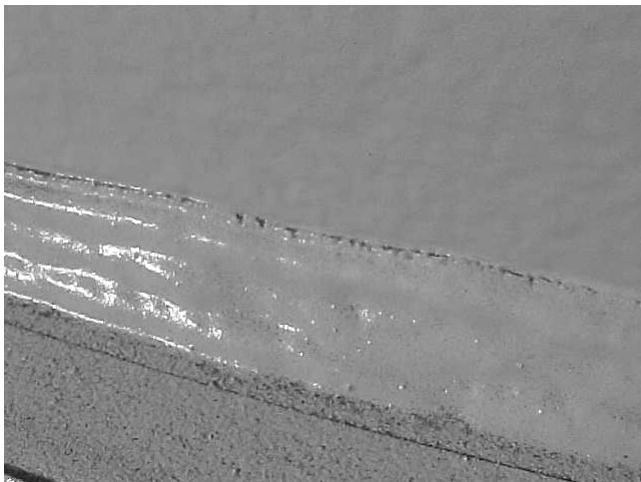


Figure 9 Overspray

Dryspray is similar to overspray and usually leaves a rough surface that looks like abrasive dust in the surface of the coating. The dry spray is poorly bonded to the painted surface and may, in some cases, provide sufficient dusting to prevent adequate bonding of the next layer of paint, leading to an adhesion weakness in the system. The problem may be compounded by the entrapment of real dust and other contaminants in the rough surface prior to the next coating operation.

Dryspray is most likely to occur when the painter is working at some height and the escaping paint particles can fall, drying as they go, or when the wind is blowing and paint particles can be carried by the wind.

The applicator should ensure the spray gun is properly adjusted and apply coatings at the optimum distance to surface. The coating should be fluid when it reaches the structure and wet the surface with good flow-out. Coatings should generally be applied in several multiple passes overlapping 50%.

Holidays (Discontinuities)

Holidays are bare spots, misses, or even thin spots in a coating where the substrate is uncoated. They are generally more significant when the coatings are linings, intended for immersion service. Pinpoint corrosion can occur, and premature coating failure is likely to be associated with any holiday.

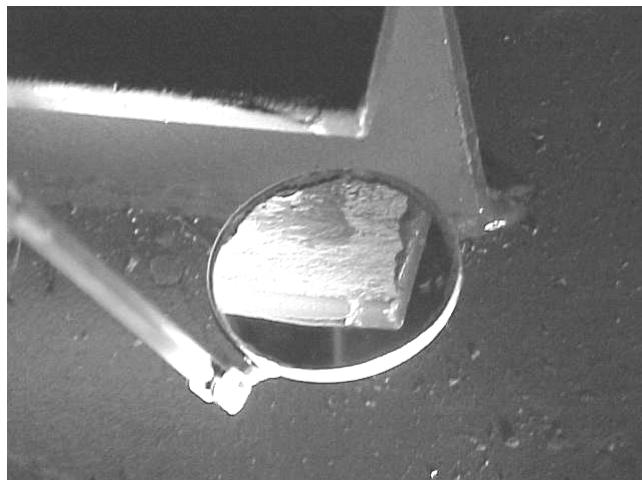


Figure 10 Holidays

(Note: Pinholes may also be defined as holidays.)

Poor Workmanship

This catch-all phrase can encompass many factors of application faults—any one of which could cause or promote an active coating failure. Applying coatings over visible contamination, applying coatings improperly (either too thin or too thick with runs and sags, pinholes, overspray, etc.)—all these faults could be corrected or avoided with better application techniques.

Poor workmanship can be overcome to some extent by training. This subject is discussed in some detail in the advanced module. Proper training is essential, however, if the trainee/worker is to become part of the team. Workers should be given the opportunity to understand the effects of workmanship on coating performance. It should then follow that they will develop confidence and pride in their workmanship that can go a long way to offset any application faults that reduce the life of the coating and lead to a coating failure.

Spray Application: The Coating Inspector's Task

Many coating defects originate in the spray application phase of the job. Proper equipment, procedures, and techniques are essential to a successful spray application of any coating.

Spray application equipment should be examined to determine whether or not it has adequate pressure-regulating devices and accurate gauges.

Hose lines for spray equipment should be of large enough diameter to prevent excessive line drops in pressure, and compressors should be of adequate capacity to handle all air tools and equipment being used at one time. The interior of the fluid line must be clean.

Traps and separators for removing oil and water from the compressed air source should be operating and effective to ensure that the air does not deposit visible oil or water on the surface.

The quality of spray air can be checked using the blotter test (ASTM D 4285), just as in checking the quality of abrasive blast air.

All spray guns should be kept clean and in good working order. In conventional air spray guns, the air cap, needle valve, and fluid nozzle for spraying a particular coating should be selected in accordance with the coating and

spray equipment manufacturers' recommendations. The coating deposited within the spray pattern should be inspected for uniformity of distribution. In airless spray guns, the tip should match the recommendations of the coating manufacturer.

When zinc-rich coatings are used, spray pots should be inspected for adequate agitators, necessary to keep the coating in uniform suspension; if these are not provided, the coating must be checked to see that it does not settle. Mechanical agitators should be used when material containers of 20 L (5 gal) capacity or more are used. With airless spray, the operator or helper should check frequently that mixing is adequate to maintain the coating components in suspension during the spray application.

In conventional spray pressure pots, the mixer may be an integral part of the design. The pressure pot agitator should be used only to keep coating material components in suspension, not as a primary mixing device.

Working pressures for spraying should be no higher than necessary to obtain satisfactory atomization of the coating, since high pressures may result in excessive fogging and overspray.

The ideal distance between spray nozzle and surface can vary depending on the equipment used but should be kept uniform, and the common habit of supplementing the painter's reach by increasing the spraying distance should not be permitted. The technique of the operator and the adjustment of the gun should be observed for any deficiencies that would result in non-uniform coating thickness.

The use of the wet- and dry-film thickness gauges to point out areas of widely varying film thickness will generally have a very beneficial effect on the efforts of the spray painter to deposit uniform coatings. The DFT gauge should be used to determine the final acceptability of the coating.



The inspector should pay particular attention to the spraying of crevices, corners, welds, bolts, rivets, and sharp edges, since these areas are generally slighted in spray application of coatings and cannot easily be checked with a film thickness gauge.

Surfaces hard to reach by spray application should be brushed or swabbed with coating.

Some coatings have a tendency to bridge across, instead of fill, cracks and crevices in the substrate. If called for in, or allowed by, the specification, a stripe coat should be applied to cracks, crevices, welds, etc. Stripe coating consists of brushing the coating into cracks, crevices, and corners, etc., to work the coating into the narrow openings.

Regarding coating application procedures, some of the coating inspector's responsibilities may include determining that proper application equipment and coating materials are on site, including:

- Pressure pot with agitator, pressure regulators, and gauges for conventional spray equipment
- Spray pump, for airless spray
- Appropriate quality brushes or rollers
- Hose lines (air and fluid if necessary)
- Moisture traps and oil separators
- Spray guns

Other responsibilities may include:

- Observing and verifying procedures for handling coatings, including:
 - Mixing
 - Thinning



- Agitation
- Safe storage
- Shelf life
- Observing application techniques, including:
 - Proper working pressures
 - Uniform distance from work piece
 - Specified WFT and DFT are achieved
 - Proper coating of hard-to-reach areas
 - Review of safety issues, including:
 - Fire hazards
 - Breathing equipment
 - MSDS information available

Inspectors must ensure their own safety. This is best accomplished by knowing and following the job safety rules.



Level 1

Chapter 3.4

Nondestructive Test Instruments

Overview

Once the applied coating is dried and cured, it should be inspected to ensure that it meets the required standards. Typical inspection tests check for adequate film thickness, pinholes, and other conditions.

In this section of the program, we will discuss the instruments used for measuring dry-film thickness (DFT) and for detecting the presence of holidays.

Much discussion has been focused on the importance of applying coatings at the thickness required by the specification. Coatings that are too thick or too thin often result in early coating failures and costly repairs.

Holidays or pinholes (i.e., discontinuities, voids, inclusions, areas of low film thickness, or breaks in the coating) should be detected and remedied to ensure an effective coating system. Any defect, even as small as a single holiday, may not be acceptable for critical coating performance situations, such as coatings in immersion service in a tank or pressure vessel, and may cause the rejection of the entire coating system.

A wide variety of test instruments are available in today's market. These may be *destructive* or *nondestructive*.

Destructive Test Instruments

This category is called *destructive* because part of the coating may be damaged or destroyed by the test procedure. Destructive test instruments are generally used in investigating coating failures and other specialized applications. They are less frequently used for regular quality-control testing.

Instruments commonly used for destructive testing include:

- Paint inspection gauge (Tooke gauge), used to measure coating thickness

- Adhesion tester, used to measure coating adhesion

Generally, no test that would damage the coating should be conducted unless it has been specified or permitted by the owner.

Destructive test instruments will be discussed in detail in the advanced modules of this program.

Nondestructive Test Instruments

Nondestructive test instruments, used properly, do not destroy the coating on which they are used. Most types of DFT gauges are nondestructive.

In this section, we'll discuss essential quality-control instruments, including:

- Wet-film thickness (WFT) gauges
- 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

Wet-Film Thickness Gauge

An essential companion to any instrument used to measure DFT is the wet-film thickness (WFT) gauge. Using knowledge of the volume-solids content of the coating, the applicator can calculate the WFT required to produce the desired DFT.

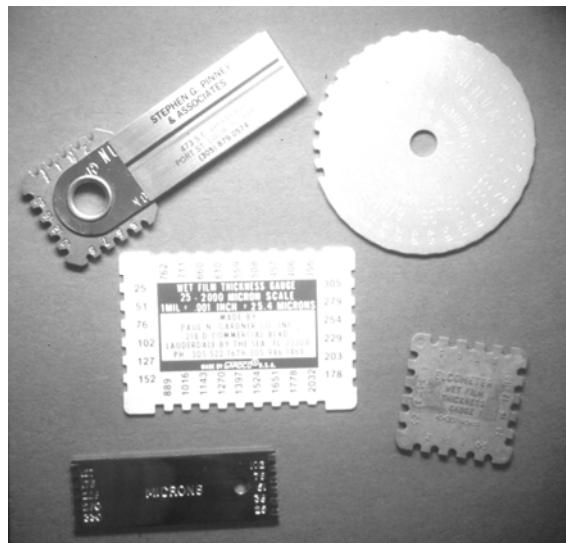


Figure 1 Wet-Film Thickness Gauges

The most common instrument for measuring WFT is the comb gauge. It consists of a series of graduated teeth lying between two outer teeth. WFT combs with different scales (e.g., μm , mils) are available.

The gauge is pushed firmly into the wet paint film so that the outermost teeth make contact with the substrate or previously coated surface. The gauge must be at a right angle to the surface. The gauge is removed and the teeth examined. Some of the heads of the teeth will be coated with paint while the remainder will remain clean. The true WFT lies between the last tooth that is coated and the next (higher) tooth that is uncoated. The reported WFT is that of the last wet or coated tooth on the gauge.

Volume Solids

Knowledge of the volume solids for any paint material allows the applicator to predict the DFT at the time of application. The *% volume solids* defines the relationship between the WFT and DFT of applied paint films.

$$\text{Volume Solids} = \frac{\text{Dry-Film Thickness}}{\text{Wet-Film Thickness}} \times 100 (\%)$$

To be useful to the painter, this formula must be turned around. Volume solids is generally quoted on the manufacturer's technical data sheets. The target DFT may also be provided on the technical data sheet but is also likely to be quoted in the specification. WFT can be calculated using the following formula:

$$\text{Wet-Film Thickness} = \frac{\text{Dry-Film Thickness}}{\text{Volume Solids}} \times 100 (\%)$$

The painter can now calculate the target WFT, check the thickness as it is being applied, and adjust the application technique to meet the required target

The addition of thinner to coatings reduces the volume solids. If thinner is added the formula works if the modified volume solids is calculated.

Magnetic DFT Gauges

Common types of simple DFT measurement instruments include:

- **Pull-off magnetic DFT gauges**, which use a calibrated spring to pull a small permanent magnet from the coated surface, including:
 - Dial-type gauge

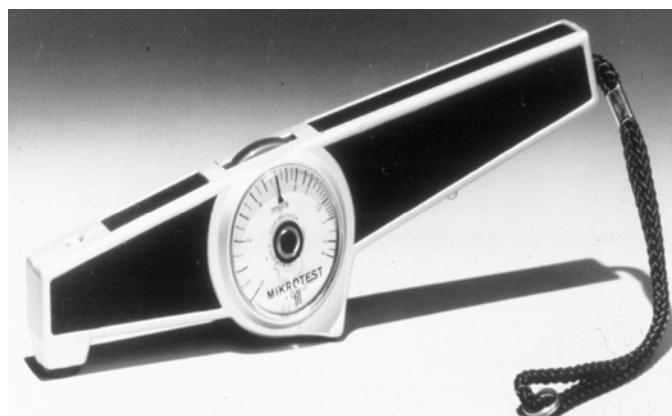


Figure 2 Dial-Type Magnetic Pull-Off DFT Gauge

- Pencil pull-off gauge

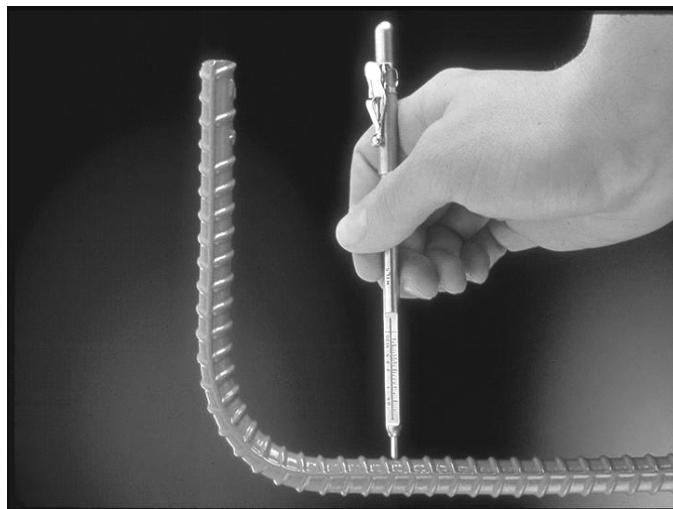


Figure 3 Pencil-Type Magnetic Pull-Off DFT Gauge

- **Magnetic constant-pressure DFT gauges**, which depend on changes in magnetic flux within the probe and include:

- Dual-probe gauge
- Single-probe gauge



Figure 4 Magnetic Constant-Pressure DFT Gauge

Care must be taken with all instruments using magnetic probes.

First, the exposed magnet may attract any nearby loose iron and steel shot or grit particles. The magnet should be cleaned of any contaminants that might alter its reading. It is important that the spot on the surface being measured is clean; otherwise, the reading may not indicate the gap between the surface and the magnet as it is designed to. The gap may, in fact, be made up of rust, residues of abrasive blasting, or other impurities, which could adversely affect the reading. Careful inspection of the surface for cleanliness, both before coating applications and between each coat, is important.

Second, if the instrument is used on tacky films, the reading may indicate a thickness that is **less** than the actual coating thickness. That is because the film itself will hold the magnet to the surface beyond the point when it would otherwise have pulled away. If used on a soft coating, the tip may depress the coating, causing a **thin** reading.

Third, vibration of the substrate might cause the magnet to pop off the surface before it otherwise normally would, giving a **high** thickness reading. Magnetic instruments are also likely to be affected by magnetic fields close to edges. If possible, the instrument should not be used closer than 25 mm (1 in.) from the edge of the surface.

Fourth, with dial-type pull-off gauges it is easy to continue to turn the dial after the point at which the magnet has lifted off the surface, giving an incorrect reading. New versions of some instruments solve this problem with an automated mechanism, which turns the dial at a fixed rate and stops when the magnet lifts off the coated surface.

Thickness measurements should be made after the application of each coat in a multi-coat system. However, with nondestructive gauges it is difficult to determine the exact thickness of each individual successive coat after

the first coat, and a total DFT measurement for the coating film must be made.

The DFT of individual coats can be estimated by calculation. The second coat, for example, can be determined by subtracting the average thickness of the first coat from the total measured. The DFT value will be an estimate only, because it is unlikely that the second set of measurements will be taken in the same position as those of the first coat, and the first coat DFT may not be truly represented.

Thickness measurements are made to ensure the specification is being met. Obviously, the inspector cannot measure the DFT for every square inch of coated surface. Inspectors, therefore, must be able to use some standard or agreed method of taking measurements, and the resulting values should be taken to represent the DFT of the coating film.

SSPC-PA 2—DFT Measurement with Magnetic Gauges

Various standards define methods of measuring DFT. ASTM D 7091 and SSPC-PA 2 define similar methods for calibrating magnetic-type DFT gauges and for taking DFT measurements of nonmagnetic coatings over a ferrous magnetic metal surface. Of the two specifications, SSPC-PA 2 will be explored in this course.

Other standards may be required by a particular specification, and the inspector should be careful to use the method defined by the specification. If no standard is required, then it would be good practice to choose a standard method, such as SSPC-PA 2, and work within guidelines defined by consensus within the coatings industry. Alternatively, the inspector can propose a method for calibration and measurement frequency, and the method should be agreed with the various parties concerned, perhaps at the pre-job conference.



The requirements of SSPC-PA 2 are as follows: Five spot measurements (average of three readings) for each 10 m^2 (100 ft^2) measured. Note that individual readings are not subjected to rules but are included in the average for a *spot* measurement.

The average of five spot measurements (i.e., 15 individual measurements) can be no more and no less than the specified thickness.

NO single spot measurement can be less than 80% of the specified thickness and no more than 120%.

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 5 SSPC-PA 2 Measurement Record

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. No single spot measurement in any 10-m^2 (100-ft^2) area shall be less than 80% of the specified minimum thickness. Any gauge reading may 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 are less than 80% of the specified minimum thickness, additional measurements may be made to define the nonconforming area.

Maximum Thickness: The average of the spot measurements for each 10-m² (100-ft²) area shall not be more than the specified maximum thickness. No single spot measurement in any 10-m² (100-ft²) area shall be more than 120% of the specified maximum thickness. Any gauge reading may over run by a greater amount. If the average of the spot measurements for a given 10-m² (100-ft²) 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 may be made to define the nonconforming area. Manufacturers' literature may be consulted to determine if higher maximum-thickness readings are allowable under specific circumstances.

Area Measured

For areas under 100 m² (1,000 ft²) randomly select and measure **three** 10-m² (100-ft²) 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 100 m² (1,000 ft²) measure first 100 m² (1,000 ft²) as above and—provided DFT is OK—for each additional 100 m² (1,000 ft²), randomly select and measure one 10-m² (100-ft²) 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.¹

As with all specified standards, inspectors should take the time to become thoroughly familiar with this specification (located at the end of this Chapter).

¹ SSPC-PA 2.

SSPC describes calibration techniques for using two methods and defines DFT gauges in two categories corresponding to the calibration techniques. Magnetic pull-off DFT gauges are described as SSPC-PA 2, Type I, while fixed-probe gauges are described as SSPC-PA 2, Type II.

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 measures 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.

Whichever standard method is used, recording the correct number of measurements is important. The inspector may use a table similar to the following (as used in the Coating Inspector Logbook) to ensure that all relevant measurements and calculations have been made.

First Coat**Specified DFT Min:** _____ **Max:** _____**Location:** _____

Spots->	1	2	3	4	5
1					
2					
3					
Avg.					

Overall Average DFT: _____

Minimum DFT: _____ Maximum DFT: _____

Conforms to Specification, Yes / No? : _____

It is helpful, when nonconforming areas are found, to mark those areas where the coating is found to be either too thick or too thin. This can be done by applying a contrasting color coat of the same coating, but in no case should any marks be made that could damage the coating.



The method of marking coating deficiencies should be agreed during the pre-job conference.

**International Maritime Organization (IMO)
Resolution MSC.216(82), Annex 3, Dry-Film
Thickness Measurements**

The new IMO² standard has a specific methodology for collecting DFT measurements. The following verification check points of DFT are to be taken:

- One gauge reading per 5 m^2 (50 ft^2) of flat surface area
- One gauge reading at 2- to 3-m (6.5- to 10-ft) intervals and as close as possible to tank boundaries, but not further than 15 mm (0.6 in.) from edges of tank boundaries
- Longitudinal and transverse stiffener members: One set of gauge readings taken at a 2- to 3-m (6.5- to 10-ft) run and not less than two sets between primary support members, as shown in Figure 6.

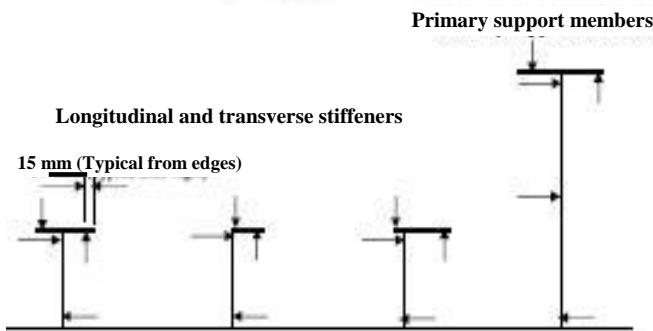


Figure 6 Readings at Longitudinal and Transverse Stiffener Members

- Three gauge readings for each set of primary support members and two gauge readings for each set of other members, as indicated by the arrows in the diagram

² International Maritime Organization (IMO), 4 Albert Embankment, London, SE1 7SR, United Kingdom.

- For primary support members (girders and transverses) one set of gauge readings for a 2- to 3-m (6.5- to 10-ft) run but not less than three sets;
- Around openings, one gauge reading from each side of the opening;
- Five gauge readings per square meter (m^2) but not less than three gauge readings taken at complex areas (i.e., large brackets of primary support members)
- Additional spot checks are to be taken to verify coating thickness for any area considered necessary by the coating inspector.

Magnetic Pull-Off DFT Gauge

The magnetic pull-off DFT gauge is a simple mechanical tool that works by magnetic attraction to a ferrous surface. The force of attraction is reduced by the presence of a nonmagnetic barrier between the permanent magnet and the surface. The measurement of the force required to pull the magnet away from the surface is equated with the thickness of the film.



Figure 7 Magnetic Pull-Off DFT Gauge Calibration on NIST Shims

The gauge is used for nondestructive measurement of the DFT of nonmagnetic coatings on a ferrous metal substrate.

Magnetic pull-off gauges do not depend on batteries or any other source of power and are therefore considered by many users to be more reliable in the hands of inexperienced users. They are also used in hazardous environments when non-spark instruments are required. They are widely used despite the frequent appearance of more sophisticated and more accurate electronic gauges. They are portable, simple to operate, and inexpensive.

Measurements are taken in accordance with the specification or referenced standard. If no specific method is mentioned in the contract documents, this issue should be discussed at the pre-job meeting and a suitable method agreed. It is always better to follow an industry standard whenever possible.

Place the gauge on a clean, dry, and cured coated surface. Do not use on soft or tacky films. Rotate the dial all the way to the highest reading on the gauge and then lift the counterbalance so that the magnetic tip contacts the coated surface. Slowly rotate the dial (increasing spring tension) at a constant speed until the magnet *oops up* from the coated ferrous surface. Where possible, the gauge should be mechanically stabilized by pressure from the operator's hand.

Keep the magnetic tip free of magnetic particles and other residues. Do **not** use the gauge within 2.5 cm (1 in.) of an edge, on or near vibrating equipment, or on metal being welded (the unit may be demagnetized). On circular pieces, locate the gauge along the longitudinal axis.

The instrument must be calibrated if reliable measurements are to be made. There are different ways to calibrate a magnetic DFT gauge. If a standard, such as SSPC-PA 2, is specified the calibration method should be that defined by the standard.

The two main options for calibration are as follows:

- Calibrate the instrument on steel whose surface profile matches the profile of the painted surface

being measured. Use nonmagnetic shims of a known thickness, close to the expected (or specified) DFT.

- Calibrate the instrument on prepared *traceable* calibration blocks, such as those supplied (in the United States) by the National Institute of Standards and Technology (NIST).³ These are described in detail in the following sections. Select a calibration plate in the expected range of DFT to be measured.

An alternative system sometimes used is to obtain a small sample of steel, approximately 15 x 10 cm, and have this blast cleaned at the start of a project. This panel can then act both as a reference panel for the surface profile agreed on and a calibration panel for calibrating DFT gauges.

The accuracy of mechanical gauges such as these is probably no better than plus or minus 10% in use. With extreme care (e.g., in laboratory conditions) the accuracy may be improved, but operation of the gauge is dependent on the repetition of the inspector's method of use. Measurements are likely to be affected by the speed of movement of the dial, the proximity of edges and curvature on the structure, and the orientation of the gauge.

The condition of the magnetic probe should be checked (visually) at frequent intervals, as the gauge tends to attract metal particles. Once attached to the probe, these particles significantly change the measurements. Calibration checks should also be made at intervals throughout the working day.

As with many other gauges, any *rogue* measurements should be checked. It is not unusual to find an occasional measurement quite different from those around the same location. If a measurement cannot be repeated, then it should be discarded as invalid and an alternative measurement made.

³ National Institute of Standards and Technology (NIST), 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070.

Pencil Pull-Off (SSPC-PA 2 Type 1B)

The pencil pull-off gauge, Type 1B is another type of magnetic pull-off gauge. The instrument is a hollow tube, similar in size to a large pencil, with an internal magnet and spring.

The extension spring is attached to the magnet and to the top of the instrument housing. The instrument is held perpendicular to the surface, and the magnet is placed in contact with the surface.

As the instrument is lifted, the magnet remains attracted to the surface until the spring tension overcomes the magnet's pull and lifts it from the surface. The tension on the spring necessary to lift the magnet is read from the scale, which may be marked in mils, μm , or both.

This type of instrument is less accurate and therefore less frequently used than other types of magnetic instruments. The inspector should check with the manufacturer or with his or her supervisor regarding the use and limitations of this instrument.

Constant-Pressure Probe DFT Gauge

Constant-pressure probe DFT gauges are nondestructive instruments that measure DFT of nonmagnetic coatings over ferrous metal substrates. They are categorized by SSPC-PA 2 as Type-II instruments. They determine coating thickness by measuring changes in the magnetic flux within the instrument probe or in the instrument circuitry. The instrument probe must remain in contact with the coating at all times during measurement.

Constant pressure probe instruments may have fixed integrated probes or separate probes. In each case the probes are placed against the coated surface and held against the surface while a measurement is taken. Probes may be magnetic or electromagnetic. Coating thickness is displayed on the meter or instrument scale.

Manufacturers of fixed-probe constant-pressure gauges recommend different methods of calibration or adjustment. Some provide built-in self-calibration routines or can revert to a factory standard calibration. Some modern gauges have many alternative methods for calibration, each of which is likely to lead to variation in results when measurements are made. All gauges should be calibrated according to the manufacturer's instructions and/or in accordance with an agreed procedure.



Figure 8 Constant-Pressure Probe Gauge Calibration with Plastic Shims

Calibration

Calibration Procedure Using NIST Standards

This procedure follows SSPC-PA 2 for Type-I gauges.

First, standardize (check calibration of) the gauge by measuring on NIST test standards within the coating DFT ranges to be measured in the field. If any deviation (+ or -) occurs, the gauge can be physically adjusted until it is accurate, or a *calibration factor* can be noted. This factor is then added to, or subtracted from, any DFT measurements made, as appropriate.

Second, measure the blast profile of the steel to be painted and record this data. This measurement

establishes an imaginary magnetic baseline in the blast profile. This imaginary line is called the *base metal reading (BMR)* and is to be deducted from any DFT reading taken on this surface later. The BMR should be a small factor, usually 8 to 20 μm (0.3 to 0.8 mil), but it could be outside this range.

When DFT measurements are made, there are two potential corrections. The first is the calibration factor, which may be added to or subtracted from the measurement. The second is the BMR, which is subtracted from the measurement.

Note: Experiments have shown that gauges calibrated on a smooth surface then used on a grit blasted surface with a 50- μm (2-mil) profile show an inaccuracy of around 25 μm (1 mil) on a coating thickness of 250 μm (10 mils).

NIST Calibration Standards

National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards, calibration standards are a certified set of four precision-chrome and nickel-plated-steel thickness panels mounted on a 15 x 10 cm (6 x 4 in.) card. They range in thickness from 0 to 2,032 cm (0 to 80 mils) with an accuracy of +/- 0.05%. The plated panels are each 28 x 28 mm (1.125 x 1.125 in.) in size; they are set on a metal plate to exceed the critical mass of steel needed to satisfy the magnetic field of Types IA and 1B (pull-off) magnetic gauges.

In accordance with SSPC-PA 2, measure a series of NIST calibration standards in the expected range of paint thickness. Record the calibration correction (+ or -) required at each standard thickness. Use the calibration correction when making actual measurements.

With use, the standards may wear, or become discolored and scratched. If their accuracy is in doubt, they can be returned to NIST for evaluation and to re-establish traceability to NIST standards.



Similar standards are manufactured by other companies or groups. Suitable guarantees of accuracy and/or traceability should be provided by the manufacturer.

Calibration Using Nonmagnetic Shims

Constant-pressure probe (SSPC-PA 2 Type II) gauges are generally calibrated using plastic shims whose thickness has been verified with a micrometer. Calibration should be made in an area free of magnetic fields (i.e., away from welding equipment, generators, or power lines).

Select shims in the range of expected coating thickness. For example, if the coating DFT is expected to be about 200 μm (8.0 mils), calibrate the unit using a shim as close to 200 μm (8.0 mils) as possible.

Some electronic gauges require calibration over a range, using either bare steel or a very thin shim at one end of the range and a shim of greater thickness than the coating to be measured at the other end of the range. The accuracy of the gauge after calibration should always be verified close to the thickness to be measured.

Place shims on a bare section of the structure to be painted after the specified surface preparation has been completed. Alternatively, place the shims on a bare steel plate at least 7.6 x 7.6 x 0.32 cm (3 x 3 x 0.125 in.), free of mill scale and rust. Note that if the calibration surface does not have a profile and the coated surface does, an adjustment should be made to allow for the profile. This typically takes the form of 12 to 20 μm (0.5 to 0.8 mils) that must be subtracted from the measurements made.

A procedure sometimes used involves obtaining a small sample of steel approximately 15 x 10 cm (6 x 4 in.) and having this blast cleaned at the start of a project. This panel can then act as a *reference* panel for the surface profile agreed on and as a calibration panel to check DFT gauge measurements. The panel should be of similar material (i.e., steel alloy) and similar thickness to that of the structure being coated.



Avoid excessive pressure that could bend the shim and indent it or impress the peaks of the blasted surface into the contact surface of the shim.

Plastic shims used for calibration are not made from precision material, and their thickness should be verified with a micrometer.

As with any other DFT gauge, recalibration may be required whenever results appear to be inconsistent or erratic. Battery-powered units may give erratic results as the battery weakens with use.

Fixed-probe gauges are generally more accurate than mechanical gauges, with accuracy around $\pm 3\%$ or better. They need a source of electrical power (battery) and are not, therefore, intrinsically safe.

In the United States, smooth calibration shims produced by NIST are commonly used. If gauges are calibrated on a smooth surface, and then used to measure coating thickness over a rough, blast cleaned surface, an adjustment must be made to ensure accuracy.

Experiments have shown that gauges calibrated on a smooth surface, then used on a grit-blasted surface with a 50- μm (2-mil) profile measure more than the true DFT by about 25 μm (1 mil) on a coating thickness of 250 μm (10 mils). In this case, subtract 25 μm (1 mil) from every measurement made to obtain the true DFT measurement.

Edge Effect

It is generally not good practice to measure DFT closer than 25 mm (1 in.) from an edge, hole, or inside corner. The probe must not overlap the edge of the sample being measured unless recalibration procedures are undertaken.

MIO Pigmented Paints

Because micaceous-iron-oxide- (MIO-) pigmented coatings are sometimes capable of inducing a magnetic error, DFTs cannot be reliably measured on some coatings. It is, therefore, important to check the WFT frequently during application. While this effect may not be common, it can create real measurement problems when it does occur.

Pinhole and Holiday Detection

Holiday detectors are used to detect holidays or pinholes in the coating. General types of holiday detectors include:

- Low-voltage DC
- High-voltage DC
- High-voltage AC

(Also Reference NACE Standard SP0188.)

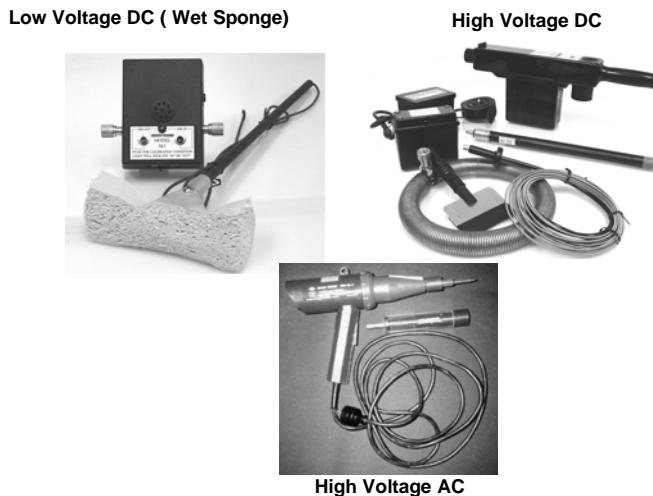


Figure 9 Holiday Detectors

Holiday testing is performed to find nicks, pinholes, and other defects or discontinuities in the film. Correction of coating defects is especially important for structures like

tanks that are intended for immersion service, and for buried pipelines.

The specifications should indicate the point in the job when holiday testing is done. The coating should be reasonably well cured (but not fully cured, for ease of repair) before testing is done.

Coatings that are not cured may show false holidays. For example, solvent remaining in the coating may create weak spots (of low electrical resistance) that a high-voltage detector may disrupt, creating a holiday 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. The coating should then be tested again, after the repair, to ensure that repairs were successful.

Low-Voltage (Wet-Sponge) Holiday Detector

This holiday detector is a sensitive, low-voltage (wet-sponge) electronic device powered by a battery with output voltages ranging from 5 to 120 V DC, depending upon the equipment manufacturer's circuit design.

The detector consists of:

- portable battery-powered electronic instrument
- nonconductive handle with clamps (to hold sponge)
- open-cell sponge (cellulose)
- ground wire.

The instrument is generally housed in a plastic case with an OFF/ON switch and a socket for headphones. Some low-voltage holiday detectors are fixed at a specific

voltage, while other may have a test voltage selected. Some common voltages used are 9, 67.5, 90, and 120 V. Different results are obtained with each voltage, so selecting the proper voltage is important. Ideally the instrument to be used and its voltage should be specified.

This type of instrument may be used to locate holidays in nonconductive coatings applied to a conductive substrate. According to NACE Standard SP0188, the low-voltage DC detector is generally used on coating films that are less than 500 μm (20 mils) thick. The instrument will still locate defects in coatings thicker than 500 μm (20 mils) and is preferred by some users because it cannot easily damage the coating film tested.

The ground cable is attached directly to the conductive substrate for positive electrical contact. For coated steel, connect directly to the bare metal, and for concrete, connect directly to the reinforcing steel (rebar) in the concrete (where possible). If no rebar 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. Wetting the concrete in the immediate areas also helps to establish continuity.

The sponge is saturated with a solution consisting of tap water (not distilled water) and a low sudsing wetting agent (such as that used in photographic film development), combined at a ratio of 1 oz fluid wetting agent to 1 U.S. gal water (7.5 mL per liter). This represents a ratio of 1 part wetting agent to 128 parts water. The sponge is wetted sufficiently to barely avoid dripping of the solution while it is moved over the coating.

Contact a bare spot on the conductive substrate with the wetted sponge to verify that the instrument is properly grounded. This procedure should be repeated periodically during the test.



With the ground wire attached to the substrate, wipe the coated surface with the wetted sponge at a maximum rate of 30 cm/s (1 linear ft/s). Avoid using excess water in the sponge because the rundown may 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 unit will emit an audible tone.

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 removal of the wetting agent before making coating repairs.

The detector is factory-calibrated and calibration in the field is not generally necessary. Typical factory calibration is set at 700 microamperes ($\pm 10\%$) of current flow to complete the circuit for the audible signal to indicate a coating holiday on metal substrates. For coatings on concrete substrates, the detector must be adjusted for current flow of 500 microamperes ($\pm 10\%$). This is generally achieved by removing a resistor from the electronic circuitry.

One typical instrument is equipped with a red and a black button on the face of the unit. To check for calibration, depress the black button (80 K). The detector should signal and LED will light if the detector is in calibration. Depress the red button (90 K), and the detector should not signal and LED not light if the detector is within calibration.

To check for calibration on concrete substrates, verify the unit is properly calibrated (80,000 ohms) and then remove the small jumper wire inside the red cover side of the detector. The detector should then signal when the black button is pressed.

Wet-sponge holiday detectors are portable and easy to operate. They can be used on coatings up to 500 μm (20



mils) thick with reliability. They are nondestructive and do not harm the coating as the test is made. The test procedure can be slow in operation, taking many hours to fully test coatings in a large vessel. The units are generally not intrinsically safe and cannot therefore be used in a hazardous environment.

Coating to be tested should be thoroughly dry and sufficiently cured for the operator to walk on the coating if necessary without damaging the coating. Ideally, the coating operation will be completed (i.e., the topcoats applied) before holiday testing to minimize intrusion by the quality-control inspector. The coating should not, however, be fully cured—if possible—since repairs will be necessary wherever holidays are found.

Note: Some users in certain industries, such as some 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 250 μm (10 mils) thick. By this action, the user has chosen to modify the standard method (e.g., NACE Standard SP0188) to suit individual needs.

High-Voltage Pulse-Type DC Holiday Detector

High-voltage pulse-type holiday detectors generally have a voltage output range from about 900 to 15,000 V and in some cases may range as high as 40,000 V. They are designed for locating holidays in nonconductive coatings applied over a conductive substrate. Generally, these devices are used on protective coating films ranging in thickness from 300 to 4,000 μm (12 to 160 mils).

The detector consists of a source of electrical energy, such as a battery, or high-voltage coil; an exploring electrode; and a ground connection from the detector to the coated substrate.



The electrode is passed over the surface. A spark will arc through the air gap or coating to the substrate at any holidays, voids, or discontinuities, simultaneously causing 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, the high-voltage holiday detector may be used with a trailing ground wire, provided the structure to be tested is also connected to the ground. This connection may be achieved with direct contact (as when a pipe lies on wet soil) or by fixing a ground 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.⁴

Set the voltage as specified or as shown in a referenced standard. If no guidelines are provided, a rule of thumb in industry in the United States is to use a voltage setting of:

2,500 V/ μ m (100 V/mil) of coating thickness.

In Europe, the rule of thumb most often used is slightly different:

5 V/ μ m (0.2 V/mil) of coating thickness.

An alternate method is to make a pinhole (or identify another type of defect, e.g., low DFT) in the coating to the substrate, and 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 particular coating.

⁴ Note: Bag should cover at least 0.2 m² (2 ft²) and effectively act as a capacitor to provide continuity.

Inspectors should obtain written authority:

- to make a pinhole in the coating, since that is a **destructive** test
- to use this procedure for setting voltage unless already specified.

It should be noted that when the voltage is set too high, the coating may be damaged. The same damage might be incurred if the coating is tested before it has released all or most of its solvent content. Once a spark has been generated through the coating to the substrate, a specific holiday exists through the coating, even if it had not been a pinhole or break in the coating before the test was performed.

When using the instrument, move the electrode at a rate of about 0.3 m/s (1 ft/s) in a single pass (according to NACE Standard SP0188). Moving the probe too fast may miss a void; moving too slowly may create damage at thin spots or prove to be more searching than was intended by the specifier.

The accuracy of the instrument can be tested using a dedicated voltmeter connected between the probe and the ground connector. The instrument must be specific to the type of holiday detector, since the pulse characteristics of the signal have to be taken into account. For most users it may be best to send the unit back to the manufacturer for calibration.

Most high-voltage holiday detectors have a wide range of electrodes available for different uses:

- 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.

The high-voltage holiday detector generates significant electrical energy. While this is not sufficient to kill the operator, even at maximum output, it certainly acts as a shock to the system and may lead to a consequent mishap such as falling from a scaffold. The operator should wear protective equipment, such as rubber boots, and should not operate the equipment in wet or damp conditions. The unit will give false indications of holidays if used on a wet surface.

The unit is not intrinsically safe and may lead to explosion if used in an explosive atmosphere.

Most holiday detectors provide a constant (low-level) signal, indicating to the operator that the unit is switched on and working. If the unit doesn't come on or the operating signal does not sound, the battery may be dead or weak. The operator should replace or recharge the battery.

If the unit does not spark or emit a sound when you touch the electrode to ground, the unit may need repair.

The high-voltage holiday detector is more searching than the low-voltage type. It will not only detect any holidays or pinholes that penetrate to the substrate but can also find defects such as areas of low film thickness, or voids hidden within the coating.

High-Voltage AC Holiday Detector

The AC-type holiday tester is used for testing nonconductive linings on steel substrates, for example, rubber, glass, or sheet linings. An AC tester has a variety of voltages but typically is used for very thick coatings, with test voltages in the range of 25,000 to 60,000 V.

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. When it passes over a break in the lining or a foreign object included in the lining but in contact with the substrate, a spark will jump to the surface at the imperfection. Surface contaminants and dampness may also cause a spark, so the area should be cleaned and retested to verify a pinhole or holiday.

AC holiday detectors (as opposed to pulsed-DC holiday detectors) are generally less frequently encountered.

Incorrectly used, AC holiday detectors may present a much higher possibility of severe shock than DC high-voltage holiday detectors; thus, great care in operation is necessary.

Standards commonly used to define holiday testing include:

- NACE Standard SP0188 (latest revision), *Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates*
- ASTM G 62 (latest revision), *Standard Test Methods for Holiday Detection in Pipeline Coatings*
- NACE Standard RP0490 (latest revision), *Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 250 to 760 μm (10 to 30 mils)*
- NACE Standard RP0274 (latest revision), *High-Voltage Electrical Inspection of Pipeline 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-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 m² (100 ft²) 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 m² (100 ft²) of area as follows:

4.1.1 For structures not exceeding 30 m² (300 ft²) in area, each 10 m² (100 ft²) area shall be measured.

4.1.2 For structures not exceeding 100 m² (1,000 ft²) in area, three 10 m² (100 ft²) areas shall be arbitrarily selected by the inspector and measured.

4.1.3 For structures exceeding 100 m² (1,000 ft²) in area, the first 100 m² (1,000 ft²) shall be measured as stated in Section 4.1.2 and for each additional 100 m² (1,000 ft²) of area or increment thereof, one 10 m² (100 ft²) area shall be arbitrarily selected by the inspector and measured.

4.1.4 If the dry film thickness for any 10 m² (100 ft²) 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 m² (100 ft²) 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 m² (100 ft²) area shall not be less than the specified minimum thickness. Although *no single spot measurement* in any 10 m² (100 ft²) 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 m² (100 ft²) 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 m² (100 ft²) area shall not be more than the specified maximum thickness. Although *no single spot measurement* in any 10 m² (100 ft²) 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 m² (100 ft²) 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 $\pm 5\%$ (see Note 7.18). For thicknesses less than 25 μm (1 mil), the gage must have an accuracy at least within $\pm 2.5 \mu\text{m}$ (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 m² (100 ft²) 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 m² (300 ft²) in area. Mentally divide the surface into three equal parts, each being about 10 m² (100 ft²).

Part A - 10 m² (100 ft²)

Part B - 10 m² (100 ft²)

Part C - 10 m² (100 ft²)

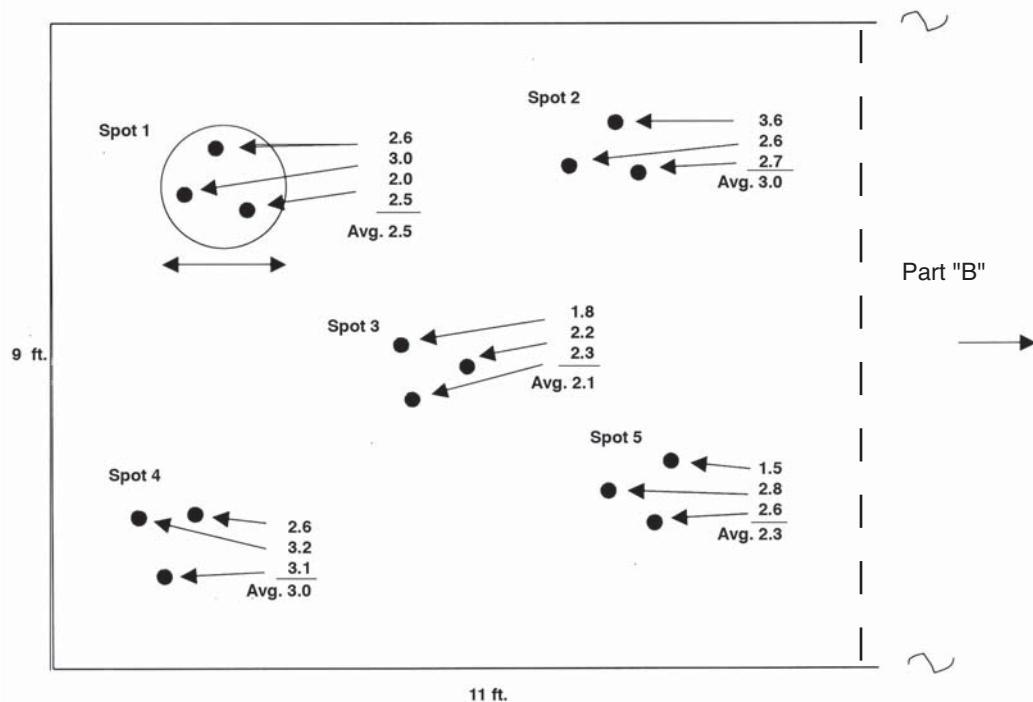
First, measure the coating thickness on Part A. This involves at least 15 readings of the thickness gage (see Figure A1).

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 ($0.80 \times 2.5 = 2.0$). 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 m² [100 ft²])
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 ($0.80 \times 64 = 51$). 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 $\pm 2\%$. The thickness of a shim might be accurate to within $\pm 3\%$. The combined tolerance of the gage and the shim will be $\pm 4\%$ 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 $\pm 4\%$ 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 $\pm 4\%$ 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 $25 \mu\text{m}$ (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 $10 \mu\text{m}$ (0.4 mil) but for coarse profiles it could be as high as $40 \mu\text{m}$ (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

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.

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

Figure A.3
The Surfaces of a Steel Beam

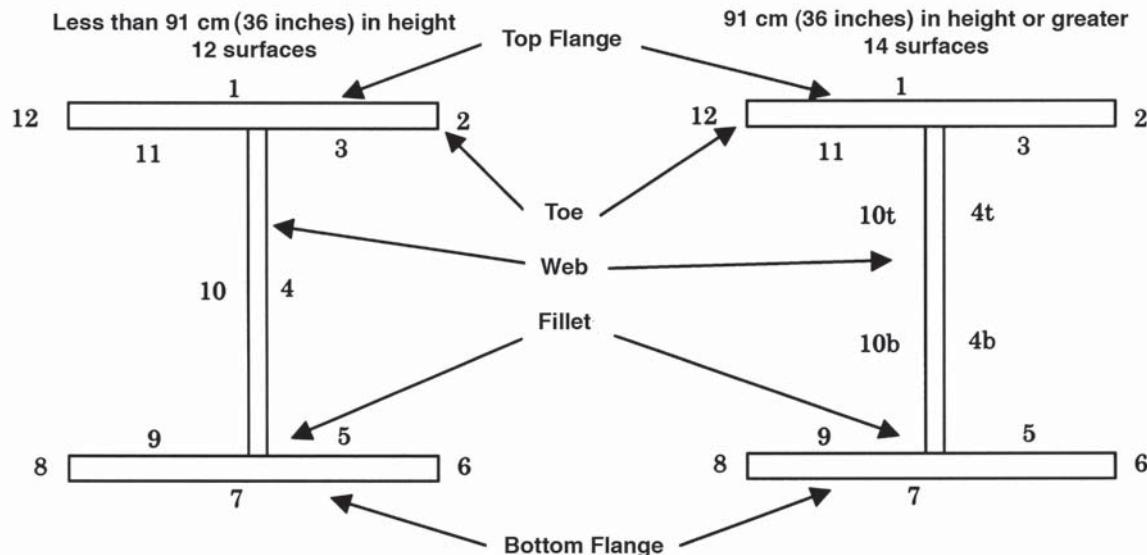


Table A3
**Datasheet for Recording Spot Measurements and Average DFT Values
for the 12 Surfaces of a Beam or Girder**

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 m² (100 ft²), take 5 spot measurements randomly distributed over the part for each 10 m² (100 ft²) 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

Length of Beam	Number of Spot Measurements per Surface	
	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 cm² (18 in²) and a maximum area of 930 cm² (144 in²); 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 cm² (18 in²) and a maximum area of 930 cm² (144 in²); 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.



Level 1

Chapter 3.5

Instrument Practice

Lab

Instrument Practice Lab

In this session, we'll build on the previous lecture by demonstrating some of the instruments that have been described in the chapters covered on Days 1, 2, and 3. Then we'll let you have some hands-on experience with those instruments in a format similar to the practical examination to be taken on the last day of this course.

During a short break, the instructors will set out the appropriate equipment in eight stations located around the room. This mirrors the format of the practical examination. The instructor(s) will then demonstrate the use of the instruments and equipment provided at each location.

Before taking a break, please take this chapter from your manuals—you will need it to perform the practice task—then clear the table of all your books, manuals, and personal possessions, leaving a clear space.

Take a break of 10 minutes at this time.

During the practical examination, each candidate will spend eight minutes at each test location. In this session, working in small groups of two or three, each group will spend 12 minutes at each location. When the time comes, please do not move to the next station until given the instruction by an instructor.

Let's now look at the task for each of these workstations.

Station 1: Environmental Test Equipment—Sling psychrometer, surface thermometer, magnetic coated steel test panel, ambient condition charts

Station 2: Anchor Pattern—Comparators and Replica Tape—Testex® (replica) tape, coarse and X-coarse, one roll each with minimum 30 tapes on each roll; anvil (spring) micrometer; surface profile gauge; two types of ISO comparators; one blast cleaned stainless steel panel, with a different anchor profile on each side

Station 3: High-Voltage DC Holiday Detector—High-voltage DC holiday detector

Station 4: Coating Thickness—Magnetic Pull-Off Gauge—

Magnetic DFT (pull-off) gauge, test panel (designation P3), plastic calibration shims, NIST calibration standard (range 0 to 1,000 μm [0 to 40 mils]), anvil micrometer

Station 5: Wet-Sponge Low-Voltage Holiday Detector—

Wet-sponge detector, surfactant, water, coated panel approximately 30 x 30 cm with pinholes

Station 6: Coating Thickness—Electromagnetic Gauge—

DFT gauge, test panel (designation P4), NIST calibration standards (range 0 to 1,000 μm [0 to 40 mils]), plastic shims, anvil micrometer

Station 7: Surface Cleanliness—SSPC-Vis 1, SSPC-Vis 3, ISO 8501-1, Book of Pictures**Station 8: Wet-Film Thickness Gauge—**Three WFT gauges with dried paint on some teeth, numbered 1, 2, and 3.

We'll only work on seven stations today as one of the stations was completed during the Environmental Instruments Practice Lab.

Now that we've been through each of the instrument work stations, let's put you together in small groups. As you progress through each station, discuss the results and working method and complete the answer portions of the practice piece worksheet on the following pages. You have 12 minutes at each station. The instructors will keep the time and tell you when to change to the next station. From station 2 go to station 3, from 3 to 4 and so on, those at station 8 moving to station 2 each time. Let's begin.

CIP Level 1—Instrument Practice Worksheet

Name: _____ Date: _____

Station 2: Anchor Pattern Comparators and Replica Tape

Equipment:

- Testex® (replica) tape—coarse and X-coarse
- Anvil (spring) micrometer
- Surface profile gauge
- ISO comparators
- One (1) blast cleaned panel with a different anchor profile on each side, Panel E2

Note: The abrasive used on both sides of the panel is steel grit (different sizes).

Assignment: Measure the anchor profile on each panel using each of the three listed instruments and record your measurements in the correct blank spaces.

	Testex® Tape		Surface Profile Gauge		ISO Comparator		These columns for administrative use only	
	Student	Instructor	Student	Instructor	Student	Instructor		
Panel Side 1	Tape Type: _____		Measurement: _____		Comparator: _____		Available Points	Score
	Measurement: _____				Measurement: _____			
Panel Side 2	Tape Type: _____		Measurement: _____		Comparator: _____			
	Measurement: _____				Measurement: _____			
Total Score								



	Testex® Tape Student	Surface Profile Gauge Student	ISO Comparator Student
Panel Side 1	Tape Type: _____	Measurement: _____	Comparator: _____
	Measurement: _____		Measurement: _____
Panel Side 2	Tape Type: _____	Measurement: _____	Comparator: _____
	Measurement: _____		Measurement: _____

Fix Testex® tapes below

Comments or additional information (if any)?

Station 3: High-Voltage DC Holiday Detector

Equipment: High-voltage DC holiday detector

Assignment: Assuming you are to use the equipment provided at this test station, answer the following questions:

Question	Answer
1. You are to inspect a polyester lining in a steel tank spray applied to a DFT of 750 μm (30 mils). You have no standard available nor does the specification spell out what voltage to use. Based on the rule of thumb formula defined in the CIP course, what maximum voltage could you safely use on this coating?	
2. How would you adjust the holiday detector provided to the voltage selected in question 1?	
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)	

Comments or additional information, if any?

Station 4: Coating Thickness—Magnetic Pull-Off Gauge (Type I)

Equipment:

Magnetic DFT (pull-off) gauge
 Test panel (designation P3)
 Plastic calibration shims
 NIST calibration standard (range 0 to 1,000 μm [0 to 40 mils])
 Anvil micrometer

Assignment: Using the method defined by SSPC-PA 2, check your gauge to determine the DFT of the two coated areas of the panel in μm or mils and provide the four answers required.

	MICRONS	MILS
BMR		
Primer DFT		
Final (total) DFT		
Calibration standard used? Check only one.	NIST	Plastic Shims

Work areas for measurements and calculations are provided below. Adjusted readings must be marked in the table above.

SSPC-PA 2 Worksheets

1. Location: Primer Coat

μm / mils?

Spots->	1	2	3	4	5	Overall Average DFT at this Location	Adjustments	
1							BMR	Deviation
2								
3						Before Adjustments	After Adjustments	
Avg.								

2. Location: Primer Coat + Finish Coat

μm / mils?

Spots->	1	2	3	4	5	Overall Average DFT at this Location	Adjustments	
1							BMR	Deviation
2								
3						Before Adjustments	After Adjustments	
Avg.								

Spots->	1	2	3	4	5
BMR					
Average Value =					



Station 5: Wet-Sponge Low-Voltage Holiday Detector

Equipment:

- Wet-sponge detector
- 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?	

Creating a sketch in the box above, show the location of holidays found.

Comments or additional information (if any)?

Station 6: Coating Thickness—Electromagnetic Gauge

Equipment:

- Type-II DFT gauge
- Test panel (designation P4)
- NIST calibration standards (range 0 to 1,000 μm , [0 to 40 mils])
- Plastic shims
- Anvil micrometer

Assignment: Using the method defined by SSPC-PA 2, check your gauge to determine the DFT of the two coated areas of the panel in μm or mils and provide the four answers required.

	MICRONS	MILS
BMR		
Primer DFT		
Final (total) DFT		
Calibration standard used? Check only one.	NIST	Plastic Shims

Work areas for measurements and calculations are provided below. Adjusted readings must be marked in the table above.

SSPC-PA 2 Worksheets

1. Location: Primer Coat

μm / mils?

Spots->	1	2	3	4	5	Overall Average DFT at this Location	Adjustments	
1							BMR	Deviation
2								
3							Before Adjustments	After Adjustments
Avg.								

2. Location: Primer Coat + Finish Coat

μm / mils?

Spots->	1	2	3	4	5	Overall Average DFT at this Location	Adjustments	
1							BMR	Deviation
2								
3							Before Adjustments	After Adjustments
Avg.								

Spots->	1	2	3	4	5
BMR					
Average Value =					



Station 7: Surface Cleanliness

Equipment:

- SSPC-Vis 1
- SSPC-Vis 3
- ISO 8501-1
- Book of Pictures

Assignment: Using the supplied surface cleanliness standards, identify the appropriate picture that correctly illustrates the answers to the following questions. Write the answer in the space provided:

Question	Answer
1. For any 6,400 mm ² (9 in. ²) area of a blasted surface, NACE No. 3/SSPC-SP 6 Joint Standard for abrasive blast cleaning allows staining up to _____%?	
2. Select the picture that most closely identifies Rust grade D blast cleaned to NACE No. 2/SSPC-SP 10.	
3. NACE No. 1/SSPC-SP 5 Joint Standard requires the removal of _____% of the paint and mill scale from the surface?	
4. Select the picture that most closely identifies Steel Condition C power tool cleaned to SSPC-SP 11.	
5. Select the picture that most closely identifies Steel Condition D blast cleaned to ISO Sa 3.	

Complete the following table of equivalent standards by entering the appropriate designations in the blank spaces:

General Equivalent Standards	ISO 8501-1	SSPC-Vis 1/Vis 3	NACE
White Metal			No. 1
Near-White			No. 2
Commercial	Sa 2		
Brush-Off		SP 7	
Power Tool	St-2		

Station 8: Wet-Film Thickness Gauge

Equipment:

- 3 WFT gauges with dried paint on some teeth, numbered 1, 2, and 3

Assignment: Answer question 1 and either question 2A or 2B

1. Inspect the 3 WFT gauges provided. They have been used to measure WFT. What was the WFT that was measured? If the paint volume solids are as shown in the table below, what would the corresponding DFT be?

Gauge #	WFT?	Volume Solids (%)	DFT?
1		50%	
2		70%	
3		88%	

2. Answer only **one** of the following questions. Use either Metric or Imperial units.

Question A (Metric)	Answer
<p>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 a 20% loss. How many liters should they order?</p>	Liters

Question B (Imperial)	Answer
<p>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 a 20% loss. How many U.S. gallons should they order?</p>	Gallons

Space below may be used for calculations



Level 1

Chapter 4.1

Field Practice Lab

Field Practice Lab

Today we are going to the field lab where you will work with the practice panel issued to you. Before we go to the lab, we will spend some time here in the classroom where we will:

- Explore safety precautions and procedures to follow at the lab
- Conduct a pre-job conference
- Discuss the work sequence we will follow at the field lab site

In the lab facility, you will be required to put to use the knowledge you have gained in class this week and you will be required to operate equipment that has the potential to cause serious injury, so this brief safety orientation is vital.

Lab Safety Orientation

Basic safety items such as long-sleeve shirts, safety glasses, and hard hats (if required by facility) are required when you are at the practice lab facility. If you have long hair, you will need to keep it under your hat at all times.

Several of the work stations have inherent hazards that need to be considered separately. These are:

- **Decontamination Station**—Wear rubber gloves while cleaning and washing your work piece with the biodegradable detergent. When using the UV light, do not look directly at the light source.
- **Power Tool Station**—You will be working with rotating equipment in close quarters. (Remember, the disk on that grinder will cut deep before it stops.) Be aware that you will be throwing sparks in the direction of rotation. Wear leather gloves, long-sleeve shirts, and earplugs at this work site during the entire operation. If electric-powered grinders are used, watch out for water on the floor and do not use a grinder if the cord is lying in standing water. Also, watch all the air hoses and electrical cords—they are tripping hazards.
- **Abrasive Blast Station**—Do not point the blast nozzle at anyone *at any time*. (This includes yourself.) Keep the hose straight and use the blast hood while blasting your work piece. Wear gloves, ear plugs, and a long-sleeve shirt at all times while you are blasting. Secure your work piece while blasting and be aware that, when energized, the nozzle will be hard to hold

as it is operating at high pressure (as high as 550 to 760 kPa (80 to 110 psi, 6 to 7 bar).

- **Conventional Spray Station**—Wear the respirator while mixing and spraying at this station. Do not mix coatings without wearing gloves for skin protection. Watch out for the hoses while walking in the area.
- **Airless Spray Station**—Never point an airless gun at yourself or others. Keep the trigger locked at all times when you are not spraying. If the tip becomes clogged, do not try to clean it, other than by reversing the tip. **Do not** try to remove the tip without depressurizing the unit and hose. This will be done by **instructors only**, regardless of your skill level with this unit. Wear your respirator and gloves while mixing or spraying. Do not wash paint from your skin with solvent. Use the hand cleanser provided.

Do not wander from your group or the station to which you have been assigned. If you must leave the station, first check with the instructor or lab assistant. These are working facilities and there may be safety hazards in areas other than those immediately around you. It is important that your instructors know where you are at all times.

Your safety is very important, and if you follow these guidelines the lab will be safe and informative. If you have any questions during the day, please ask the instructors for clarification.

In addition to these rules, a representative of the facility will provide a site safety briefing, specific to the site, after the group arrives and before any work is performed. Typical issues addressed will be:

- Emergency warnings and escape routes
- Gathering points in event of evacuation of the facility
- Rules on hardhats, safety glasses, moving around the area
- Smoking areas, if any

Pre-Job Conference

The purpose of this brief meeting today is to go over the specifications for your practice panel to clarify any part of the specification you may have doubts about. As we go through the specifications, make notations in your logbook on those items discussed.

Coating Schedule

The front face of the practice panel, which contains the angle iron, shall be cleaned and coated in accordance with the attached specifications governing this project. The edges and rear faces of the panel shall not be coated.

Pre-Inspection

The area to be coated shall be inspected for any fabrication defects and for the presence of oil, grease, and other foreign matter. The ultraviolet light shall be used to determine the presence of oil or grease. The results of the inspection shall be recorded on the specified report form.

Pre-Cleaning

All oil and grease shall be removed by solvent cleaning in accordance with the SSPC-SP 1, "Solvent Cleaning," using the specified biodegradable detergent. The panel shall be inspected again for any traces of oil or grease.

After all signs of oil and grease have been removed, the panel shall all be cleaned by hand and power tools in accordance with SSPC-SP 2 and SSPC-SP 3. Sufficient weld spatter shall be left on the panel so that it may be observed that blast cleaning does not effectively remove such fabrication defects.

Cleaning

The area to be coated shall be blast cleaned to white metal in accordance with Joint Surface Preparation Standard NACE No. 1/SSPC-SP 5 to achieve the specified surface profile.

Application

A full coat of primer shall be applied by conventional air spray. A stripe coat of the specified second coat shall be applied by brush to all welds and the edges of the angle iron.

Materials

The coating materials shall be as specified or as modified by a specific waiver. In the event of a waiver being given, the coatings shall be as follows:

The primer shall be _____

manufactured by _____.

The topcoat shall be _____

manufactured by _____.

Inspection and Documentation

Each inspection test instrument will be used and each specified test procedure will be conducted by each individual student, except the following:

- Blotter test
- Hypodermic-needle pressure gauge

Specific instructions for conducting these tests will be provided by the facility.

Lab Site Work Sequence and Procedures

All students will be required to wear long-sleeve shirts while working at the power tool station and the abrasive blast station and to safely secure any ponytails or long hair. Any student who is unable or unwilling to comply with these requirements will not be allowed to complete his or her practice panel.

Students will be required to comply with all on-site safety requirements and to work safely at all times.

At the lab site, all students will work with their respective teams, and the teams will be conducted from one work station to the next by an instructor.

Lab Site Work Sequence

Work Station 1: Solvent Cleaning

Students will wear rubber gloves when cleaning their panels.

Work Station 2: Hand and Power Tool Cleaning

Students must use each hand tool and each power-assisted hand tool at this station.

- DO NOT remove ALL of the weld spatter, but leave enough on the panel to demonstrate that abrasive blasting does not remove all the weld spatter.
- DO NOT polish the metal.
- DO NOT grind the outer edge of the panel.
- DO cooperate with your team members and rotate the equipment so that each member will have access to each tool and will have sufficient time to use it.

After cleaning the panel, inspect and record your findings.

Work Station 3: Air Abrasive Blast Station

As a team, use the blotter test to look for oil or water in the air stream at the nozzle discharge. Use the hypodermic-needle pressure gauge to check the air pressure at the nozzle discharge. Record your findings. Record ambient conditions and determine the dew point and relative humidity.

Prepare the surface by abrasive blasting and perform the following tests:

- Check for traces of abrasive dust residue using transparent tape; add tape to the report form.
- Use the Type-I DFT gauge to determine the BMR (Base Metal Reading) of the blast cleaned surface. Record the serial number of the gauge so you can use the same gauge again for other DFT readings.
- Use the surface profile comparators to estimate the profile depth, then use Testex® tape to measure the actual surface profile. Record all results.

Work Station 4: Paint Station

As a class (all groups), you will observe the mixing of the primer and, if possible, epoxy topcoat. Record ambient conditions and determine dew point and relative humidity.

Apply one coat of inorganic zinc to the panel by conventional spray. Measure the DFT of the zinc with the same gauge used to measure the BMR at the blast station. Verify the gauge accuracy with the NIST calibration standards and record the deviation, if any. For comparison only, measure the DFT using the Type-II electromagnetic gauge.

Brush-apply a light stripe coat of the topcoat (unthinned) to the welds and edges of the angle iron. Do not stripe coat the holes or the outer edges of the panel

As directed, apply one coat of epoxy by airless spray; check the WFT with the WFT gauge and record all results. Set the panel aside to cure.





Level 1

Chapter 4.2

Case Study 1-B

Case Study 1-B—DFT Measurements

John Simmons had begun to develop a reputation at Razorback Industries as a knowledgeable and capable coating inspector. So when a plant addition was built, he was the natural choice to inspect the coating operation.

Extensive blast cleaning and coating operations were taking place on a critical area of the plant addition, and it was highly important that this area be coated as quickly as possible within the specification and that there be no delays or repairs, as progress on many other tasks was being held up until this area was complete.

The specification for these coating operations called for a primer with a DFT of $65 \mu\text{m} \pm 12 \mu\text{m}$ (2.5 mils ± 0.5 mil), plus two applications of the topcoat to give a total of $300 \mu\text{m} \pm 25 \mu\text{m}$ (12 mils ± 1 mil).

The blasting and priming operations began the day after John arrived. Two days later the steelwork had been blast cleaned and primed to his satisfaction.

As John was taking DFT measurements of the primer, he ran into the coating contractor, Al Black, who mentioned that he had checked the DFT of the dry primer and found that it measured $50 \mu\text{m}$ (2 mils).

“Hope you’re not going to try to squeeze another coat of primer out of me, Simmons,” Al growled. “I’ve checked this job from one end to the other, and it’s 2 mils, just like the spec says. You don’t have to waste your time looking, ‘cause you’re not going to find any place thinner.”

“Well, I think I’d like to check this anyway. After all, that’s what Razorback is paying me for,” John replied.

“Suit yourself,” Al said over his shoulder as he walked off. “But make it quick ‘cause I got men hanging around waiting for your OK to start topcoating.”



As John checked the primer DFT, he found it to be just under 75 μm (3 mils) at almost every point, never over 75 μm (3 mils), hardly ever as low as 67 μm (2.5 mils), and nowhere at 50 μm (2 mils).

The next day, the next coat was applied over the primer. The day after, this coat had dried. On inspecting the coated area, John observed a very uniform thickness averaging 225 μm (9 mils).

Later, while talking to Al Black, John found out Al had measured the DFT of the two dry coats and come up with thicknesses averaging 150 μm (6 mils).

Al was obviously worried about having to apply an extra topcoat to meet the specification.

John and Al were both using dial-type magnetic pull-off gauges to measure the DFT. John was sure his was accurate, as it was brand new and he frequently checked and adjusted the calibration on a freshly blasted surface of the steel being coated. He also had a single-probe electronic DFT instrument, carefully calibrated, with which he got exactly the same measurements as with his dial-type pull-off gauge.

Al's gauge, while the same make and model, appeared to be old, and looked like it had seen a lot of rough handling.

John had not mentioned anything about his readings to Al, and it occurred to him that if he didn't, Razorback would get a slightly thicker coating than the specification called for, but at no extra cost to his company since Al was working on a fixed tender contract.

What, if anything, should John say to Al Black about his DFT measurements?

Discussion Question

What, if anything, should John say to Al Black about his DFT measurements?

Read the case study, discuss the situation with your team for no more than 35 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:



Level 1

Chapter 4.3

Self-Study Questions

Chapter 3.2—Coating Application by Conventional Spray

1. Conventional airspray and airless spray equipment is sometimes modified for special-use situations such as:
 - a. _____ component spray
 - b. _____ spray
 - c. _____ spray
 - d. _____ spray
2. True or False One advantage of conventional airspray is that the spray pattern is easily adjusted.
3. True or False Loss by overspray is NOT a problem with conventional airspray.
4. Some advantages of airless spray include:
 - a. _____ is possible
 - b. _____ rate is _____
5. True or False In airless spraying, a pressure pot is not required.
6. True or False With airless spray, the fan width of each spray is fixed.
7. Surfaces hard to reach by spray application should be _____ or _____
8. In spray application, safety issues include _____ and _____ equipment.
9. There are four primary types of respirators available to protect the painter:
 - a. _____ fed _____
 - b. _____ respirators
 - c. _____ respirators
 - d. _____ respirators

10. True or False Organic-vapor respirators can be used in areas deficient in oxygen.
11. True or False Air-supplied respirators are designed to cover the nose and mouth only.
12. Hood respirators can protect the wearer from heavy concentrations of _____ and _____.
13. True or False Dust masks are not designed to remove vapors from the air.
14. True or False The air hose (for conventional spray guns) is usually red.
15. True or False A double-regulator tank should be used for industrial (conventional spray) application.
16. True or False The internal-mix (conventional spray) gun is used when a fine finish is not required.
17. True or False The external-mix (conventional spray) gun produces fine atomization.
18. True or False A mist-coat application can be used on inorganic zinc to displace air before overcoating.
19. True or False Stripe coating is an effective way to build extra thickness on welds and edges and in sharp corners.
20. True or False A WFT gauge can become a destructive test instrument.

Chapter 3.3—Airless Spray

1. True or False In an airless spray system, the coating material is under pressure in the material container.
2. True or False One advantage of airless spray is better penetration of coating into pits and crevices.
3. True or False Airless spray pumps can be powered only with compressed air.
4. True or False An airless unit in operation develops static electricity and should be grounded.
5. True or False The longer the spray hose and smaller its internal ID, the lower the paint pressure at the spray gun.
6. True or False In the United States, OSHA requires a safety tip at the end of the gun.





Level 1

Chapter 5.1

Surface Preparation Standards

Surface Preparation Standards

The information presented in this section is an overview of commonly used surface preparation standards for abrasive blast cleaning and power tool cleaning, including:

Written standards, such as:

- NACE/SSPC joint blast cleaning standards
- SSPC hand and power tool cleaning standards

and visual standards, such as :

- SSPC-Vis 1¹
- SSPC-Vis 3
- ISO 8501-1

Earlier it was stated that 60 to 80% of all premature failures were caused completely or partially by inadequate or improper surface preparation. It follows that users should aim to achieve a properly prepared surface to get adequate performance from their selected coatings.

Standards are used to define the level of cleaning required and to aid judgment of the level of cleaning actually achieved. To determine which standard should be used and achieve good results, the specifier must

- Determine the condition of the steel to be cleaned and painted. In construction, the condition of the steel should be specified. In maintenance, the knowledge is essential for correct selection of working methods.

¹ The information provided has been approved by SSPC: The Society for Protective Coatings. The slides used in this section were furnished by SSPC.

- Select the optimum surface preparation standard and methods of cleaning the surface in question.

Coating inspectors play an important role in the surface preparation operation; on most job sites they are required to verify that the specified cleanliness standard is achieved. To do this, inspectors must:

- Be able to identify the various conditions of the steel to be cleaned, whether unpainted or previously painted
- Be thoroughly familiar with the cleanliness standard referenced in the specification
- Understand the specific cleaning sequence necessary to achieve the final standard of cleanliness
- Be able to recognize when the surface has been cleaned properly
- Monitor each step of the surface preparation operation and document the results

The entire surface preparation program, including interpretation of referenced standards, should be discussed by all parties involved in the project at the pre-job conference. A consensus must be reached regarding the cleaning methods and materials to be used and the expected final condition of the prepared surface.

In addition to this review at the pre-job conference, some users take another step and require the contractor to prepare a sample in the field representative of the **agreed** surface cleanliness for that particular job.

Typically, a field-prepared visual comparator consists of a plate, or perhaps a part of the structure, 0.9 to 1.3 m² (3 or 4 ft²), which is abrasive blast cleaned (or hand or power tool cleaned, if required) and coated with a clear plastic coating. This prepared area can be used by the contractor and inspector as they monitor the cleaning operations to verify that the surface is being cleaned as

agreed. The surface must be preserved in its *as agreed* condition, which may be achieved by keeping the sample in a low-humidity environment or by covering the area with lacquer or varnish.

Since surface preparation is such an important factor in the service life of a coating system, we want to expand on our previous discussion of surface preparation standards. The objectives for today's session are:

- To review the SSPC/ISO designations of the general conditions (rust grades A, B, C, and D) of unpainted steel
- To explore in some detail the requirements of the NACE/SSPC joint surface preparation standards for abrasive blast cleaning (white, near-white, commercial, and brush-off blast cleaning)
- To review use of SSPC-Vis 1, "Visual Standard for Abrasive Blast Cleaned Steel," (based on rust grades A, B, C, and D) and SSPC-Vis 3, "Visual Standard for Power and Hand Tool Cleaning of Steel," based on seven general conditions before surface preparation (rust grades A, B, C, and D, and conditions E, F, and G)

General Conditions of Steel Surfaces

The general conditions of unpainted steel as illustrated in SSPC-Vis 1 (and, with small differences in wording, in ISO 8501-1) are described as follows:

SSPC-Vis 1

This standard illustrates four initial rust grades before surface preparation and covers the range from intact mill scale to rusted and pitted steel. These rust grades are:

- 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

ISO 8501-1

Four rust grades, designated A, B, C, and D, are specified. The rust grades are defined by written descriptions together with representative photographic examples:

- 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



Joint Surface Preparation Standards (NACE/SSPC) for Abrasive Blast Cleaning

For many years, industry referenced the NACE and SSPC surface preparation standards as though they were exact equivalents, even though there were differences in the wording of the standards issued by the two societies.

In 1990, NACE and SSPC formed a joint task group with the express purpose of establishing joint and identically worded standards for abrasive blast cleaning of steel. These joint standards were published in October 1994.

The joint standards are:

- 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”

Other joint standards have also been developed, including those for waterjetting (NACE No. 5/SSPC-SP 12), surface preparation of concrete (NACE No. 6/SSPC-SP 13), and industrial blast cleaning (NACE No. 8/SSPC-SP 14).

Let's review the four basic blasting standards individually.

Each standard consists of 10 sections (listed below) that are identified in *Section 1: General* of each standard. The first nine sections listed in the General section and noted below are mandatory requirements of the individual standard, while Section 10 consists of *Comments* and



Appendix A, *Explanatory Notes*, which are **NOT** mandatory requirements of the standard.

- Section 1: General
- Section 2: Definition
- Section 3: Reference Documents
- Section 4: Procedure Before Blasting
- Section 5: Blast Cleaning Methods and Operation
- Section 6: Blast Cleaning Abrasives
- Section 7: Procedure Following Blast Cleaning and Immediately Prior to Coating and Lining
- Section 8: Inspection
- Section 9: Safety and Environmental Requirements

Section 2: Definition

This section is the *heart* of the standard—the definition of the standard. The essential definitions of each of the four blasting standards are given below.

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
- Rust
- Grease
- Coating
- Dust
- Oxides
- Dirt
- Corrosion products
- Mill scale
- 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 6,400 mm² (9 in.²) (i.e., a square 80 x 80 mm [3 x 3 in.]) 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 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
- Rust
- Grease
- Coating
- Dust
- Oxides
- Dirt
- Corrosion products
- Mill scale
- Other foreign matter except for staining

Random staining shall be limited to no more than **33%** of each unit area approximately 6,400 mm² (9 in.²) (i.e., a square 80 x 80 mm [3 x 3 in.]) 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.

For any of the blast cleaning standards, when *coating* is specified, the surface shall be suitably roughened for that coating specified, and, just prior to painting the surface, shall comply with the specified degree of cleaning.

This section also provides for the use of visual comparators or standards to supplement the written document. In the case of a dispute, the written standard takes precedence over the visual comparator or standard.

Section 3: Reference Documents

This section lists referenced SSPC documents and indicates that the latest issue, revision, or amendment of reference documents in effect on the date of invitation to tender shall govern unless otherwise specified.

Section 4: Procedure before Blast Cleaning

This section calls for removal of visible oil and grease before blasting in accordance with SSPC-SP 1, "Solvent Cleaning," or another agreed-upon method. Also, it requires that surface imperfections, such as sharp fins, edges, weld spatter, and burning slag, be removed as required by the project specifications.

Section 5: Blast Cleaning Methods and Operation

This section describes other methods of surface preparation to achieve the particular blast cleaned surface, such as:

- Dry abrasive blast cleaning using compressed air, nozzle, and abrasive
- Closed-cycle recirculating systems, with or without vacuum for dust recovery
- Dry abrasive blasting using a closed-cycle recirculating system with centrifugal wheels and abrasive

- Wet abrasive blast system (**Note:** Inhibitors may need to be added to the water or applied to the surface immediately after blast cleaning. See Appendix A:9.)

This section also stipulates that clean, dry, compressed air shall be used for nozzle blasting.

Section 6: Blast Cleaning Abrasives

This section refers to the selection of abrasive type and size based on:

- Type, grade, and surface condition of steel to be cleaned
- Type of blast cleaning system used
- Finished surface to be produced (cleanliness and roughness)
- Whether abrasive is to be recycled

Also, reference is made to:

- Need to maintain cleanliness and size of recycled abrasives
- Any limitations and restrictions on:
 - use of specific abrasives
 - quantity of contaminants
 - degree of embedment

All of these should be included in the project specifications covering the work, because abrasive embedment and abrasives containing contaminants may not be acceptable by some service requirements.



Section 7: Procedure Following Blast Cleaning and Immediately Prior to Coating

This section refers to the cleaned surface condition just before coating and calls for:

- Removal of oil, grease, or other contaminants by SSPC-SP 1 or other agreed upon method
- Removal of dust and residues by brushing, blowing off with clean dry air, vacuum or other methods agreed upon by the parties involved
- Removal of surface imperfections (e.g., sharp fins, weld spatter, etc.) to the extent required in the project specification. Any damage resulting from removal of surface imperfections must be corrected to meet the particular blast cleaning standard.
- Removal of visible rust from the surface after cleaning by reblasting the rusted area to meet the requirement of the standard

Section 8: Inspection

This section acknowledges that:

- Work and materials supplied under this standard are subject to inspection by a representative of those responsible for establishing the requirements
- Materials and work area should be accessible to the inspector
- Procedures and times of inspection should be agreed upon by those responsible for establishing the requirements and those responsible for performing the work
- Conditions not complying with the particular standard shall be corrected
- Because disputes may occur, an arbitration or settlement procedure should be established in the



project specification; if not, a procedure mutually agreeable to purchaser and supplier shall be used

Section 9: Safety and Environmental Requirements

This section calls for abrasive blast cleaning to be conducted in compliance with applicable insurance underwriters, local, state, and federal occupational environmental health and safety rules and regulations.

Section 10: Comments (Non-Mandatory)

This part of the standard contains additional information and data relative to the standard, and Appendix A contains explanatory notes and recommendations believed to represent good practice but not considered requirements of the standard.

With the exception of the definitions, which are clearly different from each other, most elements of the blast cleaning standards are similar in the respective sections of the four documents.

Use of SSPC Visual Standards

SSPC-Vis 1

Now that we have discussed the wording of the joint surface preparation standards, let's consider the visual standards that support those words. First, we'll look at SSPC-Vis 1, "Visual Standard for Abrasive Blast Cleaned Steel."

This visual standard consists of standard reference photographs for steel surfaces prepared by abrasive blast cleaning using **sand** abrasive. They are intended to be used 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, we will identify specific descriptions according to Table 1.



Rust Grade A—Blasted

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*.

These first pictures show rust grade A (100% adherent mill scale) blast cleaned to SP 10 (near-white) and to SP 5 (white metal), with the designations being *A SP 10* and *A SP 5*.

Note also, no photograph is provided for *A SP 7* because of the wide variations in appearance possible when brush-off blast cleaning adherent mill scale. There is no photograph for *A SP 6*, because this condition cannot normally be obtained when removing adherent mill scale.

Rust Grade B—Blasted

The next pictures 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 the various blast cleaning methods on different initial rust grades is easily seen.

Rust Grade C—Blasted

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.

Rust Grade D—Blasted

Next is 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

Blasting Rust Grade A with Nonmetallic and Metallic Abrasives

The appendix of Vis 1 is provided for information only and does not constitute part of the SSPC standard. It shows supplementary photographs which represent adherent mill scale (rust grade A) blast cleaned to white metal by:

- 3 nonmetallic abrasives
- 3 metallic abrasives

The variations in appearance are shown only for white metal, but these same variations must be considered when assessing steel prepared to other degrees of cleaning.

These photographs illustrate the range of appearances produced by nonmetallic abrasives such as silica sand, garnet, and coal slag and metallic abrasives such as steel grit and steel shot.

Panels blast cleaned with nonmetallic abrasives are designated as follows:

- A SP 5-N1



- A SP 5-N2
- A SP 5-N3

Panels blast cleaned with metallic abrasives are designated as follows:

- A SP 5-M1
- A SP 5-M2
- A SP 5-M3

The abrasive used for each photograph is not specifically identified in the standard, because wide variations in appearance were observed among the abrasives within a specific generic class, such as copper slag.

Note that the joint NACE/SSPC standards for abrasive blast cleaning and SSPC-Vis 1 refer to steel that has not been previously painted. Additionally, in Appendix B, Condition *G1*, *G2*, and *G3* are also shown with G2 and G3 as being representative of *steel previously painted*.

SSPC-Vis 3

These photographs supplement the written SSPC power and hand tool surface preparation specifications and are not to be used as substitutes for those written documents.

Vis 1 is concerned with abrasive blast cleaning of new construction steel, not that previously painted. Vis 3 is concerned with power and hand tool cleaning of unpainted steel (rust grades A, B, C, and D) and also cleaning of previously painted steel (conditions E, F, and G).

According to this standard, conditions E, F, and G are **maintenance** surface conditions. Condition E and F represent surfaces with aged coatings originally applied over blast cleaned steel. Condition G represents surfaces with aged coatings originally applied over mill-scale-bearing steel.

Many surfaces encountered in the field may not correspond closely with conditions E, F, and G; however, careful extrapolation of the photographs in SSPC-Vis 3 can still aid in determining conformance with cleaning requirements.

Weld seams were included in conditions A, B, C, and D to show the appearance of welds cleaned by power and hand tool cleaning prior to coating.

Table 1 for SSPC-Vis 3 lists the method of cleaning for a given condition of steel.

For example:

If SSPC-SP 2 hand tool cleaning was specified, the designation SP 2 is used.

If SSPC-SP 3 power tool cleaning was specified, it must be determined if cleaning was done using:

- Power wire brush SP 3/PWB
- Sanding disk SP 3/SD
- Needle guns SP 3/NG

When SP 3 is specified, inspectors should use the photograph corresponding to the type of power tool used (e.g., for power wire brush use SP 3/PWB). If it is not known what power tool was used, any one of the end conditions (i.e., SP 3/PWB, SP 3/SD, or SP 3/NG) is acceptable.

If power tool cleaning to bare metal (SP 11) was specified, it must be determined whether the intent was to *produce* a profile or *restore* (re-expose) a profile.

If no profile exists, or if the profile condition is not known, the designation SP 11 is used. This condition can be achieved by using a:

- Rotary flap peening assembly
- 2-mm needle gun

If an existing profile is to be restored (re-exposed), use the designation:

- SSPC-SP 11 (non-woven disk to restore [re-expose] profile)
- SSPC-SP 11/R

Steel surfaces show variations in texture, shade, color, tone, pitting, flaking, mill scale, etc., that should be considered when making comparison with the reference photographs.

Initial Conditions (Rust Grades A, B, C, and D)

Four conditions of unpainted steel are illustrated, and it can be seen that these are similar to the rust grades depicted in SSPC-Vis 1, except that weld seams are included in the pictures.

Condition A—Hand and Power Tool Cleaning

Steel condition A (100% adherent mill scale) may be cleaned as follows:

- A SP 2 - Hand Tool Cleaning/Wire Brush
- A SP 3/PWB - Power Tool Cleaning/Power Wire Brush
- A SP 3/SD - Power Tool Cleaning/Sanding Disk
- A SP 3/NG - Power Tool Cleaning/Needle Gun
- A SP 11 - Power Tool Cleaning to Bare Metal (SSPC-SP 11/Needle Gun or Rotary Flap Peen—Produce Profile)

An SP 11/R standard is not illustrated because the initial condition (A) did not have an original profile to restore or re-expose.

Condition B—Hand and Power Tool Cleaning

Steel condition B (mill scale and rust) may be cleaned as follows:

- B SP 2 - Hand Tool Cleaning/Wire Brush
- B SP 3/PWB - Power Tool Cleaning/Power Wire Brush
- B SP 3/SD - Power Tool Cleaning/Sanding Disk
- B SP 3/NG - Power Tool Cleaning/Needle Gun
- B SP 11 - Power Tool Cleaning to Bare Metal (SSPC-SP 11/Needle Gun or Rotary Flap Peen—Produce Profile)

(SSPC-SP 11/R is not appropriate)

Condition C—Hand and Power Tool Cleaning

Steel condition C (100% rust) may be cleaned as follows:

- C SP 2 - Hand Tool Cleaning/Wire Brush
- C SP 3/PWB - Power Tool Cleaning/Power Wire Brush
- C SP 3/SD - Power Tool Cleaning/Sanding Disk
- C SP 3/NG - Power Tool Cleaning/Needle Gun
- C SP 11 - Power Tool Cleaning to Bare Metal (SSPC-SP 11/Needle Gun or Rotary Flap Peen—Produce Profile)

(SSPC-SP 11/R is not appropriate)

Condition D—Hand and Power Tool Cleaning

Steel condition D (100% rusted and pitted) may be cleaned as follows:

- D SP 2 - Hand Tool Cleaning/Wire Brush
- D SP 3/PWB - Power Tool Cleaning/Power Wire Brush
- D SP 3/SD - Power Tool Cleaning/Sanding Disk
- D SP 3/NG - Power Tool Cleaning/Needle Gun
- D SP 11 - Power Tool Cleaning to Bare Metal (SSPC-SP 11/Needle Gun or Rotary Flap Peen—Produce Profile)

(SP 11/R is not appropriate)

Condition E, F, G—Definitions

The following definitions are provided for three surface conditions that have been previously painted:

Condition E: Previously painted steel surface; light-colored paint applied over blast cleaned surface, paint mostly intact

Condition F: Previously painted steel surface; zinc-rich paint applied over blast cleaned steel, paint mostly intact

Condition G: Painting system applied over mill-scale-bearing steel; system thoroughly weathered, thoroughly blistered, or thoroughly stained

Condition E: Hand and Power Tool Cleaning

Surface condition E may be cleaned as follows:

- E SP 2 - Hand Tool Cleaning/Wire Brush
- E SP 3/PWB - Power Tool Cleaning/Power Wire Brush
- E SP 3/SD - Power Tool Cleaning/Sanding Disk



- E SP 3/NG - Power Tool Cleaning/Needle Gun
- E SP 11/R - Power Tool Cleaning to Bare Metal (SSPC-SP 11/Non-Woven Disk—Restore [Re-Expose] Profile)

Condition F: Hand and Power Tool Cleaning

Surface condition F may be cleaned as follows:

- F SP 2 - Hand Tool Cleaning/Wire Brush
- F SP 3/PWB - Power Tool Cleaning/Power Wire Brush
- F SP 3/SD - Power Tool Cleaning/Sanding Disk
- F SP 3/NG - Power Tool Cleaning/Needle Gun
- F SP 11/R - Power Tool Cleaning to Bare Metal (SSPC-SP 11/Non-Woven Disk—Restore [Re-Expose] Profile)

E SP 11/R, and F SP 11/R are separately illustrated on the last page of the standard SSPC-Vis 3.

Condition G: Hand and Power Tool Cleaning

Condition G is cleaned as follows:

- G SP 2 - Hand Tool Cleaning/Wire Brush
- G SP 3/PWB - Power Tool Cleaning/Power Wire Brush
- G SP 3/SD - Power Tool Cleaning/Sanding Disk
- G SP 3/NG - Power Tool Cleaning/Needle Gun
- G SP 11 - Power Tool Cleaning to Bare Metal (SSPC-SP 11/Needle Gun or Rotary Flap Peen—Produce Profile)

There is no G SP 11/R, since the initial condition is unlikely to have had any original profile to be restored.

Corrosion over many years is also likely to create very uneven and inconsistent surface roughness.

ISO 8501-1 Visual Standards

ISO 8501-1 was originally developed as a Swedish standard, designated SIS 05 59 00. It has since been adopted by most countries of the world, first as a national standard and more recently as the (ISO) international standard.

ISO 8501-1 is a visual standard with illustrations that show four rust grades A, B, C, and D cleaned to various grades of abrasive blast cleaning. The pictorial standard describes the surface condition in several languages, then provides photographs that show the meaning (or result) of the described finish.

The ISO designations for surface preparation are:

- St 2: Thorough Hand and Power Tool Cleaning
- St 3: Very Thorough Hand and Power Tool Cleaning
- Sa 1: Light Blast Cleaning
- Sa 2: Thorough Blast Cleaning
- Sa 2½: Very Thorough Blast Cleaning
- Sa 3: Blast Cleaning to Visually Clean Steel

The wording of these standards is comparable to but different from the NACE and SSPC standards and the inspector should become equally familiar with them. ISO standards are likely to be encountered in most specifications written outside the United States.



Starting conditions shown in ISO 8501-1 are:

- Rust grades A and B
- Rust grades C and D

Hand and power tool cleaning are illustrated only for steel conditions B, C, and D, since condition A has no loose contamination to remove by mechanical cleaning. Two resulting surfaces are shown, St 2 and St 3 for each of the starting conditions. These include:

- C St 2
- C St 3
- D St 2
- D St 3

Illustrations are provided for:

- Condition A cleaned to Sa 2½ and Sa 3
- Conditions B, C, and D cleaned to Sa 1, Sa 2, Sa 2½, and Sa 3

It can be seen that the surface cleanliness standards we have reviewed here are straightforward **BUT** are very detailed. Coating inspectors must be thoroughly conversant with these standards to do an effective job when judging work that must comply with the specified standard.





Level 1

Chapter 5.2

Material Safety Data Sheets and Technical Data Sheets

Material Safety Data Sheets (MSDS) and Technical Data Sheets

In most countries, legislation has been passed 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. The usual method of providing this information is on a *Material Safety Data Sheet* or *MSDS*.

MSDS (or their national equivalent) are mandatory in many countries as a result of *Right to Know* legislation. Any manufacturer of potentially hazardous substances must provide information to anyone who might be exposed to the hazard, describing the potential problems, and providing instructions to minimize hazardous exposure. MSDS 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. In the United Kingdom, for example, safety data is provided on a *COSHH sheet*. COSHH means Control of Substances Hazardous to Health and is referred to by regulations in this way.

Whatever the name given, the information is likely to be similar when coating or paint materials are concerned. Appendix A shows an sample MSDS, similar in style and content to those used in the United States. In the coating industry worldwide, MSDS generally follow the outline determined by ANSI (American National Standards Institute) in standard ANSI Z400.1.



Understanding the Material Safety Data Sheet (MSDS)

Material Safety Data Sheets (MSDS) are prepared and supplied by material manufacturers to inform users of the potential hazards of that product. The MSDS also lists the proper action to take in the event of a spill, fire, or hazardous contact.

The ANSI MSDS is divided into sixteen sections (in the ANSI format). Each section provides specific information.

Note: Legislation in various states and countries outlines requirements for workers' *Right to Know* about safety and health hazards of products and equipment.

ANSI Z400.1 MSDS Sections

Section 1: Identification of the Chemical Product and Company

Section 1 identifies:

- The product
- Product (coating) manufacturer (or an appointed distributor) and address
- Emergency telephone or contact information

Section 2: Composition (Information on Ingredients)

Section 2 provides product class (shipping information) and identifies specific hazardous ingredients. Some information is provided for each hazardous ingredient, including the approximate quantity and the Chemical Abstract Service (CAS) identity number. It has become common to use *risk phrases* with identifying reference numbers, e.g., *R20 Harmful by Inhalation* or *R38 Irritating to Skin*.

The CAS number of each hazardous ingredient takes the form of a group of numbers, e.g., Xylene 1330-20-7. In the United States, the Environmental Protection Agency (EPA) and the chemical industry use the CAS number for computer tracking and identification of each chemical product (over 100,000 of them).

Section 3: Hazard Identification

Section 3 lists potential health effects and provides a simple description of the type of hazard that may be encountered, e.g., *Flammable* or *Harmful by Inhalation*.

Section 4: First Aid Measures

Section 4 describes emergency first-aid procedures or instructions. It may also include descriptions of the effects of overexposure and dangerous symptoms.

Section 5: Firefighting Measures

Section 5 describes flammable properties and extinguishing media, including:

- Details of suitable media used to fight fire, e.g., foam, CO₂, powder, etc.
- Special firefighting instructions
- Unusual fire and explosion hazards

Section 6: Accidental Release Measures

Section 6 describes environmental precautions and emergency cleanup procedures for spills or leaks.

Section 7: Handling and Storage

Section 7 describes precautions that must be taken during handling and storage and includes:

- Required storage conditions, including temperature limitations
- Instructions for handling during mixing
- Precautions to maintain health and safety in the storage area



Section 8: Exposure Controls and Personal Protection

Section 8 includes:

- Engineering measures to minimize exposure (e.g., ventilation requirements)
- Occupational exposure limits (TLV, etc.) for hazardous ingredients

Section 8 also defines personal protective equipment requirements, including:

- Eye protection
- Breathing protection, respirators, etc.
- Gloves, coveralls, boots, etc.

Section 9: Physical and Chemical Properties

Section 9 includes descriptions of both the physical nature of the product (e.g., liquid, solid, etc.) and specific chemical information. The information relates to the combined product, not to the individual ingredients, and may include:

- Appearance and color
- Boiling-point temperature
- Specific gravity (weight relative to the weight of a similar volume of water)
- Evaporation rate of the solvents
- Freezing point of the coating (if applicable)
- Vapor density (relative to air) of the solvent vapors. The higher the number, the heavier the solvent vapor
- Solids by volume (indicates the amount of solvent per liter [gallon])
- Relative water solubility



Section 10: Stability and Reactivity

Section 10 includes:

- Conditions under which the product is unstable
- Details of items with which the product will react
- Description of expected reaction products (e.g., carbon monoxide, smoke)

Section 11: Toxicological Information

Section 11 includes:

- Description of the medical effects of exposure to the product, both long-term and short-term
- Specific medical warnings where appropriate

Section 12: Ecological Information

Section 12 includes:

- General warnings regarding the potential effect of the product on the environment
- Specific listing of substances harmful to the environment

Section 13: Disposal Considerations

Section 13 includes:

- Warnings related to disposal of the product and its waste or containers
- Information regarding any specific (and known) regulatory issues

Section 14: Transport Information

Section 14 includes information related to the specific transport regulations in the region to which the MSDS applies. Information may include:

- Official category of the product (e.g., *paint*)

- Classification by the authorities (e.g., *Class 3*)
- Identifying codes or names

Section 15: Regulatory Information

Section 15 includes information required by applicable regulations. This may include:

- Symbols to be shown on labels
- Classification of the product
- Risk phrases (R-phrases)
- Safety phrases (S-phrases)
- Other warnings that may be required

Section 16: Other Information

Section 16 includes any other specific information the manufacturer believes is beneficial. This may include an explanation of phrases and terms used in the MSDS. It may also include disclaimers and general warning statements.

Important Note: All workers should read the MSDS, try to understand it, and understand how to work safely. If any section is not easy to understand, further advice should be sought. For the safety of all workers, unsafe practices should be reported whenever they are found.

One potential problem with MSDS is that many readers do not have enough detailed chemical knowledge to understand the information provided. The use of complex chemical names, abbreviations, and acronyms makes the data very difficult to read, even for the experienced and knowledgeable reader. The use of symbols and pictograms may be useful to increase understanding.

MSDS sheets are produced in various languages and designed to meet local regulations. Larger paint companies may have many versions of their MSDS to suit the region of use. Smaller paint companies may not

produce differing versions of their MSDS, and the regulations referenced are likely to be those of the country of origin and not necessarily the location of coating application.

HazComm

When coating materials are transported by road, there is a constant risk of spillage or exposure to potentially toxic chemicals. In some countries the law requires that MSDS sheets are carried by the transporter whenever *industrial quantities* of coatings are moved by road, rail, or air. Most observers will be familiar with the multicolored hazard-identifying signs, carried by trucks or rail cars, depicting explosion or toxic hazard categories for the product. The same warning signs can sometimes be seen on paint cans.

The purpose of such hazard communication is to inform emergency services of potential hazards in the event of a spill. MSDS are required to provide a 24-hour emergency telephone number that links to a source of specific information regarding the particular product.

Chemicals commonly used by industry and judged to be hazardous are listed by various industry or national authorities.

Generally, information on the chemicals is freely available online via computer. For example, the National Occupational Health and Safety Commission of Australia (NOHSC) provides 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 can be found at www.acgih.org.

Regardless of the source of the information, chemical listings show the universally applied CAS number from which the properties of the chemical can be determined. In particular, when an event such as an exposure, release,

spill, or fire occurs, the emergency services can determine the best course of action.

The CAS database 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 has resulted in the *International Chemical Safety Cards*, published generally by the World Health Organization but made available in the United States 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 growing lists of chemicals hazardous to health reported by various medical research bodies.

Product Technical Data Sheets

Coating manufacturers' product data sheets are intended to communicate technical facts related to the specific material and its application properties. Important sections of most technical data sheets include:

- General description of the coating, including an overview of the intended (or recommended) uses
- Specific description of the product, including the generic type of coating
- Approvals and certificates
- Description of the way the coating is used, including recommended primers and/or topcoats
- Recommendations for application method and equipment, including brush, roller, conventional spray, and airless spray, as appropriate



- Surface preparation required
- Specific technical features of the product, including:
 - Color
 - VOC
 - Recommended DFT and WFT
 - Theoretical and practical coverage
 - Mixing ratio(s)
 - Induction time and pot life, including indications of the variation with temperature change
 - Allowed thinner
 - Packaging and shipping information
 - Flash point
 - Volume solids

In addition, there are many details related to safety on a typical technical data sheet. Important physical properties such as flash-point temperature and volume solids are listed and can be used, to some extent, to establish safe storage or working conditions.

The format and content of product technical data sheets is less formalized than the ANSI format of the MSDS. There is, however, significant conformance between data sheets issued by most major coating manufacturers.

Inspectors should consider product technical data sheets an essential part of the coating specification. Much of the technical data is essential to verify the equipment use and setup at the beginning of a job. In addition, technical data for quality control is largely stated in the technical data sheets. Although the information is generally clearly stated, some applicators often appear to overlook such fundamental data as:

- Induction time



- Pot life
- Over-coating intervals
- Mixing instructions
- Thinner recommended
- Clean up instructions

The product technical data sheets provide this information for all users.



IB2257270

SAMPLE

MATERIAL SAFETY DATA SHEET

CUSTOMER NAME:

CUSTOMER NUMBER: 1234567

CUSTOMER INVOICE NO: 345678

Section 1: Product Identification

Manufacturer's Address:

Mf. Telephone No.: 1-800-228-5635

24-Hr. Emergency Phone No.:

Chemical Name or Family: Paint Product

Formula: 0089T1R-122-A-06

Trade Name: Or Equal VC HB Epoxy (Beige)

Revision Date: 4-12-91

Date Printed: 5-11-91

Section 2: Hazardous Ingredients

Name	Approx Wt. %	Recm. Level	TLV	PEL
Common (NA): Aliphatic Petroleum Distillates CAS: 64742-88-7 Chemical: Solvent Naphtha (Petroleum), Light Aliph.	1%	Not Est	Not Est	500.00 (1)
Common (NA): Naphtha CAS: 94742-89-8 Chemical: Naphtha	5%	Not Est	300.00 (2)	Not Est
Common (NA): Talc CAS: 14807-95-6 Chemical: Talc	50%	Not Est	2.00 (2)	2.00 (2)
Common (NA): Epoxy Adduct CAS: 68424-41-9 Chemical: Fatty Acids, C18 Unsatd., Dimers, Polymers w/Triethylenetetramine, reaction products with Poly (Bisphenol a Diglycidyl Ether)	15%	Not Est	Not Est	Not Est
Common (NA): Butyl Alcohol CAS: 71-36-3 Chemical: 1-Butanol	15%	Not Est	50.00 (1)	100.00 (1)
Common (NA): Toluene CAS: 108-68-3 Chemical: Phenyl, Methyl	5%	Not Est	100.00 (1)	200.00 (1)

(1) = ppm

(2) = mg/m³

Section 3: Physical Data

Boiling Point:	110°C (230°F)
Vapor Pressure MM HG at 38°C; (100°F):	30.0
Vapor Density (Air = 1.0):	5.9
Specific Gravity:	1.35
Percent Volatile by Volume:	48.61
Evaporation Rate (Butyl Acetate = 1):	2.0
Solubility in Water:	No
Appearance and Odor:	Normal for a coatings product.

Section 4: Fire and Explosion Hazard

Flash Point TCC/PM Degree C: 10; Degree F:	49
Lower Explosive Limit:	1.00
Upper Explosive Limit:	11.00
Extinguishing Media: Carbon dioxide, dry chemical, foam, and water fog.	
Special Fire-Fighting Procedures:	
Fire-fighters must wear self-contained breathing apparatus or air masks.	
Containers exposed to fire should be kept cool with water spray.	
Unusual Fire and Explosive Hazards: None	

Section 5: Health Hazard Data

Threshold Limit Value: Not required for mixture

Effects of Overexposure:

Immediate Effects (Acute):

Can be absorbed through the skin.

Harmful if inhaled; may affect the brain, nervous system, or respiratory system, causing dizziness, headache, nausea, or respiratory irritation.

Overexposure to ingredients in this product may cause nose and throat irritation, eye irritation, skin irritation, CNS digression, corneal injury/eye damage.

Delayed Effects (Chronic):

Notice: Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage. Intentional misuse by deliberately concentrating and inhaling the contents may be harmful or fatal. Contains ingredients which may cause liver damage, kidney damage, and hearing loss.

Medical conditions generally aggravated by exposure-any respiratory or skin condition.

Emergency and First-Aid Procedures:

Inhalation: Remove person from exposure area. If breathing has stopped, use mouth-to-mouth resuscitation and get medical attention.

Eye Contact: Flush with water for 15 minutes.

Skin Contact: Wash with soap and water.

Possible Routes of Entry: Inhalation, ingestion, skin absorption.

Section 6: Reactivity Data

This product is stable

Conditions to Avoid: None

Incompatibility: Strong oxidizers

Hazardous Decomposition Products:

Ammonia compounds Nitrogen oxides

Carbon dioxide/monoxide

Hazardous Polymerization: None

Section 7: Spill or Leak Procedures

Ventilate area. Avoid breathing of vapors. Use self-contained breathing apparatus or air mask for large spills in a confined area.

Eliminate ignition sources.

Remove with inert absorbent and nonsparking tools.

Avoid all personal contact.

Waste Disposal Method:

Dispose in chemical disposal area or in a manner that complies with local, state, and federal regulations. **Do not incinerate closed containers.**

Section 8: Special Protection Information

Respiratory Protection:

Wear appropriate, properly fitted respirator (NIOSH/MSHA approved) during and after application unless air monitoring vapor/mist levels are below applicable limits.

Follow respirator manufacturer's directions for respirator use.

Ventilation:

Required for spraying or in a confined area, ventilation equipment should be explosion proof. Eliminate ignition sources.

Protective Gloves: Usual hand protection for paint application.

Eye Protection: Usual eye protection for applying paint.

Other Protective Equipment: Usual clothing for painting operations.

Section 9: Special Precautions

Precautions to be Taken in Handling and Storage:

Containers should be grounded when pouring. Avoid freefall of liquid in excess of a few inches.

Keep away from heat, sparks, and open flames. Keep container closed when not in use. Do not store above 49°C (120°F); based on the product flash point and vapor pressure, suitable storage should be provided in accordance with OSHA regulation 1910.106. Empty containers may contain product residue, including flammable or explosive vapors. Do not cut, puncture or weld on or near container. All label warnings must be observed until the container has been cleaned or reconditioned.

Abbreviations Used:

OSHA-Occupational Safety and Health Administration
IARC-International Agency for Research on Cancer
LEL-Lower Explosive Limits
UEL-Upper Explosive Limits
MG CU M-Milligrams per m³;
MM-Millimeters
MPPCF-Millions of Particles Per Cubic Foot
MSHA-Mine Safety and Health Administration
NA-Not Applicable
NIOSH-National Institute of Occupational Safety and Health
Not Est-Not Established
NTP-National Toxicology Program
PB-Lead
PEL-Permissible Exposure Level
PPM-Parts per Million
TCC/PM-Tag Closed Cup/Pensky-Marten
Recm-Recommended
TLV-Threshold Limit Values

******* Disclaimer Section *******

The furnishing of the information contained herein does not constitute a representation by _____ that any product or process is free from patent infringement claims of any third party nor does it constitute the granting of a license under any patent of _____ or any third party.

_____ assumes no liability for any infringement which may arise out of the use of the product. _____ warrants that its products meet the specifications which it sets for them.

_____ disclaims all other warranties relating to the products, and disclaims all warranties relating to their application, express or implied, including but not limited to warranties of merchantability and fitness for particular purpose. Receipt of products from _____ constitutes acceptance of the terms of this warranty, contrary provisions of purchase orders notwithstanding. In the event that _____ finds that the products delivered are off-specification, _____ will, at its sole discretion, either replace the products or refund the purchase price thereof, and _____ choice of one of these remedies shall be buyers sole remedy. _____ will under no circumstances be liable for consequential damages, except insofar as a liability is mandated by law. _____ will deliver products at agreed times insofar as it is reasonably able to do so, but _____ shall not be liable for failure to deliver on time when the failure is beyond its reasonable control.

Selection & Specification Data

Generic Type	Waterborne Acrylic
Description	Weathering finish with excellent performance properties. Frequently used in the bridge market as a finish coat over inorganic zinc primers, as well as a user-friendly finish for numerous other substrates.
Features	<ul style="list-style-type: none"> Excellent performance over inorganic zinc primers Superior color and gloss retention Single component Spray, brush and roll Low odor, low VOC
Colors	Refer to Carboline Color Guide
Finish	Semi-Gloss
Primers	Inorganic Zinxs and others as recommended under <i>Substrates & Surface Preparation</i> . A mist coat may be required to minimize bubbling over Inorganic Zinc primers.
Dry Film Thickness	2.0-3.0 mils (50-75 microns) Do not exceed 3.0 mils (75 microns) in a single coat.
Solids Content	By Volume: 36% ± 2%
Theoretical Coverage Rate	577 mil ft ² (14.1 m ² /l at 25 microns) Allow for loss in mixing and application.
VOC Values	As supplied: 0.9 lbs/gal (119 g/l) EPA Method 24: 2.0 lbs/gal (250 g/l) (Calculated minus water and exempt solvent.) These are nominal values and may vary slightly with color.
Dry Temp. Resistance	Continuous: 200°F (93°C) Non-Continuous: 250°F (121°C) Slight discoloration and loss of gloss is observed above 200°F (93°C).
Limitations	Apply and cure at 50°F (10°C) and above for 24 hour period.

Substrates & Surface Preparation

General	Surfaces must be clean and dry. Employ adequate methods to remove dirt, dust, oil and all other contaminants that could interfere with adhesion of the coating.
Steel	SSPC-SP6 with a 1.0-2.0 mil (25-50 micron) surface profile for maximum protection. SSPC-SP2 or SP3 as minimum requirement. Prime with specific Carboline primers as defined in <i>Market Guides</i> or as recommended by your Carboline sales representative.
Galvanized Steel	SSPC-SP1. Prime with Carbocrylic® 120 or others as recommended in <i>Market Guides</i> .
Concrete	Concrete must be cured 28 days at 75°F (24°C) and 50% relative humidity or equivalent. Laitance, form oils, curing agents and hardeners must be removed by suitable method prior to coating application. Prime with specific Carboline primers as defined in <i>Market Guides</i> or as recommended by your Carboline sales representative.
CMU	Mortar joints should be thoroughly cured for a minimum of 15 days at 75°F (24°C) and 50% relative humidity or equivalent. Prime with appropriate block filler.
Drywall & Plaster	Joint compound and plaster should be fully cured prior to coating application. Prime with Carbocrylic® 120.
Wood	Lightly sand with fine sandpaper and remove dust. Prime with Carbocrylic® 120.
Previously Painted Surfaces	Lightly sand or abrade to roughen surface and degloss the surface. Existing paint must attain a minimum 3B rating in accordance with ASTM D3359 "X-Scribe" adhesion test. Prime with Carbocrylic® 120.

Performance Data

Test Method	System	Results	Report #
ASTM D4541 Adhesion	Blasted Steel 1 ct. 10Z 1 ct. 3350	500-600 psi (Elcometer)	08332 02566 SR321
ASTM D4213 Scrub Resistance	1 ct. 3350	.0384/.0138 Microliters per 100 cycles Wet/Dry Film Volume	03403
Midwest Weathering	Blasted Steel 1 ct. 10Z 1 ct. 3350	No effect on plane area after 24 months exposure	08332 02566 SR321

Test reports and additional data available upon written request.

July 2001 replaces April 2000

To the best of our knowledge the technical data contained herein is true and accurate on the date of publication and is subject to change without prior notice. User must contact Carboline Company to verify correctness before specifying or ordering. No guarantee of accuracy is given or implied. We guarantee our products to conform to Carboline quality control. We assume no responsibility for property damage or人身 injury resulting from use. Liability, if any, is limited to replacement of products. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY CARBOLINE. EXPRESS OR IMPLIED, STATUTORY, BY OPERATION OF LAW, OR OTHERWISE, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Carboline® and Carbocrylic® are registered trademarks of Carboline Company.

Carbocrylic® 3350

Application Equipment

Listed below are general equipment guidelines for the application of this product. Job site conditions may require modifications to these guidelines to achieve the desired results.

General Guidelines:

Spray Application (General)	The following spray equipment has been found suitable and is available from manufacturers such as Binks, DeVilbiss and Graco.
Conventional Spray	Pressure pot equipped with dual regulators, 3/8" I.D. minimum material hose, .043" I.D. fluid tip and appropriate air cap.
Airless Spray	Pump Ratio: 30:1 (min.) GPM Output: 3.0 (min.) Material Hose: 3/8" I.D. (min.) Tip Size: .015-.019" Output PSI: 1800-2100 Filter Size: 60 mesh Teflon packings are recommended and available from the pump manufacturer.
Brush & Roller (General)	Multiple coats may be required to achieve desired appearance, hiding and recommended dry film thickness. Avoid excessive re-brushing or re-rolling.
Brush	Use a synthetic bristle brush.
Roller	Use a short-nap synthetic roller cover with phenolic core.

Mixing & Thinning

Mixing	Power mix until uniform in consistency. Avoid excessive air entrapment.
Thinning	May be thinned up to 6 oz/gal (5%) with clean, potable water. Use of thinners other than those supplied or recommended by CarboLine may adversely affect product performance and void product warranty, whether expressed or implied.

Cleanup & Safety

Cleanup	Use clean potable water followed with suitable solvent to dry equipment. In case of spillage, absorb and dispose of in accordance with local applicable regulations.
Safety	Read and follow all caution statements on this product data sheet and on the MSDS for this product. Employ normal workmanlike safety precautions. Use adequate ventilation and wear gloves or use protective cream on face and hands if hypersensitive. Keep container closed when not in use.

Application Conditions

Condition	Material	Surface	Ambient	Humidity
Normal	60°-90°F (16°-32°C)	65°-85°F (18°-29°C)	65°-90°F (18°-32°C)	10-85%
Minimum	50°F (10°C)	50°F (10°C)	50°F (10°C)	0%
Maximum	100°F (38°C)	130°F (54°C)	120°F (49°C)	90%

Do not apply when the surface temperature is less than 5°F (3°C) above the dew point. Water-based products are sensitive to moisture during cure. Protect from rain for 72 hours at 75°F (24°C). Do not apply if temperatures are expected to drop below 50°F (10°C) within 24 hours of application. Condensation due to substrate temperatures below the dew point can cause flash rusting on prepared steel and interfere with proper adhesion to the substrate. Special application techniques may be required above or below normal application conditions.

Curing Schedule

Surface Temp. & 50% Relative Humidity	Dry to Touch	Dry to Topcoat
50°F (10°C)	8 Hours	8 Hours
60°F (16°C)	4 Hours	4 Hours
75°F (24°C)	2 Hours	2 Hours
90°F (32°C)	1 Hour	1 Hour

These times are based on a 2.0 mil (50 micron) dry film thickness. Higher film thickness, insufficient ventilation, high humidity or cooler temperatures will require longer cure times.

The acrylic film forming process may require several weeks at 75°F (24°C) with proper ventilation to develop adhesion and water resistance. High humidity, high film thickness, insufficient ventilation or cooler temperatures will lengthen the Dry to Touch and Dry to Topcoat times due to slower water evaporation rate. Waterborne acrylics are sensitive to moisture during early cure and are susceptible to handling damage.

Packaging, Handling & Storage

Shipping Weight (Approximate)	1 Gallon 12 lbs (5 kg)	5 Gallons 55 lbs (25 kg)
Flash Point (Setaflash)	>200°F (93°C)	
Storage (General)	Store Indoors. Keep from Freezing	
Storage Temperature & Humidity	40° -110°F (4°-43°C) 0-90% Relative Humidity	
Shelf Life	24 months at 75°F (24°C)	



July 2001 replaces April 2000

To the best of our knowledge the technical data contained herein is true and accurate on the date of publication and is subject to change without prior notice. User must contact CarboLine Company to verify correctness before specifying or ordering. No guarantee of accuracy is given or implied. We guarantee our products to conform to CarboLine quality control. We assume no responsibility for coverage, performance or injuries resulting from use. Liability, if any, is limited to replacement of products. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY CARBOLINE, EXPRESS OR IMPLIED, STATUTORY, BY OPERATION OF LAW, OR OTHERWISE, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. CarboLine® and Carbocrylic® are registered trademarks of CarboLine Company.

SECTION I - PRODUCT: CARBOCRYLIC 3350 (0257S1NL)

Date: 11/15/99 Replaces 09/14/99
(aka CARBOLINE 3350)CHEMTREC TRANSPORTATION EMERGENCY PHONE NO.: 800-424-9300
PITTSBURGH POISON CONTROL CENTER HEALTH EMERGENCY NO.: 412-681-6669

SECTION II - HAZARDOUS INGREDIENTS EXPOSURE LIMITS

CHEMICAL NAME	(A)	(B)	(C)	(D)	(E)
COLOR PIGMENT	MIXTURE		15% 3.5MG/M3	NE	NE
ALUMINUM SILICATE	1332-58-7		10% 10mg/m3	NE	NE
HEXYLENE GLYCOL	107-41-5		5% 25PPM	25PPM	25PPM

HAZARDOUS INGREDIENTS ADDITIONAL DATA

CHEMICAL NAME	(F)	(G)
COLOR PIGMENT	NOT AVAILABLE	NO/YES
ALUMINUM SILICATE	NOT AVAILABLE	NO/NO
HEXYLENE GLYCOL	NOT AVAILABLE	NO/NO

TABLE (A) CAS NUMBER (B) LESS THAN WT (C) TLV-TWA (D) STEL (E) CEILING (F)
 TOXICITY DATA (LD50/Route,LC50/Route) (G) SARA 302/SARA 313/ SARA 311-312
 CATEGORIES/CERCLA. NE = not established, NR = not required, NO = no. Color
 Pigment Mixture may contain Iron Oxides, Titanium Dioxide, Carbon Black,
 and other particulates not otherwise regulated in varying amounts depending
 on color of product.

WHMIS CLASSIFICATION: Not WHMIS Regulated

HMIS/NFPA CLASSIFICATION: HEALTH 1, FLAMMABILITY 1, REACTIVITY 0,
 PERSONAL PROTECTION CODE G, NFPA FIRE FIGHTING PHASE 2

SECTION III - PHYSICAL DATA:

BOILING RANGE: N/A. VAPOR DENSITY: N/A EVAPORATION RATE: N/A VOLATILE BY WEIGHT 51 %. VOLATILE BY VOLUME: 64 %. PRODUCT WT/GAL: 10.3 LBS/U.S.GAL. 1.24 sp gr.

SECTION IV - FIRE AND EXPLOSION HAZARD DATA:

FLAMMABILITY CLASSIFICATION: FLASH POINT: 301 F(149C) (Setaflash) LEL: N/A
 UEL: N/A

OSHA-COMBUSTIBLE LIQUID/OSHA/CLASS/IIIB, DOT-PAINT, NOT REGULATED, CANADIAN
 TDGA: NOT REGULATED

EXTINGUISHING MEDIA: Dry chemical, Foam, Carbon Dioxide, Water Fog.

UNUSUAL FIRE AND EXPLOSION HAZARDS: NONE

SECTION V - HEALTH HAZARD DATA:

INHALATION: Overexposure will be irritating to mucous membranes.

CONTACT: May cause eye irritation. May cause skin irritation.

MEDICAL CONDITIONS PRONE TO AGGRAVATION BY EXPOSURE: If you have a condition
 that could be aggravated by exposure to dust or organic vapors see a
 physician prior to use.

PRODUCT: CARBOCRYLIC 3350

(0257S1NL)

Date: 11/15/99 Replaces 09/14/99

PRIMARY ROUTE(S) OF ENTRY: Inhalation, Dermal, Ingestion.

EMERGENCY FIRST AID PROCEDURES: When exposed always get medical attention.

EYE CONTACT: Flush with water for 15 minutes.

SKIN CONTACT: Wash with soap and water. Remove contaminated clothing and clean before reuse.

INHALATION: Remove to fresh air. Provide oxygen if breathing is difficult. Use artificial respiration if not breathing. Get medical attention.

IF SWALLOWED: DO NOT INDUCE VOMITING!! Always get medical attention.

SECTION VI - REACTIVITY DATA:-----
STABILITY: This product is stable under normal storage conditions.

HAZARDOUS POLYMERIZATION: Will not occur under normal conditions.

HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide and unidentified organic compounds. Consider all smoke and fumes from burning material as very hazardous. Welding, cutting or abrasive grinding can create smoke and fumes. Do not breathe any smoke or fumes from these operations.

CONDITIONS TO AVOID: NONE

INCOMPATIBILITY: NONE

SECTION VII - SPILL OR LEAK PROCEDURES:-----
STEPS TO BE TAKEN IN CASE OF SPILL: If a leak or spill occurs contain the material. It can be allowed to dry or cure and presents no health or fire hazard. The material can then be removed and disposed of as non-hazardous waste. Before drying the material can be washed or removed using soap and water.**SECTION VIII - SAFE HANDLING AND USE INFORMATION:**-----
RESPIRATORY PROTECTION: Use with good ventilation.

SKIN AND EYE PROTECTION: Recommend gloves and safety glasses to avoid skin and eye contact. Hypersensitive persons should wear gloves or use protective cream.

HYGIENIC PRACTICES: Wash with soap and water before eating, drinking, or using toilet facilities. Launder contaminated clothing before reuse.

SECTION IX - SPECIAL PRECAUTIONS:-----
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Keep containers closed. Store in cool dry conditions.

OTHER PRECAUTIONS: Do not weld, heat, cut or drill on full or empty containers.

The information contained herein is, to the best of our knowledge and belief accurate. However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages incurred by use of this material. It is the responsibility of the user to comply with all applicable federal, state, and local laws and regulations.

PRODUCT: CARBOCRYLIC 3350 (0257S1NL)
Date: 11/15/99 Replaces 09/14/99

Carboline Company 350 Hanley Ind. Ct. St. Louis, MO 63144
PHONE NO. 314-644-1000 FOR INDUSTRIAL USE ONLY

CARBOLINE CO. MATERIAL SAFETY DATA SHEET
PRODUCT: CARBOCRYLIC 3350
Date: 11/15/99 Replaces 09/14/99

(0257S1NL)

SPECIFIC STATE REGULATORY INFORMATION

NEW JERSEY

PENNSYLVANIA

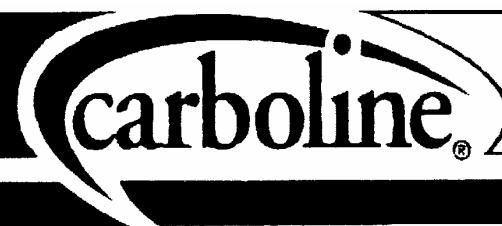
Non-Hazardous Materials above 1 Percent:

Name	CAS	Pct
WATER	7732-18-5	45%
ACRYLIC EMULSION	MIXTURE	25%
PROPYLENE GLYCOL	57-55-6	10%

CALIFORNIA

WARNING: This product contains a chemical(s)
known to the State of California to cause
cancer, and birth defects or other reproductive harm.

product data



Carbomastic® 90

Selection & Specification Data

Generic Type	Cycoaliphatic Amine Epoxy
Description	Economical, aluminum-pigmented mastic with excellent performance properties. Designed for the same broad range of applications as Carbomastic® 15, this material provides good corrosion resistance, film build and surface tolerance. Can be applied at lower temperatures and cures quicker than Carbomastic 15.
Features	<ul style="list-style-type: none">Very good performance over minimal surface preparationSuitable as a tie-coat/topcoat for most tightly adhered existing coatingsExcellent film build on edgesCan be applied at temperatures as low as 40°FVOC compliant to current AIM regulations
Color	Aluminum (C901); Red (M500)
Finish	Flat
Primers	Self-priming. May be applied over most tightly adhering coatings.
Topcoats	Acrylics, Alkyds, Epoxies, Polyurethanes
Dry Film Thickness	3.0 mils (75 microns) over existing coatings and 5.0 mils (125 micron) on rusted steel substrates. 8.0-10 mils (200-250 microns) in one or two coats for severe exposures and immersion conditions. Do not exceed 10.0 mils (250 microns) in a single coat.
Solids Content	By Volume: 90% ± 2%
Theoretical Coverage Rate	1444 mil ft ² (36.0 m ² /l at 25 microns) Allow for loss in mixing and application
VOC Values	As supplied: 0.7 lbs./gal (84 g/l) Thinned: 32 oz/gal w/ #2: 2.0 lbs./gal (237 g/l) 32 oz/gal w/ #10: 2.0 lbs./gal (240 g/l) 32 oz/gal w/ #33: 2.0 lbs./gal (245 g/l) 45 oz/gal w/ #2: 2.3 lbs./gal (282 g/l) These are nominal values. *Maximum thinning for 250 g/l restricted areas is 35 oz/gal for #2 and 33 oz/gal for #33. Use Thinner 76 up to 38 oz/gal where non-photochemically reactive solvents are required
Dry Temp. Resistance	Continuous: 180°F (82°C) Non-Continuous: 250°F (121°C) Discoloration is observed above 180°F (82°C).
Limitations	<ul style="list-style-type: none">Epoxies lose gloss, discolor and eventually chalk in sunlight exposure.

Substrates & Surface Preparation

General	Surfaces must be clean and dry. Employ adequate methods to remove dirt, dust, oil and all other contaminants that could interfere with adhesion of the coating.
Steel	Non-Immersion: SSPC-SP6 with a 2.0-3.0 mil (50-75 micron) surface profile for maximum protection. SSPC-SP2, SP3, or SP7 are also acceptable methods.
Galvanized Steel (Aged)	SSPC-SP1
Galvanized Steel (New)	SSPC-SP1 and prime with specific Carboline primers defined in <i>Market Guides</i> .
Previously Painted Surfaces	Lightly sand or abrade to roughen and degloss the surface. Existing paint must attain a minimum 3B rating in accordance with ASTM D3359 "X-Scribe" adhesion test.

Performance Data

Test Method	System	Results	Report #
ASTM D 522 Flexibility	1 ct CM 90	No cracking 8" cylindrical mandrel	ITL91-11-04783
ASTM D 1014 Outdoor Weathering	A.1 ct CM 90 over rusted steel (SP-2) B.1 ct. CM 90 Over abrasive blasted steel (SP-10)	No blistering and less than 1% rusting on either A & B systems.	08933
ASTM B 117 Salt Fog	2 coats CM 90 over rusted steel (SP-2)	No blistering, rusting, cracking or delamination, rust in scribe, no creepage from scribe.	02566
ASTM D 4060 Abrasion	2 coats CM 90	110 mg. loss CS-17 wheel, 1,000 gm. load, 1,000 cycles	08093

Test data available upon written request.

June 2002 replaces February 2002

To the best of our knowledge the technical data contained herein is true and accurate on the date of publication and is subject to change without prior notice. User must contact Carboline Company to verify correctness before specifying or ordering. No guarantee of accuracy is given or implied. We guarantee our products to conform to Carboline quality control. We assume no responsibility for coverage, performance or injuries resulting from use. Liability, if any, is limited to replacement of products. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY CARBOLINE. EXPRESS OR IMPLIED, STATUTORY, BY OPERATION OF LAW, OR OTHERWISE, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Carboline® and Carbomastic® are registered trademarks of Carboline Company.

Carbomastic® 90

Application Equipment

Listed below are general equipment guidelines for the application of this product. Job site conditions may require modifications to these guidelines to achieve the desired results.

General Guidelines:

Spray Application (General) The following spray equipment has been found suitable and is available from manufacturers such as Binks, DeVilbiss and Graco.

Conventional Spray Pressure pot equipped with dual regulators, 3/8" I.D. minimum material hose, .070" I.D. fluid tip and appropriate air cap.

Airless Spray Pump Ratio: 30:1 (min.)
GPM Output: 3.0 (min.)
Material Hose: 3/8" I.D. (min.)
Tip Size: .017-.021"
Output PSI: 1800-2200
Filter Size: 60 mesh
Teflon packings are recommended and available from the pump manufacturer.

Brush & Roller (General) Multiple coats may be required to obtain desired appearance, recommended dry film thickness and adequate hiding. Avoid excessive re-brushing or re-rolling.

Brush Use a medium bristle brush.

Roller Use a medium-nap synthetic roller cover with phenolic core.

Mixing & Thinning

Mixing Power mix separately, then combine and power mix.
DO NOT MIX PARTIAL KITS.

Ratio 1:1 Ratio (A to B)

Thinning* Spray: Up to 32 oz/gal (25%) with Thinner #2, and or Thinner #10.
Brush/Roll: Up to 32 oz/gal (25%) with #33 or 45 oz/gal (35%) with #2. Thinner #2 is used typically for cooler temperatures and Thinner #33 for hot/windy conditions. Use of thinners other than those supplied or recommended by CarboLine may adversely affect product performance and void product warranty, whether expressed or implied.
*See VOC values for thinning limits.

Pot Life 4 Hours at 75°F (24°C) and less at higher temperatures. Pot life ends when coating loses body and begins to sag.

Cleanup & Safety

Cleanup

Safety

Ventilation

Caution

Application Conditions

Condition	Material	Surface	Ambient	Humidity
Normal	60°-80°F (16°-27°C)	60°-80°F (16°-27°C)	60°-80°F (16°-27°C)	0-90%
Minimum	50°F (10°C)	40°F (5°C)	40°F (5°C)	
Maximum	90°F (32°C)	130°F (54°C)	100°F (49°C)	95%

This product simply requires the substrate temperature to be above the dew point. Condensation due to substrate temperatures below the dew point can cause flash rusting on prepared steel. Special application techniques may be required above or below normal application conditions.

Curing Schedule

Surface Temp. & 50% Relative Humidity	Dry to Handle	Dry to Recoat or Topcoat
40°F (10°C)	28 Hours	20 Hours
50°F (10°C)	24 Hours	18 Hours
60°F (16°C)	16 Hours	12 Hours
70°F (21°C)	10 Hours	8 Hours
80°F (27°C)	6 Hours	5 Hours
90°F (32°C)	4 Hours	3 Hours
100°F (32°C)	3 Hours	2 Hours

These times are based on a 5.0-8.0 mil (125-200 micron) dry film thickness. Higher film thickness, insufficient ventilation or cooler temperatures will require longer cure times and could result in solvent entrapment and premature failure. Maximum recoat/topcoat times are 30 days for epoxies and 90 days for polyurethanes at 75°F (24°C). Excessive humidity or condensation on the surface during curing can interfere with the cure, can cause discoloration and may result in a surface haze. Any haze or blush **must** be removed by water washing before recoating. If the maximum recoat time has been exceeded, the surface must be abraded by sweep blasting prior to the application of additional coats. Note: This product contains conductive pigments and cannot be holiday tested.

Packaging, Handling & Storage

Shipping Weight (Approximate)	<u>2 Gallon Kit</u> 29 lbs (13 kg)	<u>10 Gallon Kit</u> 143 lbs (65 kg)
Flash Point (Setaflash)	Part A: 72°F (22°C) Part B: 100°F (38°C)	
Storage (General)	Store Indoors.	
Storage Temperature & Humidity	40° - 110°F (4° - 43°C) 0-95% Relative Humidity	
Shelf Life	24 months at 75°F (24°C)	



350 Hanley Industrial Court St. Louis, MO 63144-1599
314-644-1000 314-644-4617 (fax) www.carboLine.com



SECTION I - PRODUCT: CARBOMASTIC 90 PART A (0191A1NL)

Date: 11/09/99 Replaces 08/21/97

(aka CARBOMASTIC 90 ALUMINUM PT A)

CHEMTREC TRANSPORTATION EMERGENCY PHONE NO.: 800-424-9300

PITTSBURGH POISON CONTROL CENTER HEALTH EMERGENCY NO.: 412-681-6669

SECTION II - HAZARDOUS INGREDIENTS EXPOSURE LIMITS

CHEMICAL NAME	(A)	(B)	(C)	(D)	(E)
SILICA	14808-60-7	35%	0.1MG/M3	NE	NE
EPOXY RESIN	25068-38-6	35%	NE	NE	NE
ALUMINUM	7429-90-5	10%	15MG/M3	NE	NE
TOLUENE	108-88-3	5%	50 PPM	150 PPM	NE

HAZARDOUS INGREDIENTS ADDITIONAL DATA

CHEMICAL NAME	(F)	(G)
SILICA	NOT AVAILABLE	NO/NO/NR/NO
EPOXY RESIN	11.4G/KG RAT, ORAL >20ML/KG SKIN, SENSITIZER	NO/NO/1,2
ALUMINUM	NOT AVAILABLE	NO/YES
TOLUENE	5.0 G/KG RAT ORAL, 14G/KG RABBIT DERMAL 8000 PPM/4HRS, RAT, INHALATION	NO/YES/1,2,3/ 1000#/U220

TABLE (A) CAS NUMBER (B) LESS THAN WT (C) TLV-TWA (D) STEL (E) CEILING (F) TOXICITY DATA (LD50/Route,LC50/Route) (G) SARA 302/SARA 313/ SARA 311-312 CATEGORIES/CERCLA. NE = not established, NR = not required, NO = no. Color Pigment Mixture may contain Iron Oxides, Titanium Dioxide, Carbon Black, and other particulates not otherwise regulated in varying amounts depending on color of product.

WHMIS CLASSIFICATION: B2 -- D2A -- D2B

HMIS/NFPA CLASSIFICATION: HEALTH 2, FLAMMABILITY 3, REACTIVITY 1, PERSONAL PROTECTION CODE G, NFPA FIRE FIGHTING PHASE 4

SECTION III - PHYSICAL DATA:

BOILING RANGE: 232F(111C)-232F(111C). VAPOR DENSITY: Heavier than air. EVAPORATION RATE: Slower than ether. VOLATILE BY WEIGHT 5 %. VOLATILE BY VOLUME: 10 %. PRODUCT WT/GAL: 13.0 LBS/U.S.GAL. 1.56 sp gr.

SECTION IV - FIRE AND EXPLOSION HAZARD DATA:

FLAMMABILITY CLASSIFICATION: FLASH POINT: 72 F(22C) (Setaflash) LEL 1.3 % UEL 7.1 %.

OSHA-FLAMMABLE LIQUID/OSHA/CLASS/1B, DOT-PAINT,3,UN1263,PGII, CANADIAN TDGA: PAINT,3,UN1263,PGII

EXTINGUISHING MEDIA: Dry Chemical, Foam, Carbon Dioxide, Water Fog.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Vapors are heavier than air and will accumulate. Vapors will form explosive concentrations with air. Vapors travel long distances and will flashback. Use mechanical ventilation when necessary to keep percent vapor below the "Lower Explosion Level" (LEL).

SPECIAL FIRE FIGHTING PROCEDURES: Evacuate hazard area of unprotected

PRODUCT: CARBOMASTIC 90 PART A (0191A1NL)
Date: 11/09/99 Replaces 08/21/97

personnel. Use a NIOSH approved self-contained breathing unit and complete body protection. Cool surrounding containers with water in case of fire exposure.

SECTION V - HEALTH HAZARD DATA:

INHALATION: Harmful if inhaled, may affect the brain or nervous system, causing dizziness, headache or nausea. May cause nose and throat irritation.

CONTACT: May cause eye irritation. May cause skin irritation. May cause allergic skin reaction.

NOTICE: Contains SILICA which can cause cancer. Risk of cancer depends on duration and level of exposure. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage.

MEDICAL CONDITIONS PRONE TO AGGRAVATION BY EXPOSURE: If sensitized to amines, epoxies or other chemicals do not use. See a physician if a medical condition exists.

PRIMARY ROUTE(S) OF ENTRY: Inhalation, Dermal, Ingestion.

EMERGENCY FIRST AID PROCEDURES: When exposed always get medical attention.

EYE CONTACT: Flush with water for 15 minutes.

SKIN CONTACT: Wash with soap and water. Remove contaminated clothing and clean before reuse.

INHALATION: Remove to fresh air. Provide oxygen if breathing is difficult. Use artificial respiration if not breathing. Get medical attention.

IF SWALLOWED: DO NOT INDUCE VOMITING!! Always get medical attention.

SECTION VI - REACTIVITY DATA:

STABILITY: This product is stable under normal storage conditions.

HAZARDOUS POLYMERIZATION: Will not occur under normal conditions.

HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide, nitrogen oxides, and unidentified organic compounds. Consider all smoke and fumes from burning material as very hazardous. Welding, cutting or abrasive grinding can create smoke and fumes. Do not breathe.

CONDITIONS TO AVOID: Heat, sparks, and open flames.

INCOMPATIBILITY: Avoid contact with strong oxidizing agents.

SECTION VII - SPILL OR LEAK PROCEDURES:

STEPS TO BE TAKEN IN CASE OF SPILL: Eliminate all ignition sources.

Handling equipment must be grounded to prevent sparking. Evacuate the area of unprotected personnel. Wear appropriate personal protection clothing and equipment. Follow safe handling and use guidelines in Section VIII. Contain and soak up residual with an absorbent (clay or sand). Take up absorbent material and seal tightly for proper disposal. Dispose of in accordance with local, state and federal regulations. Refer to Section II for Sara Title III and CERCLA information.

PRODUCT: CARBOMASTIC 90 PART A

(0191A1NL)

Date: 11/09/99 Replaces 08/21/97

SECTION VIII - SAFE HANDLING AND USE INFORMATION:

RESPIRATORY PROTECTION: Use only with ventilation to keep levels below exposure guidelines. (Section II). User should test and monitor exposure levels to insure all personnel are below guidelines. If not sure or if not able to monitor use MSHA/NIOSH approved supplied air respirator.

VENTILATION: Use explosion-proof ventilation when required to keep below health exposure guidelines and Lower Explosion Limit (LEL).

SKIN AND EYE PROTECTION: Recommend impervious gloves, clothing and safety glasses with side shields or chemical goggles to avoid skin and eye contact. If material penetrates to skin, change gloves and clothing.

HYGIENIC PRACTICES: Wash with soap and water before eating, drinking, applying cosmetics, or using toilet facilities. Use of a hand cleaner is recommended. Launder contaminated clothing before reuse. Leather shoes can absorb and pass through hazardous materials. Check shoes carefully after soaking before reuse.

SECTION IX - SPECIAL PRECAUTIONS:

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Keep away from heat, sparks, open flame, and strong oxidizing agents. Keep containers closed. Store in cool, dry place with adequate ventilation. If pouring or transferring materials, ground all containers and tools.

OTHER PRECAUTIONS: Do not weld, heat, cut or drill on full or empty containers.

The information contained herein is, to the best of our knowledge and belief accurate. However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages incurred by use of this material. It is the responsibility of the user to comply with all applicable federal, state, and local laws and regulations.

Carboline Company 350 Hanley Ind. Ct. St. Louis, MO 63144
PHONE NO. 314-644-1000 FOR INDUSTRIAL USE ONLY

CARBOLINE CO. MATERIAL SAFETY DATA SHEET
PRODUCT: CARBOMASTIC 90 PART A
Date: 11/09/99 Replaces 08/21/97

(0191A1NL)

SPECIFIC STATE REGULATORY INFORMATION

NEW JERSEY

PENNSYLVANIA

Non-Hazardous Materials above 1 Percent:

Name	CAS	Pct
SILICA AMORPHOUS	NE	15%
ALKYL PHTHALATE	68515-42-4	10%

CALIFORNIA

WARNING: This product contains a chemical(s)
known to the State of California to cause
cancer, and birth defects or other reproductive harm.

SECTION I - PRODUCT: CARBOMASTIC 90 PART B (0191B1NL)

Date: 11/09/99 Replaces 01/11/99

(aka CARBOMASTIC 90 ALUMINUM PT. B)

CHEMTREC TRANSPORTATION EMERGENCY PHONE NO.: 800-424-9300

PITTSBURGH POISON CONTROL CENTER HEALTH EMERGENCY NO.: 412-681-6669

SECTION II - HAZARDOUS INGREDIENTS EXPOSURE LIMITS

CHEMICAL NAME	(A)	(B)	(C)	(D)	(E)
SILICA	14808-60-7	35%	0.1MG/M3	NE	NE
CYCLOALIPHATIC AMINE TRADE SECRET		10%	NE	NE	NE
DIAMINOCYCLOHEXANE	694-83-7	5%	NE	NE	NE
ISOPROPANOL	67-63-0	5%	400 PPM	500 PPM	NE
N-BUTANOL	71-36-3	5%	NE	50PPM/SKIN	NE

HAZARDOUS INGREDIENTS ADDITIONAL DATA

CHEMICAL NAME	(F)	(G)
SILICA	NOT AVAILABLE	NO/NO/NR/NO
CYCLOALIPHATIC AMINE	1230 MG/KG ORAL RAT; 2000 MG/KG DERMAL	NO/NO/1,2
DIAMINOCYCLOHEXANE	750 MG/KG ORAL 160 MG/KG DERMAL	NO/NO
ISOPROPANOL	4720MG/KG RAT, ORAL 16000PPM/8HRS RAT, INHALATION	NO/NO/3
N-BUTANOL	2500MG/KG RAT, ORAL >800PPM/4HRS RAT, INHALATION	NO/YES/1,2,3/ 5000#/U140

TABLE (A) CAS NUMBER (B) LESS THAN WT (C) TLV-TWA (D) STEL (E) CEILING (F) TOXICITY DATA (LD50/Route, LC50/Route) (G) SARA 302/SARA 313/ SARA 311-312 CATEGORIES/CERCLA. NE = not established, NR = not required, NO = no. Color Pigment Mixture may contain Iron Oxides, Titanium Dioxide, Carbon Black, and other particulates not otherwise regulated in varying amounts depending on color of product.

WHMIS CLASSIFICATION: B3 -- D2A -- D2B -- E

HMIS/NFPA CLASSIFICATION: HEALTH 3, FLAMMABILITY 2, REACTIVITY 0, PERSONAL PROTECTION CODE G, NFPA FIRE FIGHTING PHASE 4

SECTION III - PHYSICAL DATA:

BOILING RANGE: 180F(82C)-243F(117C). VAPOR DENSITY: Heavier than air. EVAPORATION RATE: Slower than ether. VOLATILE BY WEIGHT 5 %. VOLATILE BY VOLUME: 10 %. PRODUCT WT/GAL: 13.9 LBS/U.S.GAL. 1.67 sp gr.

SECTION IV - FIRE AND EXPLOSION HAZARD DATA:

FLAMMABILITY CLASSIFICATION: FLASH POINT: 100 F(37C) (Setaflash) LEL 1.4 % UEL 12.7 %.

OSHA-FLAMMABLE LIQUID/OSHA/CLASS/II, DOT-PAINT, 3, UN1263, PGIII, CANADIAN TDGA: PAINT, 3, UN1263, PGIII

EXTINGUISHING MEDIA: Dry Chemical, Foam, Carbon Dioxide, Water Fog.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Vapors are heavier than air and will accumulate. Vapors will form explosive concentrations with air. Vapors

PRODUCT: CARBOMASTIC 90 PART B (0191B1NL)
Date: 11/09/99 Replaces 01/11/99

travel long distances and will flashback. Use mechanical ventilation when necessary to keep percent vapor below the "Lower Explosion Level" (LEL).
SPECIAL FIRE FIGHTING PROCEDURES: Evacuate hazard area of unprotected personnel. Use a NIOSH approved self-contained breathing unit and complete body protection. Cool surrounding containers with water in case of fire exposure.

SECTION V - HEALTH HAZARD DATA:

INHALATION: May cause allergic respiratory reaction, effects may be permanent. Harmful if inhaled, may affect the brain or nervous system, causing dizziness, headache or nausea. May cause nose and throat irritation. May cause lung irritation.

CONTACT: May be harmful if absorbed through the skin. Can cause eye burns. Can cause skin burns. Can cause allergic skin reaction.

NOTICE: Contains SILICA which can cause cancer. Risk of cancer depends on duration and level of exposure. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage.

MEDICAL CONDITIONS PRONE TO AGGRAVATION BY EXPOSURE: If you have a condition that could be aggravated by exposure to dust or organic vapors see a physician prior to use.

PRIMARY ROUTE(S) OF ENTRY: Inhalation, Dermal, Ingestion.

EMERGENCY FIRST AID PROCEDURES: When exposed always get medical attention.

EYE CONTACT: Flush with water for 15 minutes.

SKIN CONTACT: Wash with soap and water. Remove contaminated clothing and clean before reuse.

INHALATION: Remove to fresh air. Provide oxygen if breathing is difficult. Use artificial respiration if not breathing. Get medical attention.

IF SWALLOWED: DO NOT INDUCE VOMITING!! Always get medical attention.

SECTION VI - REACTIVITY DATA:

STABILITY: This product is stable under normal storage conditions.

HAZARDOUS POLYMERIZATION: Will not occur under normal conditions.

HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide, nitrogen oxides, and unidentified organic compounds. Consider all smoke and fumes from burning material as very hazardous. Welding, cutting or abrasive grinding can create smoke and fumes. Do not breathe.

CONDITIONS TO AVOID: Heat, sparks, and open flames.

INCOMPATIBILITY: Avoid contact with strong oxidizing agents.

SECTION VII - SPILL OR LEAK PROCEDURES:

STEPS TO BE TAKEN IN CASE OF SPILL: Eliminate all ignition sources.

Handling equipment must be grounded to prevent sparking. Evacuate the area of unprotected personnel. Wear appropriate personal protection clothing and equipment. Follow safe handling and use guidelines in Section VIII. Contain and soak up residual with an absorbent (clay or sand). Take up absorbent

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Date: 11/09/99 Replaces 01/11/99

material and seal tightly for proper disposal. Dispose of in accordance with local, state and federal regulations. Refer to Section II for Sara Title III and CERCLA information.

SECTION VIII - SAFE HANDLING AND USE INFORMATION:

RESPIRATORY PROTECTION: Use only with ventilation to keep levels below exposure guidelines. (Section II). User should test and monitor exposure levels to insure all personnel are below guidelines. If not sure or if not able to monitor use MSHA/NIOSH approved supplied air respirator.

VENTILATION: Use explosion-proof ventilation when required to keep below health exposure guidelines and Lower Explosion Limit (LEL).

SKIN AND EYE PROTECTION: Recommend impervious gloves, clothing and safety glasses with side shields or chemical goggles to avoid skin and eye contact. If material penetrates to skin, change gloves and clothing.

HYGIENIC PRACTICES: Wash with soap and water before eating, drinking, applying cosmetics, or using toilet facilities. Use of a hand cleaner is recommended. Launder contaminated clothing before reuse. Leather shoes can absorb and pass through hazardous materials. Check shoes carefully after soaking before reuse.

SECTION IX - SPECIAL PRECAUTIONS:

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Keep away from heat, sparks, open flame, and strong oxidizing agents. Keep containers closed. Store in cool, dry place with adequate ventilation. If pouring or transferring materials, ground all containers and tools.

OTHER PRECAUTIONS: Do not weld, heat, cut or drill on full or empty containers.

The information contained herein is, to the best of our knowledge and belief accurate. However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages incurred by use of this material. It is the responsibility of the user to comply with all applicable federal, state, and local laws and regulations.

Carboline Company 350 Hanley Ind. Ct. St. Louis, MO 63144
PHONE NO. 314-644-1000 FOR INDUSTRIAL USE ONLY

CARBOLINE CO. MATERIAL SAFETY DATA SHEET
PRODUCT: CARBOMASTIC 90 PART B
Date: 11/09/99 Replaces 01/11/99

(0191B1NL)

SPECIFIC STATE REGULATORY INFORMATION

NEW JERSEY

PENNSYLVANIA

Non-Hazardous Materials above 1 Percent:

Name	CAS	Pct
SILICA AMORPHOUS	NE	40%
BENZYL ALCOHOL	100-51-6	5%
POLYSTYRENE	9003-53-6	5%
HYDROCARBON RESIN	68648-87-3	5%
POLYMER SOLUTION	MIXTURE	5%

CALIFORNIA

WARNING: This product contains a chemical(s)
known to the State of California to cause
cancer, and birth defects or other reproductive harm.



Level 1

Chapter 5.3

Case Study 1-C

Case Study 1-C

Theory or Practice?

There is a debate in the coatings industry. Some people think inspectors are part of the **application team** and should be able to contribute knowledge of how equipment is set up and operated.

Others think inspectors are independent **quality controllers** and should be completely separate from the applicator and his/her problems. In this case, the inspectors need to understand when work complies with the specified requirements but don't need to understand the fine details of how they are applied.

Should the inspector be capable of operating blast cleaning or spray application equipment? What does your group think?

Answer **Yes** or **No** and give at least 3 reasons for your decision. Please write your answers on a flip chart.

Discussion time allowed = 20 minutes

Notes:





Level 1

Chapter 5.4

Panel Inspection

Panel Inspection

Each participant should now have his or her own fully coated practice panel. The purpose of this next exercise is to complete the inspection of panels by:

- Measuring final DFT
- Observing and reporting the finished condition of the coatings
- Performing holiday detection tests
- Making any other measurements or observation that may be appropriate
- Completing the assignment record (i.e., the inspector's logbook)

The following notes may be useful:

1. List all visible surface defects, including sags, runs, craters, orange peel, and pinholes.
2. Measure DFT accurately, remembering to calibrate the gauge, and record the correct number of measurements to demonstrate compliance with the specified standard.
3. Test for holidays at low voltage first and record results. Try testing at high voltage, but note that this may induce some irreversible changes to the coating, making further low-voltage tests inaccurate. Calculate and record the appropriate high voltage used.
4. Record the results of all inspection steps.





Level 1

Chapter 5.5

Coatings Technology

Coatings Technology

Earlier in the course we briefly discussed the way coatings cure. In this section, we'll consider the curing reaction in more detail.

Two categories of cure are generally recognized by the coating manufacturers:

- Nonconvertible coatings
- Convertible coatings

Nonconvertible (Solvent-Evaporation Cure) Coatings

Coatings that cure solely by solvent evaporation are made by dissolving a resin, such as a vinyl or chlorinated rubber, in a suitable solvent, such as xylol (xylene) or toluol (toluene).

When one of these materials is applied, it forms a film by simple evaporation of the solvent. The resin remains unchanged and can be redissolved by its original hydrocarbon solvent, no matter how old the film.

Evaporation-cure coatings should **not** be topcoated with a different type of coating containing a strong solvent, since the solvent may attack the base coating causing it to redissolve. Coatings of this type are also less resistant to chemical exposure and should not be applied where chemical contact is likely to degrade the coating film.

Evaporation-type coatings may be applied over a different type of base coat. For example, a vinyl coating can be applied to an epoxy basecoat; however, if the epoxy coating surface is hard and slick (as when fully cured), poor intercoat adhesion will result.

Since all the solvent must evaporate for the coating to be properly cured, evaporation-type coatings should **not** be applied too thickly. If applied too thickly, the coating is likely to have solvent trapped within the film. These pockets of trapped solvents will ultimately become voids as the solvent escapes and form a weakness in the coating integrity.

Some common coatings that cure by solvent evaporation alone include:

- **Chlorinated rubber**—an elastomer formed when natural rubber or a polyolefin is reacted with chlorine. These materials must be modified with other (more resistant) resins to obtain higher solids, reduced brittleness, and increased adhesion. These coatings are sometimes low in solids (though high-build formulations are available) and are generally applied in thin coats of 25 to 75 μm (1 to 3 mils) dry-film thickness. Chlorinated rubber coatings should not be used in an environment where they will be exposed to temperatures higher than 60°C (140°F).
- **Vinyl**—made by dissolving polyvinyl chloride copolymers in a suitable solvent such as MEK. Toluene and xylene are used as diluents with the MEK. Vinyls are also low in solids and must be applied in thin coats of 25 to 75 μm (1 to 3 mils) DFT.
- **Acrylics**—thermoplastic copolymers of acrylic acid and methacrylic acid, esters of these acids, or acrylonitrile. These materials can be combined with vinyls to improve color retention and exterior weatherability.
- **Bitumen**—hydrocarbon product that may occur in a natural state (as gilsonite) or as a residue from petroleum distillation. Asphalts are probably the best known bituminous products. Coal tar (coal-tar pitch) is a byproduct of the destructive distillation of coal. Asphalts and coal



tars used as coatings are generally heavy-bodied materials that are often described as *bituminous*. Asphalt coatings are made by dissolving the base material in an aliphatic hydrocarbon solvent, such as mineral spirits, while coal-tar coatings are made by dissolving coal-tar pitch in an aromatic hydrocarbon solvent, such as xylene or toluene. Both asphalt and coal-tar coatings may be successfully applied in thicker films, often 400 to 625 μm (15 to 25 mils) wet per coat.

In the United States, because of current federal, state, and local regulations regarding VOCs (volatile organic compounds), low-solids materials, such as chlorinated rubber and vinyl, are rapidly being removed from the market. In some parts of the industrial world, these coatings are still being used. However, with worldwide focus on environmental issues, some coating users believe that these two types of coatings may not be available at all in 10 years.

When used in a multiple-coat system, solvent evaporation coatings fuse together, forming a single solid film rather than a layered film. Ease of maintenance painting is considered to be a major advantage of these coatings.

Solvent evaporation coatings are generally considered to retain most of their initial properties unless chemical changes take place, such as ultraviolet effects, plasticizer migration, etc.

Coalescence/Evaporation-Cure Coatings

Coalescence is a special case of evaporation. In these types of coatings, tiny particles of resin are encapsulated in a soap-like material and then dispersed in water, which acts as a carrier rather than a true solvent. This type of blend is known as an *emulsion*.

When the water evaporates, the resin particles fuse together (*coalesce*), forming a stable coating film. These coatings, once cured, will **not** redisperse in water, though they may dissolve in strong solvent.

Coalescence/evaporation-cure coating types include:

- Acrylic/latex/emulsion
- Epoxy emulsion

Waterborne coatings, such as emulsions, are significant, since they allow formulation of VOC-compliant coatings using high-performance, chemically resistant resins. Resin blends used for coatings that can be called emulsions are generally high molecular weight. In the case of epoxy emulsions, the resin forms cross-links by curing, thereby achieving high molecular weight.

The high-molecular-weight resins also do not easily redissolve because of their higher molecular weight.

Items of particular concern when water-based emulsion coatings are used include the following:

- These coatings should not be exposed to moisture such as dew, rain, or spray before they are fully cured. Such exposure may cause streaking, wash-off and running, and inadequate protection of the substrate.
- Liquid components should not be exposed to freezing temperatures during shipment, storage, or application. Freezing can disrupt the emulsion and cause separation of the coating components.

Polymerization Cured Coatings

Polymerization occurs when two or more resin molecules combine to form a single, more complex molecule. Polymerization is a chemical reaction in

which a compound is formed from the joining of many similar chemical groups called *monomers*. The major characteristics of monomers are:

- They are inherently stable
- They are capable of linking together chemically

This joining together of monomers within a resin in the process called *polymerization* is the most common curing method of today's high-performance coatings.

Types of Polymerization

Four main types of polymerization can occur:

- Oxygen-induced
- Chemically induced
- Heat-induced
- Moisture-induced

It should be noted that other forms of induction reactions do exist, e.g., ultraviolet light is used to induce curing in some glues to bond glass together.

The polymerization may form long chain molecules (one-dimensional linking) or a more complex three-dimensional molecule (cross-linking). The result of such cross-linking is a rigid, three-dimensional molecular structure formed as a coating film on the substrate.

The more effective the cross-linking polymerization process is, the stronger and the more chemically resistant the cured resin becomes.

One example of polymerization is the joining of the monomer ethylene (C_2H_4) into the common polymer *Polyethylene* in which up to 1,400 ethylene monomer groups may be joined. Polyethylene is a thermoplastic material that may be used for coating buried pipes as



an extended sheath, as a sintered (heated) powder, or as a tape wrap.

Many resins used in coatings are partially developed polymers, which cure by completing the polymerization. Polymerization can describe the reaction used to produce synthetic resins, or it can describe the cure process of a coating after mixing and application.

An important characteristic of the polymerization process is the *Glass Transition Temperature* (Tg) of the completed (formed) polymer. Tg is related to the flow and brittle properties of the cured coating and is discussed in detail in the advanced module of this program.

With age, some additional polymerization continues, and the coating film becomes more glasslike, harder, and less resilient. This effect can be said to increase the Glass Transition Temperature.

Oxygen-Induced Polymerization Coatings

These types of coatings form a solid film by a process called *oxidative cross-linking* using atmospheric oxygen. There is some evaporation because solvents are added for ease of application.

The main ingredients in many oxidation types, such as alkyd coatings, are *vegetable oils*, such as linseed, tung, soybean, and dehydrated castor oil and *fish oils*, such as menhaden. Film formation depends on the oil reacting with oxygen to form a cross-linked structure. To speed up the reaction between the oil and oxygen, small amounts of metallic catalysts, called *driers*, are added during manufacturing. The usual driers are cobalt, lead, and manganese compounds.

Because film formation depends on oxygen in the air entering the wet film and reacting with the oil, curing can take a considerable amount of time. The time taken to form a solid film can vary from two to several days.

Since the oxygen in the air can enter the film only at the surface, there is a limit to the wet-film thickness (WFT) that may be applied. The maximum WFT achievable is around 125 μm (5 mils), equivalent with these coatings to 50 to 75 μm (2 to 3 mils) DFT. If the wet-film thickness is greater than this, the oxygen may not completely penetrate to the bottom of the wet film, resulting in a situation in which the film is solid at the top and liquid at the bottom. This can cause the film to pucker and wrinkle at the top and take a very long time to turn into a solid at the bottom.

Like most chemical reactions, the speed of the reaction is increased with an increase in temperature. Thus, the coating will dry faster in warmer temperatures. Because the reaction depends on oxygen from the air reaching the surface, a regular change of air over the surface will speed up the reaction.

On the other hand, if a thin film of moisture forms on the surface, because of humidity or other factors, the oxygen uptake will be slowed extending the drying time. Wax and oil contaminants will have a similar but more pronounced effect.

Manufacturers of oxidation-type coatings usually add a small amount of a material that prevents the oxygen reaction while the coating is stored in the can. This is usually effective only while the can is full and only for a stated shelf life. If some of the coating is removed and the can resealed, the coating will react with oxygen in the can to form a solid film skin on the top of the remaining coating. This must be entirely removed and the coating strained before the coating is used.

The oils used in oxidation-type coatings may react with alkali to form soap, a process known as *saponification*.

Oxidation-type coatings are generally not suitable for use in conditions where severe corrosion may be encountered. Oxidation-type coatings are also not suitable for application on alkaline surfaces, such as

new concrete or over zinc coatings such as inorganic zinc or hot-dip galvanizing, because they may saponify and become detached from the substrate.

Oxidation-cured coating films can be attacked by strong solvents, such as acetone, methyl ethyl ketone, ethyl acetate, etc. These solvents will cause the film to swell and wrinkle. It is generally not recommended that a dry film of an oxidation-type coating be over coated with a coating that contains strong solvents, such as the vinyls, epoxies, etc.

Types of coatings that cure by oxidation include:

- Alkyds
- Drying oils
- Epoxy ester
- Oil-modified urethane
- Oil-modified phenolic

Chemically Induced Polymerization Coatings

These coatings are formed when the resin is reacted with a curing agent, activator, converter, or catalyst. (Note: Some of us use the term *catalyst* to mean activator, curing agent, etc. In fact, a catalyst is used to start a chemical reaction, to accelerate it, or both, but it does not become part of the final product.)

Coatings that cure by chemically induced polymerization include:

- Epoxies
- Polyurethanes
- Vinyl wash primers (polyvinyl butyrate—PVB)



Heat-Induced Polymerization Coatings

Coatings that cure by heat-induced polymerization include:

- Phenolics
- Epoxy-modified phenolics
- Silicones

Some types of powder coatings, such as fusion-bonded epoxies, form another class of coatings that cure by heat polymerization. These are discussed in the advanced module of this program (Specialist Coatings).

Baked phenolic and most silicone coating films are formed when the resins are cross-linked upon being subjected to high temperatures, ranging from 95 to 245°C (203 to 473°F). This cross-linking process, known as the condensation reaction, is characterized by the release of water during the resin polymerization.

Hydrolysis

Coatings are cured by hydrolysis when the reactive resins combine with moisture from the air to form the hardened (chemically resistant) films. Some urethanes and some inorganic zinc coatings are formed by this process.

Coating Systems

Three main types of coating systems are common:

- Single-coat systems
- Multi-coat systems of the same generic type
- Multi-coat systems of different types



Single-Coat Systems

In a single-coat system, only one layer of coating is applied.

Single-coat systems are most commonly used:

- When a short life is all that is required, such as when structural steel is coated at the mill to protect it until it can be properly blast cleaned and coated later at the construction site
- When it is applied for purely decorative reasons, such as in painting the interior of a house or office building
- When the coating has been specifically formulated for one-coat application, as with coal-tar urethane or certain types of zinc-rich coatings

Some problems frequently encountered with one-coat systems include:

- Solvent entrapment
- Difficulty in maintaining specified coating thickness and uniformity
- Holidays and misses

More than most coating systems, single-coat systems would be significantly improved by the addition of a stripe coat to welds, edges, and corners, but this is unlikely to happen when the user has specifically chosen a one-coat system.

Multiple-Coat Systems

Multiple-coat systems may consist of more than one coat of the same coating material, generally applied in contrasting colors.



This type of system is frequently found when a coating can be formulated as both a primer and a topcoat. Many systems, including epoxy, are frequently applied this way.

The use of multiple barrier coats is the basis for the *impermeable coating concept*. All organic coatings are permeable to some degree.

Barrier coatings should be impervious to air, water, oxygen, carbon dioxide, and the passage of electrons and ions, forming an inert barrier over the surface. This type of coating is often used in immersion service and must be inert to chemicals contained or in the surrounding liquids.

Barrier coatings must:

- Resist the passage of electrical currents (i.e., have good high-dielectric strength)
- Have good adhesion to the underlying surface
- Be able to wet the surface well enough to prevent voids at the coating substrate interface
- Resist the absorption of water or other liquids

Multiple-coat systems may also consist of multiple applications of different types of coatings. This is the type of system most frequently found in structural steel application, such as on offshore platforms, which generally have two, and occasionally three, different types of coatings. An example of this type of system is a zinc-rich primer with epoxy topcoats or with epoxy intermediate and a urethane topcoat.

Types of Primers

Primers are a class of coating used within a multi-coat system. The primer is the first coating applied to the work piece. The functions of a primer include:



- To adhere to the substrate
- To provide a base or key for subsequent applications of coatings
- To protect the substrate against corrosion by acting as a corrosion inhibitor, a barrier coating, or a sacrificial coating

Primers are often known by the name of their pigmentation, since the pigment plays a significant, active role in the coating.

There are generally considered to be three types of primers: galvanic (or sacrificial), inhibitive, and barrier.

Galvanic/Sacrificial Primers

Galvanic primers have a high concentration of zinc dust and actively protect the steel substrate, much like zinc galvanizing. Zinc in electrical contact with steel will protect the steel by sacrificing itself, acting as an anode.

Galvanic primers provide electrochemical protection to the steel even if the steel is exposed at small discontinuities, such as breaks, scratches, etc. This protection will be localized and cannot extend for more than a fraction of an inch from the source of the zinc coating.

Inhibitive Primers

To create a rust-inhibitive primer, inhibitive pigments must be added to the coating during manufacture. Inhibitive pigments interact with corrosion-promoting influences (e.g., water vapor passing through a coating) to modify the chemical conditions at the substrate and thus inhibit (slow down or prevent) corrosion.

Frequently used inhibitive pigments are:

- Red lead



- Zinc phosphate
- Barium metaborate
- Strontium chromate
- Zinc chromate

Health and safety issues are particularly important with inhibitive primers, since many of the traditional inhibitors are based on heavy metals.

Barrier (Noninhibitive) Primers

These primers, like most coatings, form a protective barrier. Barrier primers range from highly cross-linked phenolic or epoxy types to a lacquer-type coating. The only difference between these primers and their topcoats is the modification of the formulation to improve surface wetting characteristics and, therefore, adhesion properties.

Intermediate Coats (Mid-Coats)

The mid-coats in a multi-coat system are typically added to the system to improve the barrier characteristics of the system.

All organic coatings are *permeable* to some extent and will allow some passage of water vapor, oxygen, and other vapors through the cured coating film. Naturally, some resins have better properties in this respect than others. Most coating systems will become more permeable as the amount of pigmentation is increased. The materials used for mid-coats often are modified by the addition of certain pigments (e.g., lamellar [flake-like] pigments) to increase their resistance to water permeation. Their DFT may also be increased by the use of inert fillers and thickening agents to give high-build properties.

Caution should be used in interpreting *high-build* as meaning automatically low permeability, since some



pigment shapes and quantities may encourage water vapor transfer by wicking.

Finish Coats

Finish coats are often chosen for their appearance. Good color retention, low levels of chalking, and good gloss are generally desired.

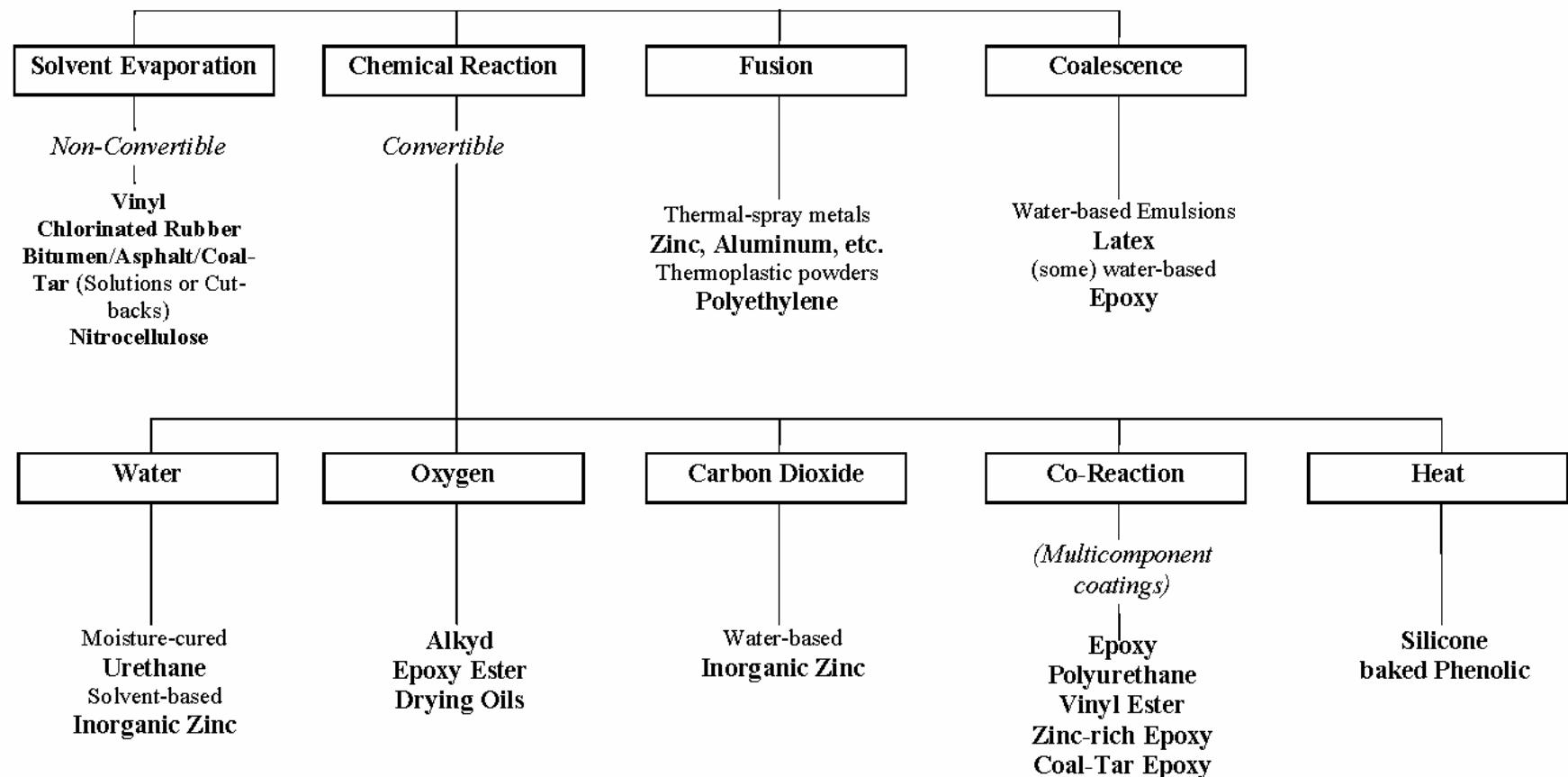
A smooth finish is necessary to discourage the retention of surface contamination and to allow rain to wash deposits away, which benefits both appearance and corrosion resistance. A smooth finish is best achieved for specific resins by using small quantities of nodular-type pigments.

In some exposures, increased chemical or solvent resistance may be beneficial; it can be achieved by selecting the correct finish coat.

Finally, good resistance to the ultraviolet (UV) component of sunlight is important to minimize degradation of the resin binder.



Film-Forming Mechanisms (Drying and / or Curing)



Coating Failures

Earlier we said that corrosion could be controlled in a combination of several ways, including:

- Design
- Materials selection
- Inhibitors
- Cathodic protection
- Protective coatings
- Alteration of the environment

The use of protective coatings is the most common method of protecting steel surfaces, regardless of the nature of the structure, whether it is a pipeline, ship, petrochemical plant, storage tank, or bridge.

Coatings are a complex mixture of interacting ingredients—chemical resins (binders), pigments, solvents, plasticizers, extenders, curing agents, and other modifiers.

Most are applied in thin films, usually 500 μm (20 mils) or less. These thin coatings must stay fluid long enough to wet the substrate properly and flow into a uniform film. The wet coating film must remain in place long enough to allow the solvents to evaporate and must develop a bond to the substrate while the material cures.

The cured coating is expected to isolate the surface of the structure from its corrosive environment, which can include rain, sun, wind, oxygen, whirling dust, airborne chemical contaminants or spillage, or a combination of these.

History has shown that coatings do not last forever; they age, weaken, and deteriorate, and eventually their



useful life ends. We can say that all coatings, organic or inorganic, eventually fail.

Coating failure occurs when the coating no longer provides the expected or intended service or protection. Premature coating failures may be defined as the breakdown or deterioration of a coating system or corrosion of the substrate more rapidly than expected for a particular in-service condition. This discussion will focus on failures that occur early in the life cycle of the coating system and are generally not anticipated.

Many coating failures are outside the control of the coating inspector, but their description is included here to enhance the inspector's awareness of the causes of premature failure.

Coating failures are discussed in several books and journals, and a comprehensive treatment of coating failures can be found in Munger's book *Corrosion Prevention by Protective Coatings* (NACE, 1997).

Failures and Their Correction

From a practical standpoint, there are two types of coating defects: those that can be corrected and repaired and those that cannot. An example of the first would be low film thickness, which (provided the coating has not cured) can generally be corrected by the addition of more coating. Another example might be holidays, or misses, which can be corrected by the addition of **extra** coats of paint, provided the coating has not cured and the defects are discovered before deterioration of the bare surface has progressed.

Defects that cannot be corrected, other than by removal of the affected coatings, include inadequate surface preparation, extensive blistering, and mudcracking. Another example of the latter is high film thickness which, contrary to popular belief, cannot be corrected by rubbing down with sandpaper until the DFT dimension is within the acceptable range. Film stresses created by the drying and curing process of coatings



with high film thickness cannot be corrected. Total removal of the coating in the affected areas is the only acceptable solution.

Premature Coating Failure

Coatings may fail prematurely for a number of reasons, including:

- Selection of the wrong coating
- Poor design or fabrication of the structure
- Coating formulation
- Improper surface preparation
- Bad application procedures and poor workmanship
- Application in adverse conditions
- Substrate-related problems
- Adhesion-related problems
- Lack of inspection and quality control

We will consider each of these reasons in turn. In addition, remedial steps will be suggested for each type of failure.

Selection of the Wrong Coating

Often a coating designed for use on specific surfaces may perform poorly or fail prematurely when applied over others. For example, polyurethane designed for application to concrete is likely to fail prematurely when applied directly to steel. Coatings should be selected to match the anticipated surface and environment.

The performance of any coating system is greatly influenced by the service exposure conditions. Failures are likely to occur if the service environment of the



coating system is not properly analyzed before the coatings are chosen.

Exposing of any coating to extreme conditions (i.e., those outside the known and predicted conditions) may also result in failure.

Responsibilities of the Specifier

Coatings may be selected based on:

- Known chemical composition and physical properties of the coatings
- Results of exposure tests of coatings under consideration
- Results of accelerated performance testing
- Known performance of coatings in similar environments

Many high-performance coatings can be used in a wide range of environments or exposures, but no one coating or coating system is resistant to all environments and service conditions.

Coatings are chosen for a specific service by a specifier. Specifiers (or users) should:

- Have a working knowledge of coatings
- Be familiar with the type of structure or surfaces to be coated
- Be aware of the intended or anticipated service for the coatings selected

Coatings should be matched to their anticipated service conditions or even chosen to exceed normal service to overcome possible upset conditions. For example, if a coating was to be used over a surface for which the normal operating temperature was to be 38°C (100°F) but where the temperature could conceivably reach



205°C (400°F), the specifier should select a coating that would withstand the higher temperature for a sustained period.

Some coatings are not compatible with all surfaces. For example, alkyds work well on steel but may saponify when applied over concrete or zinc coatings. If these surfaces are adjacent and the coating could be extended over both surfaces, then the specifier should recognize the boundary and select a coating suitable for both surfaces. The inspector should ensure the coating scheme is applied properly.

Failures have occurred in tanks (railcars, ships) where the lining was used for alternate cargoes of different materials. Properly selected coatings may work well with one cargo but be severely damaged by an alternate. For example, a tank lined with a coating designed to contain refined oil may hold up well to gasoline, diesel oil, and lube oil, but if deionized water were to be loaded in the vessel, severe blistering could occur causing the coating to fail.

Tank cars and tankers are often steam cleaned or washed with hot water when changing cargoes. The coating may withstand immersion in the cargo, but hot water or steam cleaning could cause blistering.

The specifier may be helped by a good working relationship with the coating suppliers (generally through their technical representatives) who are qualified to give sound technical assistance in the selection of coatings for anticipated conditions such as these. Care should be taken to evaluate the advice given for which some experience and expertise may be useful.

It would also be useful for the specifier to consider practical aspects of the application process. Some relevant factors include:



- Some coatings are easier to apply than others. Some coatings of the same type but made at different times or by a different manufacturer may have different application characteristics.
- Skilled labor may not be available to apply some modern coatings.
- Necessary equipment may not be available at the site location.

The pre-job conference is an ideal forum to review the coatings specified and their match-up with the anticipated service conditions. Materials used in recoating should be compatible with the original coating.

[Note: The subject of specifications and selection of coating systems is addressed in the Advanced module of this program.]

Poor Design or Fabrication of the Structure

Skip welds, sharp edges, crevices, back-to-back angles, and similar design problems may lead to early coating failures. These problems may result from lack of foresight at the design stage or may be due to poor practices by the fabricator.

Many structures are not designed with the coating process in mind. Design flaws and fabrication faults can easily complicate the procedures necessary to achieve a successful coating system.

Typical problem areas include:

Sharp Edges—may be rounded by grinding, but this may be an expensive and time-consuming option. The use of stripe coating may reduce the problem by adding extra coating thickness at the critical area.



Welds—Often, welds are not cleaned properly, leaving weld spatter, slag, and acid-flux residues. Weld areas, especially in tanks and vessels, should be cleaned, ground smooth or flush (depending on the operating conditions), and stripe coated. Grinding of welds, however, is not always advisable and should not be performed without consulting the structural engineer.

Skip welding—leaves gaps that will be difficult to coat and inevitably lead to rust staining. The most effective solution, although not foolproof, is to fill the gaps between welds with an appropriate caulking compound.

Temporary construction aids—designed to be removed after construction are sometimes left in place and become over coated along with the original coating application. In these cases, surface preparation or coating application may be less than ideal and early coating failure may occur. Construction aids, such as scaffolding, may also mask areas and prevent adequate coating. These aids should be removed, the surface properly prepared, and a proper coating applied to avoid a premature failure.

Poor drainage—Features that collect dirt or water may accelerate corrosion by restricting the run-off or drainage of water. Appropriate (immersion) coatings should be specified or drainage channels created

Poor ventilation—slows the dispersal of condensing moisture. A micro-climate of condensing vapors encourages corrosion and can create concentrations of corrosive liquids and perhaps bacterial growth. The potential for corrosion is greatly increased.

Applicators or inspectors cannot be held responsible for problems arising out of the work of designers, engineers, or fabricators. They can, however, provide a valuable service by helping to identify problem areas resulting from a particular design or from fabrication of the work piece. This assistance may result in



remedial action to solve the problem or modify future designs to avoid the problems.

When the design cannot be changed, the inspector, in the initial survey of the project, should document all design flaws and fabrication faults for review and evaluation at the pre-job meeting. If authorized, the inspector should ensure fabrication faults are corrected before surface preparation and coating operations begin.

Coating Formulation

If a coating is poorly formulated, it can fail early in service despite efforts to ensure quality application. Failures may occur because of the:

- Basic ingredients used (the resins, pigments, and solvents)
- Combination of ingredients in the coating formula
- Use of the wrong ingredients.

Some common failure modes are described below. All are directly related to the type and/or formulation of the coating. These failure modes may be the expected failure after many years or may happen prematurely when formulation is poor.

- Chalking
- Erosion
- Checking
- Alligatoring
- Cracking
- Wrinkling
- Bacteriological Failure



- Poor Formulation

Chalking

Chalking is a surface phenomenon, due largely to exposure to UV light generated by the sun and the action of the radiation on the organic binder. Coatings in shaded areas seldom chalk.

Along with the sun, such airborne reactants as oxygen, humidity, and pollution react with the resins in the binder, causing it to disintegrate and leave the pigments free on the surface. Rainfall washes the residues off and chalking continues.

Typically, amine-cured epoxies and epoxy esters chalk rapidly. Acrylics and acrylic-modified resins have good chalk-resistant properties since they are less affected by the sun's radiation.

Chalking can be controlled but not eliminated by the choice of pigments used to shield the resins from the sun. Leafing aluminum pigment, which overlaps in the paint film, is often chosen to protect the binder.

Chalking is not always considered to be coating failure; self-chalking coatings are sometimes specified to provide a constant (color) appearance through the life of architectural coatings.

Chalking may not be a serious problem, and typically the coating will continue to provide protection in most cases, even though it may look faded.

Erosion

Erosion is a surface effect often associated with chalking and is often seen in brush-applied coatings where the brush marks are exposed as the coating wears away.

More significant erosion can be caused by heavy rainfall, high winds, hail, or a combination of wind and rain; by sand erosion along beach areas; or by sandstorms in desert areas. Sand erosion by wave action creates an ongoing attack on coated bulkheads and pilings. Erosion of internal linings can be a significant problem in pipes carrying slurry or cooling water (with sand particles).

The same type of resistant resins and pigments mentioned earlier can be effective against erosion. Resins with some elastomeric quality may also be effective, providing resilience to combat the impact of the eroding particles.

Checking

Checking is identified by small breaks in the coating that form as the coating ages and becomes harder and more brittle. *Checking* is a surface phenomenon that does not go all the way to the substrate. It can be caused by the mixture of resins and pigments that are not properly combined during formulation. As the applied coating dries or continues to react, its surface becomes hard and brittle and surface stresses develop.

To minimize *checking*, the coating should be formulated with weather-resistant resins, nonreactive pigments that do not contribute to *checking*, long-lasting and stable plasticizers, and reinforcing pigments that reduce stress in the coating surface.

Some zinc coatings contain fibrous pigments to help prevent *checking* and often contain slower solvents to aid in controlling the drying and the *checking*. As with organic coatings, *checking* is initially a surface reaction, but in the case of inorganic zinc coatings small imperfections may heal because of the continuing curing reactions in the zinc-silicate film.

If coatings that have checked are not maintained, they eventually will fail as checks develop into cracks and expose the underlying surface.



Alligatoring

This can be considered a checking reaction in which the surface of the coating hardens and shrinks at a faster rate than the body of the coating itself. This is a macro-cracking type of failure caused by stresses set up in the surface of the coating.

Alligatoring, like checking, does not initially penetrate all the way through the coating and most often occurs where a hard, tough coating is applied over a softer, extensible coating. The harder material tends to shrink and float on the surface of the underlying softer material, with surface cracking in large segments.

Coal-tar coatings exposed to sunlight and weather tend to alligator, especially if applied thickly. The coal tar hardens on the surface, while the underlying area stays relatively soft.

Alligatoring can also occur when an air drying or a chemically cured coating is applied over a coated surface and heat is applied from the coated side, with rapid (temperature-induced) curing of the coated surface relative to the underlying material.

Alligatoring is most often a formulation-related failure and prevention is a matter of selection. The coating system selected should not specify a soft primer under a harder topcoat. The coating should be applied in thin coats, which should be allowed to cure before application of successive coats.

A rule of thumb might be: **Never** apply a hard coating that oxidizes or requires polymerization over a permanently softer or more rubbery primer.



Cracking

This formulation-related failure is due to premature aging or weathering and, unlike checking or alligatoring, the cracks break through the coating, extending to the substrate. Cracking is a much more serious type of failure than checking.

Checking results from stress on the coating surface, while cracking results from stress throughout the film and between the film and the substrate.

The use of proper resins, plasticizers, and pigments in coating formulation minimizes the tendency of the coating to crack. Fibrous or acicular (needle shaped) reinforcing pigments can help in reinforcing the coating against cracking. Plasticizers aid in softening the coating, allowing it to be more extensible and elastic, which tends to reduce the stress caused by temperature changes, weathering, and continued polymerization. Plasticizers tend to migrate from the film leading to embrittlement of coatings over time.

Cracking occurs as the coating ages, as it is subject to expansion and contraction, wetting and drying, etc. The thicker the applied film, the greater the stress within the film.

Oils and alkyds, which continue to oxidize or polymerize over a period of time, are more susceptible to cracking failure than fully polymerized vinyls and chlorinated rubbers.

Wrinkling

Wrinkling generally occurs when coatings are applied too thickly. It results from the swelling of a coating where the surface of the coating expands more rapidly during the drying period than the body of the coating.

Wrinkling occurs most often with oil-based coatings, alkyds, and similar materials, which contain driers (catalysts) to speed surface cure and other driers as through-drying materials. If a coating contains an excess of surface driers, wrinkling may occur wherever the coating is thicker than normal.

Temperature can influence wrinkling. Coatings that cure without wrinkling at ordinary application temperatures may wrinkle badly if curing is accelerated by baking, because an increase in temperature tends to cure the surface more rapidly than the body of the coating.

Wrinkling is likely to occur in cold weather when the thickened coating is applied so that a heavy film develops or in hot weather when the topcoat dries quickly but the coating underneath remains soft.

Bacteriological Failure

Bacteria and fungi are microorganisms that can act on coatings in two ways:

- Bacteria or fungi can merely live on contamination on the surface of the coating and do not necessarily affect its resistance.
- Microorganisms can use the coating for food and derive their energy from it. In many cases, the coating can be rapidly disintegrated by this type of action.

In the second case, the coatings are organic, usually alkyd- or oil-types, polyamide epoxies, or coatings that use biodegradable plasticizers. Most bacteria rely on oxygen in addition to the food of the coating material. Some exceptional types do not require oxygen, but generate it as part of the food conversion process. These are known as *anaerobic bacteria*, and are often found in tanks and vessels that have an accumulated sludge deposit.

Epoxies, including coal-tar epoxy, can be effective in sewage conditions or where moisture, bacteria, and fungi are active. Polyamide curing agents are more vulnerable than amine-type curing agents.

Fungus growth can be reduced or eliminated by using zinc oxide as part of the pigmentation, together with the addition of fungicides and bactericides in the formulation of the coating.

Fungus must be removed prior to over coating by scraping, power sanding, or light blasting. Washing with a mixture of detergent, trisodium phosphate, chlorine bleach (sodium hypochlorite), and water to clean the surface and kill fungus is also useful, preferably before other surface preparation. The treated surface then should be washed with clean water, containing sodium hypochlorite, and dried before over coating.

Poor Formulation

Failures can occur because of bad coating formulation. Many paint formulations are developed, some more successfully than others. The chemical formula may simply be untried or inadequately tested. Paint manufacturers have also been known to make mistakes, adding too much or too little of some component, using poor quality components, or even using the wrong component. These types of mistakes are rare, given the effectiveness of modern quality control, but do occur from time to time.

The coating manufacturer retains samples of each batch of coating made, but the prudent owner, specifier, or inspector may also choose to keep a sample of any coatings used for future reference. Analysis of formulation problems is much easier with a wet sample of coating than with dry flakes or scrapings.

Specific remedies for the failure modes we have discussed may include:



- **Chalking and Erosion:** Select coatings formulated with chalk-resistant binders and pigments that protect the binder. Over coat with such materials as acrylics, which are less susceptible to chalking.
- **Checking:** Select coating formulated with weather-resistant resins and reinforcing pigments. Apply in thin multiple passes.
- **Alligatoring:** Select a coating system that does not use a softer undercoat than topcoat. Apply in thin, multiple passes, and DO NOT apply any one coat too heavily. Allow successive coats to dry before over coating. Use caution in heating the coating surface, which will help to avoid surface curing before through-body curing can proceed properly. Avoid runs and sags.
- **Cracking:** Select coating formulated with nonreactive weather-resistant resins and reinforcing pigments. Apply in multiple thin passes; allow the underbody to dry adequately before over coating.
- **Wrinkling:** Select coating with a balance between surface driers and through-drying materials. Apply evenly and uniformly in multiple passes, especially in hot weather, to avoid surface curing. Allow each coat to dry before over coating. Do not apply too thickly, and avoid runs, sags, and puddling.

Improper Surface Preparation

Much has been said about the importance of proper surface preparation and the failure rate due to inadequate or improper surface preparation. Poor surface preparation or no preparation at all; the presence of such contaminants as soluble salts, condensation, mill scale, or oxides; or other surface-related problems can affect the life of the coating.



Coating adhesion is almost directly proportional to the cleanliness of the surface, with maximum adhesion being attainable on clean, dry, abrasive blast cleaned surfaces free of contamination.

Coating performance decreases down the ladder of surface cleanliness from white metal blast to only a solvent cleaned surface. Some coatings require white metal blast; others can perform well on a commercial blast cleaned surface, while still others are specially formulated for use on marginally prepared (e.g., hand cleaned) surfaces.

Abrasive blast cleaning is generally the most effective method of surface preparation. Sand, if used, should be free of clay to avoid leaving dust as a contaminant on the surface. For best results, a clean abrasive such as aluminum oxide can be used. The surface profile should be in the range suitable for the coating used.

Surfaces blasted with grit receive a strong angular profile, but if steel shot is used, the rounded profile decreases the opportunity for good coating adhesion.

The specifier, in selecting the coating systems for specific environments, must not only have a good working knowledge of coatings, but also must be aware of the surface preparation parameters for each coating.

Once the coating systems have been chosen, and as work commences, it is the responsibility of the inspector to ensure the surface preparation operations are performed effectively and in accordance with the specification.

Bad Application Procedures and Poor Workmanship

Bad application technique can cause failure. Typical problems resulting from faulty application techniques might include:



- Improper thickness
- Pinholes
- Overspray
- Holidays (discontinuities)
- Cratering (fisheyes)
- Poor workmanship
- Mudcracking
- Pinpoint rusting

Most application-related failures could be said to be due to carelessness or poor workmanship, though this may sound like harsh judgment. Poor workmanship refers to such practical issues as holding the spray gun too close to or too far away from the surface or at a significant angle to the surface being coated.

These matters are largely a question of training, or the lack of it, leading to a simple lack of understanding of what causes paint application problems. There is a significant need to improve the levels of training given to painters, particularly those who apply modern, high-performance coatings.

Some common problems are reviewed below.

Improper Thickness

If a coating is too thin, pinpoint corrosion can occur; if too thick, the coating can check, alligator, or crack. A high film thickness can result in more problems than a low film thickness because of the development of stress during the coating's drying and curing cycle. High DFT (in excess of the specified maximum) is more difficult to correct than low DFT since removal is the most effective solution.



Excessively thick coatings may retain solvent, leading to problems with cure and possibly to blistering in extreme cases. With polymerized coatings (particularly those intended to be applied at high DFT—500 µm [20 mils] per coat or more), there may be internal shrinkage due to the excessive thickness, leading to cracking, flaking, or delamination (loss of adhesion). It must be remembered that many of the newer, 100%-solids, polymerized coatings have relatively poor wetting and film-forming characteristics.

Care should be used to ensure that the application stays within the recommended parameters, particularly the DFT range.

Coating applicators often are not adequately instructed on acceptable thickness ranges for coatings they apply. There are many examples of manufacturers' technical data sheets that state a recommended DFT without addressing the need for a DFT range at all. Other specifications may require a narrow range of DFT that clearly cannot be achieved in real working conditions. One of the most important factors the applicator (and the inspector) should address is recognizing the limits of the acceptable DFT range for any specified coatings, preferably by stating a minimum and a maximum DFT for each coat.

Coatings should be applied in an even, uniform film, allowing the coating to wet the surface. Use thin, multiple passes with 50% overlap to achieve a uniform film and ultimately the final proper thickness.

Pinholes

Pinholes are small (visible) holes in a coating, usually caused by application of a thicker organic coating over a porous surface (e.g., coating epoxy over concrete or over inorganic zinc) or by holding the spray gun too close to the surface which can force bubbles into the coating.



Coatings with the wrong solvent balance may also suffer pinholing caused by the inability of solvent to escape from the rapidly curing coating. High ambient temperatures may also lead to pinholing since the film sets more rapidly.

Fast-drying coatings, such as vinyl or chlorinated rubber, are most likely to suffer pinholing. The fast-drying surface does not allow the air entrained in the paint as a result of spraying or the solvents to escape. The name often given to this effect is *gassing*.

The effect can often be seen after coating application as a form of bubbling, rather as if the surface is boiling. Some vapors may escape completely and the pinholes close as the coatings flow together. Any interruption of this process is likely to solidify the coating film before the necessary flow has taken place. The result may be seen as bubbles at the surface (not to be confused with blistering), as craters where the blisters have broken, or as pinholes where the craters have filled but the pinhole has not.

Applicators may apply a thin coating that can penetrate the porous substrate; these materials, when specially designed, are called *tie coats*. Alternatively, if allowable, thinning the first coating with up to 50% thinner may help penetration of the substrate and achieve better adhesion.

Applicators may simulate these specially adjusted coatings by applying a *mist coat* that is a thin layer of the specific coating applied in a fast pass and allowed to dry slightly before application of the full coat.

Proper adjustment of the spray equipment and spraying at an optimum distance to the substrate may also be effective. If pinholes occur during spraying, no attempt should be made to spray material into pinholes. It would be more practical to use a brush to work the coating into the surface (pinhole).



In extreme cases, it may be necessary to judge the time of application to minimize the tendency to pinhole. It has been known, for example, that painting concrete during the night, when temperatures are lower, reduces the gassing effects. The applicator must be sure the concrete is dry (i.e., not suffering from condensation) or lack of adhesion and blistering may result.

Overspray

Overspray usually leaves a rough surface that looks like abrasive dust in the surface of the coating. The effect of overspray is to perform exactly like a layer of dust. The overspray is poorly bonded to the painted surface and may, in some cases, provide sufficient dusting to prevent adequate bonding of the next layer of paint, leading to an adhesion weakness in the system. The problem may be compounded by the entrapment of real dust and other contaminants in the rough surface of the overspray prior to the next coating operation.

The applicator should ensure the spray gun is properly adjusted and apply coatings at the optimum distance to the surface, make certain the coating is fluid enough to wet the surface with good flow-out and apply coating in thin multiple passes, overlapping 50%.

Holidays (Discontinuities)

Holidays are bare spots, misses, or even thin spots in a coating where the substrate is uncoated. They are generally more significant when the coatings are linings intended for immersion service. Pinpoint corrosion can occur and premature coating failure is likely to be associated with any holiday.

Coatings should be applied in a smooth uniform film; the applicator must make certain all areas are coated, even hard-to-reach areas, and should overlap each spray pass 50%.

Note: Pinholes may also be defined as holidays.



Cratering (Fisheyes)

Localized thin areas, looking like craters distributed randomly over the surface, may be caused by oil on the surface or by oil in the spray-atomizing air. To prevent cratering, check to ensure absence of oil and check the surface for contamination. If fisheyes occur, roughen the cratered surface and apply another coat by brush, working coating into the cratered areas.

Poor Workmanship

This catch-all phrase can encompass many application faults, any one of which could cause or promote an active coating failure. Application of coatings over visible contamination, too thick, too thin, or with runs and sags could be corrected or avoided by better application techniques.

It is important for painters to be adequately trained to ensure they understand the nature of the coatings to be used, the effects of poor surface preparation on coating performance, and the effects of careless or improper application procedures. It is equally important for the applicators providing the training to be aware of these problems.

All paint applicators should be trained, and their training should be verified by the person for whom they are working. Training and certification programs for applicators are discussed in detail in the Advanced module of this program (Specifications).

Inspectors must have the skill and knowledge to recognize poor workmanship when they see it and the authority to remedy the problem. Without specific authority, inspectors can only report the problems and request action to resolve them.



Mudcracking

Mudcracking and alligatoring seem similar, except unlike alligatoring, mudcracking goes directly to the substrate and presents an immediate corrosion problem with possible chipping and flaking of coating from the surface.

Mudcracking occurs when highly filled coatings, particularly zinc-rich coatings, are applied too heavily, as could be shown by the presence of runs and sags. Highly filled water-based coatings sometimes fail by mudcracking, with the reaction occurring as soon as the solvent or water carrier begins to dry out of the coating. The more rapidly the solvent or water evaporates, the greater the likelihood mudcracking will occur.

Zinc-rich coatings often mudcrack. The reason is the high pigment/vehicle ratio and the nature of the zinc particles, which have poor reinforcing characteristics. The high pigment loading and low tensile binder lead to a high rate of shrinkage, particularly when drying is fast due to high ambient temperatures or when the coating thickness is high, leaving a mudcracked surface. The effect is seen quickly after application, often within minutes. There is no effective cure other than to remove the coatings and replace them.

Inorganic zinc (IOZ) coatings are made with silicate vehicles—alkali silicates or ethyl silicate. Neither of these silicates is a good film former and only after reaction with the zinc and the substrate do they develop a film with strength and adhesion. IOZ coatings are highly filled with powdered zinc metal and some other pigments, and the pigment/vehicle ratio is high. When the applied coating dries rapidly or unevenly, fine surface checking can occur.

Mudcracking can be prevented by a combination of coating selection and proper application. If fast-drying conditions exist or are expected, the user should avoid



highly filled water-based coatings. The coatings should be applied during more moderate drying conditions, in thin coats, without runs and sags.

There is no effective cure for mudcracking in zinc-silicate coatings other than removing the affected zinc and replacing it with other coatings. Overlap of zinc silicate onto zinc silicate is rarely effective. Some users recommend using organic zinc-rich primers to repair inorganic zinc that has mudcracked.

Pinpoint Rusting (or Flash Rusting)

Flash rusting frequently occurs when an inadequate thickness of primer coating has been applied and left to withstand the weathering process too long. Judging what is an inadequate thickness is a complex equation and depends on many factors, including the type of coating, the anchor profile, and the porosity of the coating (most primers are vulnerable in this respect).

It is good practice, however, to apply more than one coat of any system before allowing the unfinished work to stand for more than 2 or 3 days. This guideline depends on the ambient weather conditions and the degree to which the unfinished surface is exposed to the weather.

Flash rusting can occur with zinc coatings that have low zinc loading. In both cases, the amount of zinc available for corrosion protection is reduced and an early failure can result. Zinc primers with high zinc loading are known to resist flash rusting well, and thin coats of zinc are often used as prefabrication primers, particularly in the marine industry.

Brush application of primers is more likely to lead to pinpoint rusting because of the uneven distribution of the coating (i.e., low areas in the brush marks).

The pinpoint rusting effect can also be seen when water-based coatings are applied in adverse conditions. Water that cannot escape into the environment is likely

to remain in the coating, held next to the steel surface, causing rusting on the surface.

Application in Adverse Conditions

Coatings are not always applied in ideal conditions.

Substrate-Related Problems

Some coatings may fail because of incompatibility between the coating and the surface. The surface may be too smooth to allow good adhesion of the coating, or there may be a chemical reaction between the coating and the surface. One example of this effect is the saponification of oil-based coatings applied to concrete surfaces.

Types of Substrate

New Steel

The surface of hot-rolled steel normally is largely covered with mill scale, which is cathodic to bare steel, and its adherence to the steel may vary from tightly adherent to lightly adherent.

If the mill scale is over coated, failure of the coating can occur because of delamination of the mill scale from the steel surface. Mill scale aggravates corrosion through the action of an unfavorable area effect—large cathode/small anode.

Mill scale is relatively smooth, a factor that is much more significant for today's high-build, highly stressed coatings. For best results, new steel should be cleaned by abrasive blasting to remove mill scale and provide an anchor pattern for optimum coating adhesion.



Previously Used Steel

Generally, previously used steel is more difficult to clean than new steel and it quite often contains chemical contaminants that are not removed in the cleaning process.

Steel that has been exposed to atmospheric contamination (e.g., sulfates, chlorides) can pose a serious problem when cleaned and over coated. Even though the steel may appear to be properly blast cleaned and free of corrosion products, it can contain enough nonvisible contamination to create a surface unsuitable for coating. In extreme cases, heavily contaminated areas will, after blasting, absorb moisture from the air, turn dark, and deteriorate rapidly.

To remedy the problem, the steel could be cleaned by a series of successive high-pressure washes and blasting, followed by testing for soluble iron (ferrous) salts and chlorides to reduce their presence down to a level acceptable to the user. The dried or inhibitor-treated surface could then be coated with reasonable assurance of successful coating performance.

Galvanized or Zinc-Coated Surfaces

Zinc exposed to the atmosphere develops a passive film of zinc oxide, zinc carbonate, or both. Provided they are tightly adherent, these layers can aid adhesion because of their relative roughness.

Coatings applied to zinc surfaces must be provided with a firm substrate, which means that loosely adherent salts must be removed. In addition, the coatings must be compatible with the alkaline surface and should therefore be chosen with care.

Oil-based coatings, such as alkyds, epoxy esters, etc., perform poorly and tend to fail early when applied over galvanized or zinc-coated surfaces because of a reaction between the coating and the zinc surface. In some cases, saponification (soap formation) occurs,



causing degradation of the oil-based binder and loss of adhesion of the coating to the zinc surface.

Many alkyds produced today are modified alkyds, and these may be more resistant to saponification

The zinc surfaces should be brush blast cleaned or treated with a commercial zinc treatment (e.g., acid-etch primer or wash solution) to enhance coating performance, and the coating used should not, generally, be oil-based.

Aluminum or Aluminum-Coated Surfaces

Aluminum oxidizes in the atmosphere much like zinc (e.g., galvanizing and zinc-coated surfaces). It forms a passive film of aluminum oxide and should be lightly blasted or wire brushed to remove loosely adherent salts and then subjected to an aluminum treatment (e.g., etch primer) before coating. A primer with known compatibility and strong adherence to the clean surface should be selected.

Adequate cleaning of aluminum, wood, concrete, galvanizing, and steel (especially previously used steel) is essential to proper performance of the coating system selected.

Substrate Cleaning

New steel should be abrasive blast cleaned to remove all mill scale. Previously used steel should be free of contaminants.

Zinc, aluminum, copper, and galvanizing should be lightly blasted to remove metal oxides and other metallic salts that could interfere with proper bonding of the coating to the substrate.



Adhesion-Related Problems

Adhesion to the substrate is one of the most fundamentally important attributes of a coating. Poor adhesion can be serious and damaging. Long-term protection depends to a large extent on the continued adhesion of the coating to the substrate.

The stages of adhesion failure may include:

- Blistering
- Peeling
- Flaking
- Intercoat delamination

Poor adhesion may be caused by a number of factors. Poor surface preparation or the presence of soluble salts on the surface may lead to a loss of adhesion. Allowing intermediate coats to become contaminated before over coating is another common cause. Allowing chemically cured coatings to fully cure prior to over coating may also result in a lack of adhesion.

Blistering

Blistering may be caused by a number of coating problems. The characteristic that blistering areas have in common is that the blister develops first in localized spots where the adhesion is weakest. Blisters can be large or small and may exist in isolation or in groups. In any case, the result is likely to be that blisters develop in size, joining up to form larger areas of delaminated or detached coating. When opened, they may contain some liquid (particularly if formed in immersion service) but may be dry. The condition of the blister(s), when examined, may indicate the cause of the blistering.

Although blisters may be initiated by a number of causes, they are formed mostly due to the presence of



moisture vapor or other vapors, such as air or solvent, within the coating. The detachment of a coating in localized areas (i.e., blistering) may be at the coating-substrate interface, or may be between coating layers. It generally first appears when the vapor within the coating is expanded by elevated temperatures, as when a coating is heated in the morning sun after a night of low temperatures and wet conditions.

Among the causes of blistering are:

- Soluble pigments in the primer. Some pigments can absorb moisture vapor as it migrates through the film or even draw moisture into the film to feed their hygroscopic nature. Impervious coatings should be used for immersion service or in areas of high humidity.
- Soluble chemical salts. Where soluble chemical salts are left on the substrate or between coats, osmosis can occur, drawing more moisture into the coating.
- Other contaminants. Such contaminants as oils, waxes, or dirt on the substrate or on the surface of coatings to be over coated do not allow good adhesion. Moisture vapor migrating through the coating at these points is likely to exploit the local adhesion weakness, leading to blister formation.
- Incompatibility. Shop primers are often selected without knowledge of the type of topcoat to be used. If an unsuitable primer (e.g., alkyd universal primer) is used and is later over coated with a high-performance coating, the system may not have the necessary adhesion or physical properties to provide adequate adhesion for the high-performance coating. Solvents in some high-performance coatings can cause the primer to disbond from the substrate. A primer should be selected that is suitable for the coatings to be used subsequently.



- Other coatings may also be incompatible with similar results. Lack of adhesion between the coating layers may indicate that the first coating, prior to application of the second, has cured to an extent that the second coating cannot soften the first and create a bond. If the disbonding is at the substrate interface, the problem is not likely to be due to compatibility problems.
- Retained solvents. Blistering can be caused by inadequate solvent release by the coating. The retained solvents act like plasticizers, making the coating softer and more pliable. If the solvent is hygroscopic (i.e., water attracting), it can increase absorption of water and moisture-vapor transmission through the coating. Where coating adhesion is marginal or non-uniform, loss of adhesion can occur and blisters can develop.
- Cathodic protection. Cathodic protection (CP) systems are often used to supplement the coating system in submerged or buried service. Blistering is often associated with the relatively high voltages (or *overvoltage*) produced close to sacrificial anodes or when impressed current levels are set too high.

Part of the cause of blistering in these conditions is the development of hydrogen gas at the substrate, where the overvoltage reaches the steel. This is generally at an existing coating defect, such as at a pinhole or an area of low film thickness, where the CP system is able to focus its power to the detriment of the coating. Coatings to be used in conjunction with cathodic protection systems should be tested for their resistance to cathodic disbonding. They should have high adhesion strength and high dielectric strength (to resist passage of electrical current). Cathodic protection is discussed in more detail in the Advanced module of this program (Corrosion).



Intercoat Delamination

Delamination is the loss of adhesion between coats in a multi-coat system and is most common where repair or maintenance coatings are applied over cured coatings. Frequently, the user has no history of the coating system to be repaired and has conducted no tests for compatibility between the new and the old coating. New coatings applied over existing coatings may not be compatible with the previous coating, and delamination can occur.

Many users misjudge the complexity of a proper coating repair and maintenance procedure and often overlook the need to clean the old coating to remove all traces of chalk, dust, dirt, oil, grease, chemicals, etc., that could prevent the new coating from bonding.

Often, the repair work is carried out where there is considerable chemical fallout and contamination may be deposited on the original coating. Precautions should be taken to minimize the problem by cleaning adequately and by applying coatings as quickly as possible after the cleaning operation.

Another cause of intercoat delamination is the application of a coating over another coating that has fully cured. Polymerized coatings, such as epoxies, develop a hard, tough surface that—if the coatings are fully cured—must be abraded to allow a second coat to *bite* into the surface and develop good adhesion between coats.

Coal-tar epoxies are generally more difficult to over coat than regular epoxies because most are formulated to cure rapidly. In the United States, the most common formulation for coal tar (Army Corps of Engineers C-200) must be over coated within eight hours if successful bonding is to be achieved.

Some polyurethane coatings are also difficult to over coat once their full cure has been achieved. They are

highly polymerized and have a high-gloss surface. They should be over coated before the coat has fully cured. Once the surface has cured hard, it too must be abraded so it can receive another coat.

Some modern coating formulations have been specifically developed with a low cross-link density to reduce this problem.

Undercutting

Undercutting of a coating is the action of rust under the coating, usually forming around small breaks in the coating. The use of inhibitive pigments in primers is intended to prevent the spread of rust beneath apparently sound coatings. The modern trend toward the use of self-priming paints requires that the adhesion be maximized by adequate surface preparation.

With high-build coatings in particular, the cohesive strength of the coating is such that undercutting can proceed unnoticed until a massive failure becomes obvious. Generally, the greater the adhesion of a coating to the substrate, the less is the tendency for the coating to undercut.

Adhesion-Related Problems

Adhesion factors—blisters, peeling, flaking, and intercoat delamination—can lead to coating failures. Shop primers that are to be topcoated should be compatible with the topcoat selected and have sufficient bond to the substrate and to the topcoat to hold the topcoat tightly to the substrate.

Coatings should be applied in multiple passes and thinned enough to allow proper evaporation of the solvents as the coating dries and cures. Coatings for use on a porous surface should be thin enough to penetrate and fill the surface voids in the substrate.

Coatings that are applied at excessive thickness may subsequently delaminate. This is particularly true of



maintenance coatings, where continued application over many years may lead to very high thickness of the multi-coat system and subsequent loss of adhesion.

Cathodic protection is often used as a supplement to the coating system. Coatings for use with cathodic protection should be alkali resistant, have good bond strength to steel, and have good dielectric strength. The cathodic protection system should be designed to tolerate the coating, and efforts must be made to avoid an unfavorable current density that could cause blisters in the coating.

Lack of Inspection and Quality Control

Many application mistakes are made for no real reason other than lack of care. Inspection can provide the check that identifies the mistakes before they become significant and lead to failure.

Inspection and/or quality control should be performed by the applicator as work progresses. If lack of inspection creates problems, the solution may be to increase inspection (or quality control) activities. This can be achieved by more and better training of the operators, or by employment of specialist coating inspectors.

Conclusion

It should be emphasized that coating failure is a comparative term. All coatings fail. The question is: *Has the coating performed for an acceptable period, or has its life been shortened by one or more avoidable factors?* We are concerned only with coatings that do not meet their performance expectations.



Level 1

Chapter 5.6

Self-Study Questions

Chapter 5.5 – Coatings Technology

1. _____ is the way a coating goes from a liquid state to solid state.
2. True or False - The resin used in convertible coatings undergoes a change when the coating cures.
3. True or False - Coatings that cure solely by evaporation of the solvent can be re-dissolved in their original solvent.
4. In the curing process called coalescence, the resin particles _____.
5. Emulsion coatings generally should not be applied when the _____ is high.
6. The three main types of polymerization are _____ induced, _____ induced, and _____ induced.
7. Oxidative-cure coatings may _____ when applied over an alkaline surface.
8. Chemically-induced polymerization coatings cure when the resin is activated by a _____ or _____.
9. Fusion-bonded epoxy (_____) is an example of a coating that cures by _____-induced polymerization.
10. True or False - All organic coatings are permeable to some extent.

Part II – Coating Failures

1. Use of _____ is most common way to protect steel/concrete.
2. All coatings _____ eventually.
3. Coating failures occur _____ in the coating _____ and are _____.
4. Coating failures occur when the coating no longer _____.

5. Specifier should:
- Have a working _____ of _____
 - Be familiar with _____ of _____ to be coated
 - Be aware of _____ for coatings to be used
6. Alkyds should not be used over _____ or _____ coatings.
7. Cleaning with hot water or steam may damage coating and develop _____ in the coating.
8. True False - Contractor and inspector are responsible for problems resulting from design/ fabrication.
9. True False - Edges should not be stripe coated.
10. _____ can create areas inaccessible for coating.
11. Other design problems that lead to coating failures include:
- _____ metals
 - _____ in outer _____
12. True False - Chalking is the degradation of the binder resin.
13. _____ is slight breaks in the coating that do not extend to the substrate.
14. True False - It is okay to overcoat softer and more rubbery primer with a coating that cures by oxidation or polymerization.
15. True False - Checking results from stress on the coating surface.
16. True False - Cracking results from stress throughout the coating film and between film and substrate.
17. True False - Wrinkling usually occurs with thin film coatings.
18. True False - Some coatings may wrinkle when baked.
19. Some bacteria can _____ the coating.

20. True False - All bacteria must have oxygen to survive.
21. The most effective method of surface preparation is by _____.
22. True False - The specification should call for a minimum/maximum range of DFT.
23. Craters (fisheyes) may be caused by _____ on the surface, in the coating or in _____ air.
24. Mud cracking can occur with _____ and highly filled _____ coatings.
25. True False - Cathodic protection can cause blistering in coatings.
26. True False - Undercutting is the action of rust under the coating.



Level 1

Chapter 6.1

Case Study 1-D

Case Study 1-D

Razorback Petroleum, a large, independent oil refiner, was nearing completion of its \$200 million refinery expansion project. For years, the off-loading and crude oil storage facilities at Razorback's refinery on the sea coast had been inadequate.

Construction was in its final phase. In fact, the only task remaining was coating the four new million-gallon crude oil storage tanks.

Completion had originally been scheduled for the previous September. Various delays had occurred, and it was now early March of the following year.

Razorback had let the coating contract to Black Coatings, Inc., a locally known and highly respected coating applicator owned by Al Black.

John Simmons stared out over the hood of his pickup truck at the seemingly endless line of cars in front of him. "Just my luck to get put on assignment at the Channelside refinery," he muttered.

John regularly worked at one of Razorback's manufacturing plants that makes plastic products from waste byproducts collected from Razorback's refineries and other operations. Several years ago John had worked entirely in manufacturing quality control. When the plant shut down for major retooling and maintenance, he had been temporarily assigned to inspect some maintenance painting work.

One thing led to another. John had begun to appreciate the importance of a good coating job and how coatings could save Razorback thousands of dollars annually. John had been self-taught until recently, when Razorback sent him to an intensive training program on coating inspection.

It was no surprise at all to John when Ralph Stone, Razorback's quality assurance manager, assigned him to the Channelside project.

John remembered the telephone call as though it were just yesterday. In fact, it was just yesterday that he found out about his new assignment.

"Ralph always was one for surprises," John remarked to one of his coworkers. "He wants me to meet him up at the Channelside refinery tomorrow at eight o'clock sharp. Says he wants me to inspect the last part of the coating job at that new tank installation, and he wants me to be at the pre-job meeting."

Even though the sun had risen an hour earlier, the morning was still gloomy from a combination of fog and the air pollution that always seemed to surround the industries at Channelside. It was exactly 8:00 when John walked into the meeting room for the pre-job conference.

“Well, Gentlemen and Lady, it’s good to see you here this morning.” Ralph Stone did not have what could be called a commanding presence, but everyone listened intently when he brought the meeting to order. As quality assurance manager, Ralph was smart, tough, and well connected in the company; nobody wanted to get on his bad side.

“Most of you know each other, but I see some new faces. Let’s take a minute to introduce ourselves. I’m Ralph Stone, quality assurance manager here at Razorback’s Channelside Refinery.”

“Stan Layton. I’m Razorback’s lead design engineer on this project. Ralph asked me to sit in on this meeting in case any clarifications or changes to the coating spec are necessary. One of my new engineers wrote this spec, so we might have a few rough spots to iron out.”

“Jim Smith. I’m with Acme Contractors, the company that built the addition.”

“Bob Johnson, production manager. I’ll get to use this facility if it’s ever finished. These delays are costing Razorback a mint of money.”

“Ann Stevens, safety engineer. We’ve had 457 days without a lost time accident. I’d like to see us make 500, and I’ll be counting on all of you to follow the safety rules to help make that happen.”

“John Simmons. I’m with quality assurance at our plant over at Bayview. Ralph has had me assigned here to be the coating inspector on this job.”

“I’m Nate Beckley. Good to meet all of you! I’m a sales representative for Maxicoat Systems. We’re supplying all the coatings being used on this job.”

“George Schmidt, purchasing agent here at Channelside. I want to make sure this project doesn’t go over budget any more than it already has.”

Last to introduce himself was Al Black. “Al Black, here, owner of Black Coatings, Inc. George, you can count on us to bring this project home for exactly what we tendered. ‘Black Ink’--that’s our motto. Bob, we’ll have our end of this project done on schedule. You can count on us.”



Ralph Stone stood up and walked over to the blackboard at the front of the meeting room. “Thank you,” Ralph said. “I know that not all of you have had a chance to read the final coating spec. I have some copies here I’ll pass around. Let’s take a couple of minutes to read it. Then we’ll talk about anything that needs to be cleared up, and we’ll make sure we have all our assignments straight. John, I’d like you to take notes at this meeting and write up a report. Get it to my secretary to type and I’ll make sure everyone here gets a copy.”



Specification for Razorback Petroleum Channelside Refinery Storage Tanks

Specification: AN9-0266

Contract: #T149-03014

Prepared by: JCB

1.0 General Conditions

- 1.1 **Scope:** This specification describes the surface preparation, coating systems, and application requirements for coating crude oil storage tanks at the Razorback Petroleum Co. Channelside Refinery.
- 1.2 **Workmanship:** All work shall be performed in strict accordance with these specifications and the manufacturer's current printed instructions. Work shall be performed by skilled workers in a safe and workmanlike manner.
- 1.3 **Contractor:** The sole contractor for performance of this specification shall be Black Coatings, Inc., under the terms and conditions set forth in Razorback Petroleum Contract #T-149-03014.

1.4 Materials

1.4.1 **Coatings:** Coatings shall be as specified and manufactured by Maxicoat Systems, Inc., as set forth in Razorback Petroleum Contract #M-369-42307.

1.4.2 **Delivery and storage:** Materials shall be delivered to the site in the manufacturer's sealed containers bearing the manufacturer's labels identifying the type, color, batch number, and shelf life data. Materials shall be stored in a space designated by the plant manager. The space will be kept neat and clean, with temperature of not less than 10°C (50°F) and not more than 32°C (90°F).

2.0 Coating Schedule

The tanks to be coated under this specification are tank numbers A-413, A-414, A-415, and A-416.



3.0 Interior Tank Surfaces

3.1 Surface preparation prior to blast cleaning

- 3.1.1 Weld flux and spatter shall be removed by power tool cleaning.
- 3.1.2 Sharp projections shall be ground to a smooth contour.
- 3.1.3 Solvent clean in accordance with SSPC-SP 1 to remove oil and grease contamination just prior to blast cleaning.

3.2 Surface preparation

- 3.2.1 Blast surfaces in accordance with SSPC Specification No. 10, "Near-White Blast Cleaning."
- 3.2.2 Anchor pattern shall have a continuous etch 3.0 mil (75 μm) in depth.
- 3.2.3 Coat blasted surface immediately after cleaning.

3.3 Interior coating system

- 3.3.1 The coating used on all interior surfaces shall be coal tar epoxy.
- 3.3.2 The coating system shall be applied with at least two applications.
- 3.3.3 The finished system will have a DFT of 18 mil (450 μm).

3.4 Interior application

- 3.4.1 The coating shall be applied by air or airless spray in accordance with the manufacturer's current recommendations.
- 3.4.2 The finished coating shall be holiday free.

4.0 Exterior Tank Surfaces

4.1 Surface preparation prior to blast cleaning

- 4.1.1 Weld flux and splatter shall be removed by power tool cleaning.
- 4.1.2 Sharp projections shall be ground to a smooth contour.
- 4.1.3 Solvent clean in accordance with SSPC-SP 1 to remove oil and grease contamination just prior to blast cleaning.

4.2 Surface preparation

- 4.2.1 Blast surfaces in accordance with SSPC Specification No. 6, "Commercial Blast Cleaning."
- 4.2.2 Anchor pattern shall have a continuous etch 1.5 mil (37 μm) in depth.
- 4.2.3 Coat blasted surface immediately after cleaning.

4.3 Exterior coating system

- 4.3.1 The primer used shall be a catalyzed epoxy primer.
- 4.3.2 The primer shall be applied to yield a DFT of 4.0 mil (100 μm).

- 4.3.3 The coating used as an intermediate and topcoat shall be a catalyzed epoxy.
- 4.3.4 The intermediate and topcoat shall both be applied to yield a DFT of 4.0 mil (100 μm).
- 4.3.5 Total system DFT shall be 12 mil (300 μm)

4.4 **Exterior application**

- 4.4.1 The coating shall be applied by air or airless spray in accordance with the manufacturer's current recommendations.
- 4.4.2 The finished coating shall be holiday free.

5.0 **Inspection**

Razorback Petroleum shall appoint an inspector to ensure that the coating systems described in this specification are attained. Written reports shall be made of each inspection.

Maxicoat High-Build Coal-Tar Epoxy Data Sheet

Performance Information: Polyamide epoxy modified with coal tar for superior immersion characteristics. Suitable for application in vessels, railcars, splash zone or ballast tank applications. Do not use in potable water service.

Characteristics

Color: Black

Curing Mechanism: Cross-link polymerization

Spreading Rate (theoretical, no loss) 55 ft²/gal @ 28 mil wet, 1.34 m²/L

Recommended Film Thickness: 28 mil (700 µm) wet/coat (spray): 20 mil (500 µm) dry/coat

Spreading Rate Coverage @ 1.0 mil (25 µm) dry (theoretical, calculated): 1,140 ft²/gal (28 m²/L)

Volume Solids: 71% ± 2%

Weight Solids: 80% ± 2

Finish: Semi-Gloss

Application Conditions: Temperature (air surface, material): 13°C (55°F) minimum, 38°C (100°F) maximum

Relative Humidity: 90% maximum

Substrate Temperature: 3°C (5°F) above dew point

Drying Schedule touch dry, 8-10 h; to handle, 48 h; to recoat, 18 h min., 72 h max (temperature dependent) @ 25°C (77°F) and 50% RH @ 28 mil wet.

Pot Life: @ 21°C (70°F), 4 h; @ 38°C (100°F), 1 h

Flash Point (catalyzed) (Pensky-Martens closed cup): 43°C (110°F)

Thinner/Cleaner: Reducer #54, R7 K54

Shelf Life: Minimum 36 months (unopened)

Packaging: Part A: 3 gal in 5 gal can, Part B: 1 gal can (12 liters Part A, 4 liters Part B)

Weight (catalyzed): 10.4 ± .1 lb./gal (1.24 kg/L)

Shipping Weight: 46.5 lb./4 gal. Kit (16.7 kg/L)

Application: Conventional or airless spray only

Surface Preparation

When surfaces are in sound condition, remove fallout, oil, dirt, rust, and paint. Remove all surface contamination before applying subsequent coats. If a touch-up or second coat is to be applied more than 3 days after initial coat, High-Build Coal Tar Epoxy must first be roughened or brush blasted.

Steel: Atmospheric exposure: Minimum preparation is Commercial Blast Cleaning per SSPC-SP 6, median profile: 2 mil (50 µm)

Steel: Immersion Service: Near-White Blast per SSPC-SP 10, median profile: 3 mil (75 µm) Follow appropriate label instructions for surface preparation when Maxicoat High-Build Primer is to be used.

Application

By mechanical agitation thoroughly mix, by volume, 3 parts Part A with 1 part Part B. Allow one hour “sweat-in” at 24°C (75°F) or 45 min at 16°C (60°F). High-Build Coal Tar Epoxy will not dry if thorough mixing and proper instructions are not followed. Usable pot life is 4 h at 21°C (70°F) or 1 h at 38°C (100°F). Do not mix more material than can be used in this period. Catalyzed material cannot be mixed with fresh material. Provide adequate ventilation.

Moisture condensation and/or insufficient mixing of Part A and Part B may cause “browning” or a residue to form on the coating surface.

Apply by airless spray, cross-coating for maximum build. Cross-coat application by conventional spray will also produce high film builds. Small areas may be applied by brush or roller, although film builds will be lower.

Clean spray equipment before use with Reducer #54. Strong solvents in the material may loosen old residual paint and cause blocking of the equipment. Clean equipment before extending downtimes to eliminate blocking.

Holiday Detection: Use a wet sponge type detector, such as K-D Bird Dog or Tinker-Rasor @ 70 volts max. Do not use a high-voltage detector. Test only cured coatings, as solvent entrapment in fresh films may provide false readings.

Equipment - Conventional Spray: Atomization: 60 psi (4.2 kg/cm²), Fluid Pressure: 40 psi (2.8 kg/cm²), Gun: Devilbiss JGA or P-MBC, Tip/Cap: D/67, Hose: Fluid hose 3/8 in. (9.5 mm) minimum; air hose 1/2 in. (13 mm) minimum

Reduction: up to 12.5% thinner by volume after induction

Equipment - Airless Spray: Pump: 30:1 ratio with surge chamber, Fluid Pressure: 2,500 to 3,500 psi (176 – 246 kg/cm²), Strainer: None, Hose: 3/8 in. (9.5mm) ID (Teflon R), Gun: Rubberset: R G-10, Tip: .031 in. (0.78 mm), Reduction: None

Precautions:

Contents are FLAMMABLE. Keep away from heat, sparks and open flame. CONTAINS MEK, MIBK VAPOR HARMFUL. Avoid breathing vapor and spray mist. USE ONLY WITH ADEQUATE VENTILATION. Avoid contact with skin and eyes. Keep container closed when not in use. Do not transfer contents into other containers for storage.



Maxicoat Epoxy Primer Data Sheet

Performance Information: High performance, quick drying, inhibited primer for use with Maxicoat high-build epoxy coating systems. May be used in immersion service. Suitable for food grade service.

Characteristics

Color: Reddish brown

Curing Mechanism: Cross-link polymerization

Spreading Rate (theoretical, no loss): 200 ft²/gal @ 8 mil wet/4 mil dry (4.9 m²/L @ 200 µm wet, 100 µm dry)

Recommended Film Thickness: 8 mil (200 µm) wet/coat (brush, roll, or spray): 4 mil (100 µm) dry/coat

Spreading Rate Coverage @ 1.0 mil (25 µm) dry (theoretical, calculated): 870 ft²/gal (21.3 m²/L)

Volume Solids: 54% ± 2%

Weight Solids: 75% ± 2%

Gloss Finish: 35 ± 20 units @ 60°

Application Conditions:

Temperature (air surface, material): 10°C (50°F) minimum, 38°C (100°F) maximum

Relative Humidity: 85% maximum

Substrate Temperature: 3°C (5°F) above dew point/min. 10°C (50°F).

Drying Schedule (@ 9 mil [225 µm] wet) touch dry, 1 h; tack free, 4 h; @ 25°C (77°F) and 50% RH

Recoat interval 6 h; (dependent on temperature)

Lower temperature, higher RH,: humidity and addition of colorants will extend drying time. Requires minimum 2 weeks dry for complete cure and maximum resistance.

Pot Life: 8 h @ 25°C (77°F)

Flash Point (catalyzed) (Pensky-Martens closed cup): 38°C (100°F)

Thinner/Cleaner: Reducer R7 K54

Shelf Life: Minimum 36 months (unopened)

Packaging: 1- and 5-gal containers (5 L & 20 L)

Weight (catalyzed): 10.7 lb./gal (1.28 kg/L) ± 1%

Shipping Weight: 11.05 lb/gal (1.32 kg/L)

Number of Components: 2 (equal volume)

Application: Brush, roll, conventional, and airless spray

Surface Preparation:

Steel: Minimum surface preparation where no mill scale is present is power tool clean per SSPC-SP 3. For moderate and severely corrosive environments, minimum surface preparation is Commercial Blast per SSPC-SP 6. Median profile 1.5 to 2.0 mil. (37 - 50 µm) Surface should be primed immediately after blasting with catalyzed epoxy primer. One coat of primer at 4 mil (100 µm) DFT is preferred over blasted metal to avoid pinpoint rusting. Primed steel exposed to warm temperatures and exterior weathering must be topcoated within 30 days.

Always clean between coats of all contamination before applying subsequent coat.

Precautions:

Contents are FLAMMABLE. Keep away from heat, sparks, and open flame. Keep work area ventilated during use. Turn off electric tools and appliances, and any other sources of ignition. CONTAINS XYLENE, VAPOR HARMFUL. Avoid breathing vapor and spray mist. USE ONLY WITH ADEQUATE VENTILATION. Avoid contact with skin and eyes. Wash hands after using. Keep container closed when not in use. Do not transfer contents into other containers for storage.

Analysis (Part A):

Pigment by weight.....	58%
Zinc Phosphate	12%
Iron Dioxide.....	26%
Silicates.....	20%
Vehicle by weight.....	42%
Polyamide Resin.....	17%
Aromatic Hydrocarbons	18%
Alcohols	7%

Analysis (Hardener, Part B):

Phenolic Ether Resin	52%
Urea Resin	1%
Aromatic Hydrocarbons	38%
Glycol Ethers	9%



Maxicoat High-Build Epoxy Data Sheet

Performance Information: Long pot life for a full day's application. Available in a full gloss for easy maintenance and an eggshell sheen for best aesthetics. High build for economical application. Resists bacterial attack.

Characteristics

Colors: Unlimited; selected colors contain lead and cannot be used for domestic, institutional, educational, or recreational facilities.

Curing Mechanism: Cross-link polymerization

Spreading Rate (theoretical, no loss): 185 ft²/gal @ 4.0 mil dry (4.53 m²/L @ 100 µm)

Recommended Film Thickness (brush, roll, or spray): 8.7 mil (220 µm) wet/coat; 4.0 mil (100 µm) dry/coat

Spreading Rate Coverage (theoretical, calculated) @ 1.0 mil (25 µm) dry: 750 ft²/gal (18.4 m²/L)

Volume Solids (Pure Wht.): 46% ± 0.2%

Weight Solids (Pure Wht.): 65% ± 2%

Gloss Finish: 90 ± 10 units @ 60°; Eggshell: 35 ± 10 units @ 60°

Application Conditions:

Temperature (air surface, material): 13°C (55°F) minimum; 35°C (95°F) maximum

Relative Humidity: 85% maximum

Substrate Temperature: 3°C (5°F) above dew point, min. 13°C (55°F)

Drying Schedule (@ 8.7 mil (220 µm) wet) touch dry, 1 h; tack free, 4 h; @ 25°C (77°F) and 50% RH

Recoat interval 6 h; (dependent on temperature)

Lower temperature, higher RH,: humidity and addition of colorants will extend drying time; requires minimum 2 weeks dry for complete cure and maximum resistance.

Pot Life: 8 h. 25°C (77°F)

Flash Point (catalyzed) (Pensky-Martens closed cup): 32°C (90°F)

Reducer/Cleaner: Reducer #54, R7 K54

Shelf Life: 36 months (unopened)

Packaging: 1- and 5-gal containers (5 liter, 20 liter can)

Weight (catalyzed): 10.0 lbs/gal (1.19 kg/L) ± 1%

Shipping Weight: 21.8 lb/2 gal. kit, 106.2 lb/10 gal. kit: (6.3 kg/5 L kit, 25.2 kg/20 L kit)

Number of Components: 2 (equal volume)

Application: Brush, roll, conventional, and airless spray

Surface Preparation

Previously coated surfaces. Surfaces are to be cleaned as outlined on the data page for the appropriate recommended primer. When surfaces are in sound condition, remove fallout, oil, dirt, loose and peeling paint. Always clean contamination before applying subsequent coats.

Steel: Minimum surface preparation where no mill scale is present is power tool clean per SSPC-SP 3. Test previously painted surfaces for lifting or bleeding. If this occurs, Commercial Blast per SSPC-SP 6 Median profile: 1.5 - 2.0 mil (37 - 50 µm)

Precautions:

Contents are FLAMMABLE. Keep away from heat, sparks, and open flame. Keep work area ventilated during use. Turn off electric tools and appliances, and any other sources of ignition. CONTAINS XYLENE, VAPOR HARMFUL. Avoid breathing vapor and spray mist. USE ONLY WITH ADEQUATE VENTILATION. Avoid contact with skin and eyes. Wash hands after using. Keep container closed when not in use. Do not transfer contents into other containers for storage.

DO NOT TAKE INTERNALLY. KEEP OUT OF REACH OF CHILDREN. Selected colors contain lead. Do not apply on toys and other children's articles, furniture, or any interior surface of a dwelling or facility which may be occupied or used by children.

Analysis (Pure White, Part A):

Pigment by Weight.....	46%
Titanium Dioxide Type III	37%
Silicates.....	9%
Vehicle by Weight.....	54%
Polyamide Resin	20%
Aromatic Hydrocarbons	26%
Glycol Ethers	7%
Additives.....	1%

Analysis (Hardener, Part B):

Phenolic Ether Resin	52%
Urea Resin	1%
Aromatic Hydrocarbons	38%
Glycol Ethers	9%



Team Discussion Questions

Answer all four questions. Place answers on a flip chart

Time Allowed 1 hour, 40 minutes

1. What problems, if any, do you think may come about on this job as a result of enforcing the specifications as written?

2. What recommendations would you make if you were John?

3. What does John need to find out in the pre-job conference in addition to those points that must be clarified in the specifications?

4. What inspection equipment does John need to perform his job?

Glossary

Acid	Having a pH of less than 7; turns blue litmus paper red
Alligatoring	Breaks in the coating film which are wide and extensive, but which do not penetrate to the substrate
Alkaline	Having a pH of more than 7; turns red litmus paper blue
Aromatic Hydrocarbon	Aromatic: of, relating to, or characterized by the presence of at least one benzene ring — used to describe cyclic unsaturated hydrocarbons and their derivatives
Binder	The non-volatile part of a medium
Blistering	Isolated convex deformation of a paint film in the form of blisters arising from the detachment of one or more of the coats
Blooming	The formation of a thin film on the tip of a paint film thereby reducing the luster or veiling its depth of color
Blushing	The formation of a milky opalescence in clear finishes caused by deposition of moisture from the atmosphere and/or precipitation of one or more of the solid constituents of the finish
Body	Used to indicate the consistency of a paint
Catalyst	A substance whose presence increases the rate of a chemical reaction
Checking	Slight breaks in the surface of a paint film which do not render the underlying surface visible when the film is viewed at a magnification of ten times

irregular pattern type	Checking in which the breaks are in no definite pattern
line type	Checking in which the breaks are, in general, in parallel lines
crow-foot type	Checking in which the breaks are in a series of three-pronged formations in which the prongs radiate from a point with an angle of approximately 120° between prongs
Chipping	The removal of paint and surface contaminants from a substrate by means of impact from a sharpened tool
Coalescent	United to a whole; fused; grown together
Cobwebbing	The formation of fine filaments of partly dried paint during the spray application of a fast drying paint
Corrosion	The deterioration of a substrate (usually metal) or its properties because of a reaction with its environments
Cracking	Formation of breaks in a paint film that expose the underlying surface
irregular pattern type	Cracking in which the breaks are in no definite pattern
line type	Cracking in which the breaks are, in general, in parallel lines
sigmoid type	Cracking in which the breaks are in relatively large curves which meet and/or intersect
Crazing	The formation of minute criss-cross cracks on the surface of a paint film
	NOTE: Crazing resembles “checking” but the cracks are deeper and broader and exhibit a polygonal pattern resembling crazy paving
Crinkling	The development of wrinkles in a paint film during drying

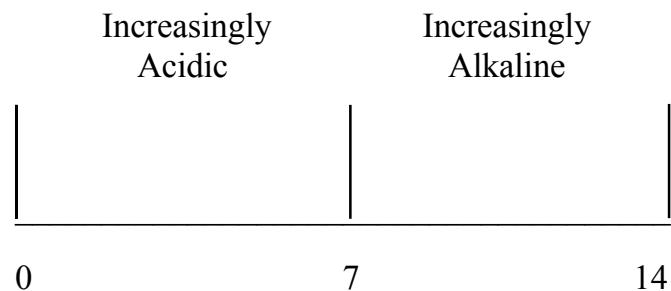
Curing Mechanism	The means by which the coating goes from a liquid to a dry film
Drier	A compound, usually organi-metallic and soluble in organic solvents and binders, which is added to paint to accelerate drying by catalytic oxidation
Drying Oil	An oil which possesses to a marked degree the property of readily taking up oxygen from the air and changing to a relatively hard, tough, elastic substance when exposed in a thin film to the air
Dry film Thickness (DFT)	The thickness of a coating after all the solvent has evaporated and the coating has cured
Ester	An often fragrant compound formed by the reaction between an acid and an alcohol
Evaporate	To convert from a liquid into vapor
Filler	A composition used for filling fine cracks and indentations to obtain a smooth finish preparatory to painting
Flattening Agent	A material added to paints, varnishes, etc. to reduce the gloss of the film
Gloss	The visual impression created by the reflecting properties of a surface
Grinning Through	The effect observed when a paint does not totally obscure the underlying surface
Hardener	A cross-linking agent used to cure a resin or paint system
Hiding Power	The ability of a paint to obliterate the color difference of a substrate; opacity
Holidays	Defects characterized by a film having areas of insufficient thickness, even to the point where parts of the surface may remain uncoated

Hydrolyzed	To undergo a chemical process of decomposition involving splitting of a bond and addition of the elements of water
Inhibitor	A material used in small proportion to slow a chemical reaction
Ketone	An organic compound; some of the more familiar ketone solvents are acetone and methyl ethyl ketone
Kick Out	Separation of constituents of a coating caused by addition of incorrect solvent
Leveling	The flowing out of a paint film after application so as to produce a level surface
Litmus	A chemical that turns red in acid solutions and blue in alkaline solutions and is used as an acid base indicator
Mastic	A heavy-bodied, paste-like coating often applied with a trowel to produce a thick, protective film
M Ohm	1,000,000 ohms
Non-Drying Oil	An oil which does not of itself possess to a perceptible degree the power to take up oxygen from the air and lose its liquid characteristics
Non-Volatile Vehicle	The total sum of the constituents of the liquid phase of the paint, not readily vaporizable at a relatively low temperature
Ohm	The standard unit of electrical resistance
Opacity	The ability of a paint to obliterate the color difference of a substrate; hiding power
Orange Peel	The pock-marked appearance of a sprayed film due to its failure to flow out to a level surface
Overspray	Sprayed paint which misses the surface to be coated
Oxidation	Combination of coating molecules with atmospheric oxygen

pH A description of the degree to which a substance is acid or alkaline; pH is expressed by means of a scale of 0 to 14, with 7 representing neutrality

As shown on the scale below, numbers less than 7 indicate acidity; the lower the number, the more acidic the substance

pH numbers greater than 7 indicate alkalinity; the higher the number the more alkaline the substance



Pigment A substance, generally in fine powder form, which is practically insoluble in media and which is physically dispersed in the binder to impart specific physical and chemical properties (optical, protective, decorative, etc.)

Pinholes Minute holes in a dry film which form during application and drying of paint

Plasticizer Chemical added, especially to rubbers and resins, to impart flexibility, workability, or stretchability

Polymer A chemical compound or mixture of compounds formed by polymerization

Polymerization A chemical reaction in which two or more small molecules combine to form larger molecules that contain repeating structural units of the original molecules

Primer The first coat of a painting system that helps bind subsequent coats to the substrate and which may inhibit its deterioration

Resin	A natural or synthetic material used to bind pigments together and to the substrate
Retarder	A slow evaporating solvent used as a thinner to slow down the speed of drying of a paint or lacquer to improve the application properties or produce a better film
Seeds	Undesirable particles or granules other than dues, found in a paint or varnish
Spreading Rate	Refers to the area, in square feet, which can be covered by one gallon of coating at a given Wet Film Thickness (WFT)
Solvent	A liquid, single or blended, which is volatile under normal drying conditions and in which the binder will dissolve completely
Streaking	The formation of irregular lines or streaks of various colors in a paint film caused by contamination of insufficient or improper incorporation of colorant
Substrate	The surface to which a coat of paint or varnish is applied
Teardrops	Drops of paint which collect on the bottom edges of items painted by dipping
Thinner	A volatile liquid, single or blended, added to paint to facilitate application by lowering the viscosity
Thixotropic	The property of a paint whereby the consistency is reduced on brushing or stirring by lowering the viscosity
Too Thick Coatings	Mil thickness is greater than specified; can result in blisters or other failures
Too Thin Coatings	Mil thickness less than specified; can result in premature coating failure

Vehicle

The total sum of the constituents of the liquid phase of the paint

Wet Film Thickness (WFT)

The thickness of a coating immediately after application, before any solvent has evaporated

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"'*)—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.

* C.W. Sisler, Monsanto Company, St. Louis, MO, chairman.

** P.E. Weaver, Dow Chemical Company, Houston, TX, chairman.

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 surface 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 controlling 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.

amines—organic substituted ammonia; organic compounds having an NH₂ group.

amino resins—those containing reactive NH₂ 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 occurring 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)—spray loss.

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 dissociates 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 damage.

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, mushrooms, smuts, etc.

furane resins—dark chemical resistant resins made from furfuryl alcohol, furfural and phenol.

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 assure 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 withstand 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; efflorescence.

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 Finish²—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 Finish²—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 Finish²—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 Surface Finish²—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; hydrocarbons 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-1, 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 character-

ized 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 occurring 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 substance can bear with-

out 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; surface 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 chloride—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)—arcng, 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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3. Industrial Maintenance Painting Program. Report of NACE Technical Unit Committee T-6D. Corrosion, 16, 301 (1960) June.

NACE Glossary of Corrosion Terms*

Corrosion—The deterioration of a substance usually a metal because of a reaction with its environment.

Aeration Cell—See *Differential Aeration Cell*.

****Aggressive Carbon Dioxide**—Free carbon dioxide in excess of the amount necessary to prevent precipitation of calcium as calcium carbonate.

Anaerobic—Free of uncombined oxygen.

Anion—A negatively charged ion or radical which migrates toward the anode under the influence of a potential gradient.

Anode—The electrode of an electrolytic cell at which a net oxidation reaction occurs. In corrosion processes, the anode is the electrode that has the greater tendency to go into solution.

****Anode Corrosion Efficiency**—The ratio of the actual corrosion of an anode to the theoretical corrosion calculated from the quantity of electricity which has passed.

****Anodic Polarization**—That portion of the polarization of a cell which occurs at the anode.

****Anolyte**—The electrolyte of an electrolytic cell adjacent to the anode.

Austenitic—The face-centered cubic crystal structure of ferrous metals.

Cathode—The electrode of an electrolytic cell at which a net reduction reaction occurs. In corrosion processes, the cathode is usually the area that is not attacked.

Cathodic Corrosion—An increase in corrosion of a metal by making it cathodic.

Cathodic Polarization—That portion of the polarization of a cell which occurs at the cathode.

****Cathodic Protection**—Reduction or prevention of corrosion of a metal surface by making it cathodic, for example, by the use of sacrificial anodes or impressed currents.

****Catholyte**—The electrolyte of an electrolytic cell adjacent to cathode.

Cation—A positively charged ion or radical which migrates toward the cathode under the influence of a potential gradient.

****Caustic Embrittlement**—Embrittlement of a metal resulting from contact with an alkaline solution.

****Cavitation Damage**—Damage of a material associated with the formation and collapse of cavities in the liquid at a solid-liquid interface.

****Chalking**—The development of loose removable powder at or just beneath a coating surface.

Chemical Conversion Coating—A protective or decorative coating produced in situ by chemical reaction of a metal with a chosen chemical solution.

Concentration Cell—An electrolytic cell, the emf of which is due to differences in composition of the electrolyte at anode and cathode areas.

Concentration Polarization—That portion of the polarization of an electrode produced by concentration changes at the metal-environment interface.

Contact Corrosion—See the preferred term *Crevice Corrosion*.

Corrosion—The deterioration of a substance usually a metal because of a reaction with its environment.

Corrosion Fatigue—Reduction of fatigue durability by a corrosive environment.

****Corrosion Fatigue Limit**—The maximum repeated stress endured by a metal without failure in a stated number of stress applications under defined conditions of corrosion and stressing.

Couple—A pair of dissimilar electronic conductors in electrical contact.

Crevice Corrosion—Localized corrosion as a result of the formation of a crevice between a metal and a nonmetal, or between two metal surfaces.

****Critical Humidity**—The relative humidity above which the atmo-

spheric corrosion rate of a given metal increases sharply.

Current Density—The current per unit area of electrode surfaces. Deactivation The process of removing active constituents from liquid as removal of oxygen from water.

Depolarization—Reduction or elimination of polarization by physical means or chemical changes in the environment.

****Deposit Attack (Deposition Corrosion)**—Corrosion occurring under or around a discontinuous deposit on a metallic surface.

Dezincification—Corrosion of a zinc-containing alloy, usually brass, involving loss of zinc, and a residue or deposit in situ of one or more less active constituents, usually copper.

Differential Aeration Cell—An electrolytic cell, the emf of which is due to a difference in oxygen concentration at two otherwise similar electrodes.

Drainage—Conduction of stray current from an underground metallic structure by means of a metallic conductor to another underground structure, usually by deliberate design. Forced Drainage requires an applied emf to secure the desired result.

Electrochemical Equivalent—The weight of an element or group of elements oxidized or reduced at 100% efficiency by a unit quantity of electricity.

****Electrolysis**—The production of chemical change in an electrolyte resulting from the passage of electricity.

Electrolyte—An ionic conductor (see Anion and Cation).

****Electrolytic Cleaning**—The process of degreasing or descaling a metal by making it an electrode in a suitable bath.

Electromotive Force Series—A list of elements arranged according to their standard electrode potentials.

Erosion—Deterioration by the abrasive action of fluids, usually accelerated by the presence of solid particles of matter in suspension. When deterioration is further increased by corrosion, the term erosion-corrosion is often used.

Exfoliation—Scaling off of a surface in flakes or layers, as a result of corrosion.

Fatigue—The tendency for a metal to fracture in a brittle manner under conditions of repeated cyclic stressing at stress levels below its tensile strength.

Ferritic—The body-centered cubic crystal structure of ferrous metals.

Filiform Corrosion—Corrosion that develops under organic coatings on metals as fine hairlines, usually curved, wavy or coiled, and randomly distributed.

Fretting—Deterioration resulting from repetitive slip at the interface between two surfaces in a corrosive environment.

Galvanic Cell—A cell in which chemical change is the source of electric energy. It usually consists of two dissimilar conductors in contact with each other and with an electrolyte, or two similar conductors in contact with each other and with dissimilar electrolytes.

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

Graphitic Corrosion—Corrosion of gray cast iron in which the metallic constituents are converted to corrosion products leaving the graphite intact.

Hydrogen Embrittlement—Embrittlement caused by entrance of hydrogen into the metal.

Hydrogen Overvoltage—Overvoltage associated with the liberation of hydrogen gas.

Impingement Attack—Localized erosion-corrosion resulting from turbulent or impinging flow of liquids.

Inhibitor—A substance which retards corrosion when added to an environment in small concentrations.

Interdendritic Corrosion—Corrosive attack which progresses preferentially along interdendritic paths.

Intergranular Corrosion—Corrosion which occurs preferentially at grain boundaries.

Internal Oxidation—See *Subsurface Corrosion*.

Ion—An electrically charged atom or group of atoms.

Local Action—Corrosion caused by local cells on a metal surface.

Local Cell—A galvanic cell resulting from inhomogeneities between areas on a metal surface in an electrolyte. The inhomogeneities may be of physical or chemical nature in either the metal or its environment.

Long-Line Current—Current flowing through the earth from an anodic to a cathodic area which returns along an underground metallic structure. Usually used only where the areas are separated by considerable distance and where the current results from galvanic cell action.

Mill Scale—The heavy oxide layer formed during hot fabrication or heat treatment of metals. Especially applied to iron and steel.

Noble Potential—A potential substantially cathodic to the standard hydrogen potential.

Open Circuit Potential—The measured potential of a cell with no current flows in the external circuit.

Overvoltage—The displacement of an electrode potential from its equilibrium (reversible) value because of flow current. (See also *Polarization*.)

Oxidation—Loss of electrons by a constituent of a chemical reaction.

Oxygen Concentration Cell—A galvanic cell resulting primarily from differences in oxygen concentration.

Parting—A term found in the older literature. The selective corrosion of one or more components of a solid solution alloy.

Passivation—The process or processes by means of which a metal becomes inert to a given environment or environments.

Passivator—An inhibitor which changes the potential of a metal appreciably to a more cathodic or noble value.

Passive-Active Cell—A cell, the emf of which is due to the poten-

tial difference between a metal in an active state and the same metal in a passive state.

Patina—A green coating which forms on the surface of copper or copper alloys exposed to the atmosphere a long time, consisting of basic sulfate, carbonate, or chloride, dependent on location.

Pickle—A solution or process used to loosen or remove corrosion products such as scale and tarnish from a metal.

Pitting—Localized corrosion taking the form of cavities at the surface.

Pitting Factor—The depth of the deepest pit resulting from corrosion divided by the average penetration as calculated from weight loss.

Polarization—The displacement of electrode potential resulting from the effects of current flow, measured with respect to either equilibrium (reversible) or steady state potentials.

Reduction—Gain of electrons by a constituent of a chemical reaction.

Rust—Corrosion product consisting primarily of hydrated iron oxide. A term properly applied only to iron and ferrous alloys.

Sacrificial Protection—Reduction or prevention of corrosion of a metal in an environment acting as an electrolyte by coupling it to another metal which is electrochemically more active in that particular electrolyte.

Scaling—1. The formation at high temperature of thick corrosion product layer(s) on a metal surface. 2. The deposition of water-insoluble constituents on a metal surface (as on the interior of water boilers).

Season Cracking—Cracking resulting from the combined effect of corrosion and internal stress. A term usually applied to stress corrosion cracking of brass.

Slushing Compound—A nondrying oil, grease, or similar organic compound which when coated over a metal, affords at least temporary protection against corrosion.

Spalling—The chipping, fragmenting, or separation of a surface or surface coating.

Standard Potential (*Standard Electrode Potential*)—The reversible potential for an electrode process when all products and reactants are at unit activity on a scale in which the potential for the standard hydrogen half-cell is zero.

****Stray Current Corrosion**—Corrosion caused by direct current through paths other than the intended circuit, for example, by any extraneous current in the earth.

Stress Corrosion Cracking—Spontaneous cracking produced by the

combined action of corrosion and static stress (*residual or applied*).

Subsurface Corrosion—Formation of isolated particles of corrosion product(s) beneath the metal surface. This results from the preferential reaction of certain alloy constituents by inward diffusion of oxygen, nitrogen, sulfur, etc. (internal oxidation).

Tarnish—Surface discoloration of a metal caused by formation of a thin film of corrosion product.

Thermogalvanic Corrosion—Corrosion resulting from a galvanic cell caused primarily by a thermal gradient.

****Tuberculation**—The formation of localized corrosion products scattered over the surface in the form of knob-like mounds.

Weld Decay—Localized corrosion at or adjacent to a weld.

* A revision of the glossaries entitled "Inter Society Corrosion Committee Glossary of Corrosion Terms" published in *CORROSION* Vol. 14, No. 2, 71t-72t (1958) February, and Vol. 14, No. 7, 319t-320t (1958) July (NACE Publications 58-5 and 58-9). Compiled by the Standard Definitions and Terminology Subcommittee of the Publication Committee, R.T. Foley, Chairman.

** Definition taken verbatim from Corrosion Handbook (H.H. Uhlig, editor) with permission of the publishers, John Wiley & Sons, New York (1948).

ANNEX 1

RESOLUTION MSC.215(82)

(adopted on 8 December 2006)

**PERFORMANCE STANDARD FOR PROTECTIVE COATINGS
FOR DEDICATED SEAWATER BALLAST TANKS IN ALL TYPES OF SHIPS
AND DOUBLE-SIDE SKIN SPACES OF BULK CARRIERS**

THE MARITIME SAFETY COMMITTEE,

RECALLING Article 28(b) of the Convention on the International Maritime Organization concerning the functions of the Committee,

NOTING the amendments to regulations II-1/3-2 and XII/6 of the International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended (hereinafter referred to as "the Convention") adopted by resolution MSC.216(82), concerning protective coatings of dedicated seawater ballast tanks and double-side skin spaces,

NOTING ALSO that the aforementioned regulation II-1/3-2 provides that the protective coatings referred to therein shall comply with the requirements of the Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (hereinafter referred to as "the Performance standard for protective coatings"),

RECOGNIZING that the Performance standard for protective coatings referred to above is not intended to inhibit the development of new or novel technologies which provide for alternative systems,

HAVING CONSIDERED, at its eighty-second session, the text of the proposed Performance standard for protective coatings,

1. ADOPTS the Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers, the text of which is set out in the Annex to the present resolution;
2. INVITES Contracting Governments to the Convention to note that the Performance standard for protective coatings will take effect on 1 July 2008 upon entry into force of the amendments to regulations II-1/3-2 and XII/6 of the Convention;
3. REQUESTS the Secretary-General to transmit certified copies of this resolution and the text of the Performance standard for protective coatings contained in the Annex to all Contracting Governments to the Convention;
4. FURTHER REQUESTS the Secretary-General to transmit copies of this resolution and the Annex to all Members of the Organization which are not Contracting Governments to the Convention;
5. INVITES Governments to encourage the development of novel technologies aimed at providing for alternative systems and to keep the Organization advised of any positive results.

ANNEX

PERFORMANCE STANDARD FOR PROTECTIVE COATINGS FOR DEDICATED SEAWATER BALLAST TANKS IN ALL TYPES OF SHIPS AND DOUBLE-SIDE SKIN SPACES OF BULK CARRIERS

1 PURPOSE

This Standard provides technical requirements for protective coatings in dedicated seawater ballast tanks of all type of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards¹ for which the building contract is placed, the keels of which are laid or which are delivered on or after the dates referred to in SOLAS regulation II-1/3-2 as adopted by resolution MSC.216(82).

2 DEFINITIONS

For the purpose of this Standard, the following definitions apply.

2.1 *Ballast tanks* are those as defined in the Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tanks (resolution A.798(19)) and the Guidelines on the enhanced programme of inspections during surveys of bulk carriers and oil tankers (resolution A.744(18), as amended).

2.2 *Dew point* is the temperature at which air is saturated with moisture.

2.3 *DFT* is dry film thickness.

2.4 *Dust* is loose particle matter present on a surface prepared for painting, arising from blast-cleaning or other surface preparation processes, or resulting from the action of the environment.

2.5 *Edge grinding* is the treatment of edge before secondary surface preparation.

2.6 “*GOOD*” condition is the condition with minor spot rusting as defined in resolution A.744(18).

2.7 *Hard coating* is a coating that chemically converts during its curing process or a non-convertible air drying coating which may be used for maintenance purposes. It can be either inorganic or organic.

2.8 *NDFT* is the nominal dry film thickness. A 90/10 practice means that 90% of all thickness measurements shall be greater than, or equal to, NDFT and none of the remaining 10% measurements shall be below $0.9 \times \text{NDFT}$.

2.9 *Primer coat* is the first coat of the coating system applied in the shipyard after shop-primer application.

¹ This Standard applies only to dedicated seawater ballast tanks in all types of ships and double-side skin spaces in bulk carriers which are constructed of steel.

2.10 *Shop-primer* is the prefabrication primer coating applied to steel plates, often in automatic plants (and before the first coat of a coating system).

2.11 *Stripe coating* is painting of edges, welds, hard to reach areas, etc., to ensure good paint adhesion and proper paint thickness in critical areas.

2.12 *Target useful life* is the target value, in years, of the durability for which the coating system is designed.

2.13 *Technical Data Sheet* is paint manufacturers' Product Data Sheet which contains detailed technical instruction and information relevant to the coating and its application.

3 GENERAL PRINCIPLES

3.1 The ability of the coating system to reach its target useful life depends on the type of coating system, steel preparation, application and coating inspection and maintenance. All these aspects contribute to the good performance of the coating system.

3.2 Inspection of surface preparation and coating processes shall be agreed upon between the shipowner, the shipyard and the coating manufacturer and presented to the Administration² for review. The Administration may, if it so requires, participate in the agreement process. Clear evidence of these inspections shall be reported and be included in the Coating Technical File (CTF) (see 3.4).

3.3 When considering the Standard provided in section 4, the following is to be taken into account:

- .1 it is essential that specifications, procedures and the various different steps in the coating application process (including, but not limited to, surface preparation) are strictly applied by the shipbuilder in order to prevent premature decay and/or deterioration of the coating system;
- .2 the coating performance can be improved by adopting measures at the ship design stage such as reducing scallops, using rolled profiles, avoiding complex geometric configurations and ensuring that the structural configuration permits easy access for tools and to facilitate cleaning, drainage and drying of the space to be coated; and
- .3 the coating performance standard provided in this document is based on experience from manufacturers, shipyards and ship operators; it is not intended to exclude suitable alternative coating systems, providing a performance at least equivalent to that specified in this Standard is demonstrated. Acceptance criteria for alternative systems are provided in section 8.

² In accordance with SOLAS regulation I/6, for the purposes of this Standard, the Administration may entrust a recognized organization acting on its behalf to determine compliance with the provisions of this Standard.

3.4 Coating Technical File

3.4.1 Specification of the coating system applied to the dedicated seawater ballast tanks and double-side skin spaces, record of the shipyard's and shipowner's coating work, detailed criteria for coating selection, job specifications, inspection, maintenance and repair³ shall be documented in the Coating Technical File (CTF), and the Coating Technical File shall be reviewed by the Administration.

3.4.2 *New construction stage*

The Coating Technical File shall contain at least the following items relating to this Standard and shall be delivered by the shipyard at new ship construction stage:

- .1 copy of Statement of Compliance or Type Approval Certificate;
- .2 copy of Technical Data Sheet, including:
 - .2.1 product name and identification mark and/or number;
 - .2.2 materials, components and composition of the coating system, colours;
 - .2.3 minimum and maximum dry film thickness;
 - .2.4 application methods, tools and/or machines;
 - .2.5 condition of surface to be coated (de-rusting grade, cleanliness, profile, etc.); and
 - .2.6 environmental limitations (temperature and humidity);
- .3 shipyard work records of coating application, including:
 - .3.1 applied actual space and area (in square metres) of each compartment;
 - .3.2 applied coating system;
 - .3.3 time of coating, thickness, number of layers, etc.;
 - .3.4 ambient condition during coating; and
 - .3.5 method of surface preparation;
- .4 procedures for inspection and repair of coating system during ship construction;
- .5 coating log issued by the coating inspector, stating that the coating was applied in accordance with the specifications to the satisfaction of the coating supplier representative and specifying deviations from the specifications (example of daily log and non-conformity report (see annex 2));
- .6 shipyard's verified inspection report, including:
 - .6.1 completion date of inspection;
 - .6.2 result of inspection;
 - .6.3 remarks (if given); and
 - .6.4 inspector signature; and

³ Guidelines to be developed by the Organization.

.7 procedures for in-service maintenance and repair of coating system.

3.4.3 *In-service maintenance, repair and partial re-coating*

In-service maintenance, repair and partial re-coating activities shall be recorded in the Coating Technical File in accordance with the relevant section of the Guidelines for coating maintenance and repair⁴.

3.4.4 *Re-coating*

If a full re-coating is carried out, the items specified in 3.4.2 shall be recorded in the Coating Technical File.

3.4.5 The Coating Technical File shall be kept on board and maintained throughout the life of the ship.

3.5 Health and safety

The shipyard is responsible for implementation of national regulations to ensure the health and safety of individuals and to minimize the risk of fire and explosion.

4 COATING STANDARD

4.1 Performance standard

This Standard is based on specifications and requirements which intend to provide a target useful coating life of 15 years, which is considered to be the time period, from initial application, over which the coating system is intended to remain in “GOOD” condition. The actual useful life will vary, depending on numerous variables including actual conditions encountered in service.

4.2 Standard application

Protective coatings for dedicated seawater ballast tanks of all ship types and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards shall at least comply with the requirements in this Standard.

4.3 Special application

4.3.1 This Standard covers protective coating requirements for the ship’s steel structure. It is noted that other independent items are fitted within the tanks to which coatings are applied to provide protection against corrosion.

⁴ Guidelines to be developed by the Organization.

4.3.2 It is recommended that this Standard is applied, to the extent possible, to those portions of permanent means of access provided for inspection not integral to the ship's structure, such as rails, independent platforms, ladders, etc. Other equivalent methods of providing corrosion protection for the non-integral items may also be used, provided they do not impair the performance of the coatings of the surrounding structure. Access arrangements that are integral to the ship structure, such as increased stiffener depths for walkways, stringers, etc., are to fully comply with this Standard.

4.3.3 It is also recommended that supports for piping, measuring devices, etc., be coated in accordance with the non-integral items indicated in 4.3.2.

4.4 Basic coating requirements

4.4.1 The requirements for protective coating systems to be applied at ship construction for dedicated seawater ballast tanks of all ship types and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards meeting the performance standard specified in 4.1 are listed in table 1.

4.4.2 Coating manufacturers shall provide a specification of the protective coating system to satisfy the requirements of table 1.

4.4.3 The Administration shall verify the Technical Data Sheet and Statement of Compliance or Type Approval Certificate for the protective coating system.

4.4.4 The shipyard shall apply the protective coating in accordance with the verified Technical Data Sheet and its own verified application procedures.

Table 1 – Basic coating system requirements for dedicated seawater ballast tanks of all type of ships and double-side skin spaces of bulk carriers of 150 m and upwards

Characteristic/ Reference standards	Requirement
1 Design of coating system	
.1 Selection of the coating system	<p>The selection of the coating system shall be considered by the parties involved with respect to the service conditions and planned maintenance. The following aspects, among other things shall be considered:</p> <ul style="list-style-type: none"> .1 location of space relative to heated surfaces; .2 frequency of ballasting and deballasting operations; .3 required surface conditions; .4 required surface cleanliness and dryness; and .5 supplementary cathodic protections, if any (where coating is supplemented by cathodic protection, the coating shall be compatible with the cathodic protection system). <p>Coating manufacturers shall have products with documented satisfactory performance records and technical data sheets. The manufacturers shall also be capable of rendering adequate technical assistance. Performance records, technical data sheet and technical assistance (if given) shall be recorded in the Coating Technical File.</p> <p>Coatings for application underneath sun-heated decks or on bulkheads forming boundaries of heated spaces shall be able to withstand repeated heating and/or cooling without becoming brittle.</p>

.2	Coating type	<p>Epoxy-based systems.</p> <p>Other coating systems with performance according to the test procedure in annex 1.</p> <p>A multi-coat system with each coat of contrasting colour is recommended.</p> <p>The top coat shall be of a light colour in order to facilitate in-service inspection.</p>
.3	Coating pre-qualification test	<p>Epoxy-based systems tested prior to the date of entry into force of this Standard in a laboratory by a method corresponding to the test procedure in annex 1 or equivalent, which as a minimum meets the requirements for rusting and blistering; or which have documented field exposure for 5 years with a final coating condition of not less than “GOOD” may be accepted.</p> <p>For all other systems, testing according to the procedure in annex 1, or equivalent, is required.</p>
.4	Job specification	<p>There shall be a minimum of two stripe coats and two spray coats, except that the second stripe coat, by way of welded seams only, may be reduced in scope where it is proven that the NDFT can be met by the coats applied, in order to avoid unnecessary over-thickness. Any reduction in scope of the second stripe coat shall be fully detailed in the CTF.</p> <p>Stripe coats shall be applied by brush or roller. Roller to be used for scallops, ratholes, etc., only.</p> <p>Each main coating layer shall be appropriately cured before application of the next coat, in accordance with coating manufacturer’s recommendations. Surface contaminants such as rust, grease, dust, salt, oil, etc., shall be removed prior to painting with proper method according to the paint manufacturer’s recommendation. Abrasive inclusions embedded in the coating shall be removed. Job specifications shall include the dry-to-recoat times and walk-on time given by the manufacturer.</p>
.5	NDFT (nominal total dry film thickness) ⁵	<p>NDFT 320 µm with 90/10 rule for epoxy-based coatings; other systems to coating manufacturer’s specifications.</p> <p>Maximum total dry film thickness according to manufacturer’s detailed specifications.</p> <p>Care shall be taken to avoid increasing the thickness in an exaggerated way. Wet film thickness shall be regularly checked during application.</p> <p>Thinner shall be limited to those types and quantities recommended by the manufacturer.</p>

⁵ Type of gauge and calibration in accordance with SSPC-PA2:2004. Paint Application Specification No.2.

2 PSP (Primary surface preparation)		
.1	Blasting and profile ^{6,7}	<p>Sa 2½; with profiles between 30-75 µm</p> <p>Blasting shall not be carried out when:</p> <p>.1 the relative humidity is above 85%; or .2 the surface temperature of steel is less than 3°C above the dew point.</p> <p>Checking of the steel surface cleanliness and roughness profile shall be carried out at the end of the surface preparation and before the application of the primer, in accordance with the manufacturer's recommendations.</p>
.2	Water soluble salt limit equivalent to NaCl ⁸	≤ 50 mg/m ² of sodium chloride.
.3	Shop primer	<p>Zinc containing inhibitor free zinc silicate based or equivalent.</p> <p>Compatibility with main coating system shall be confirmed by the coating manufacturer.</p>
3 Secondary surface preparation		
.1	Steel condition ⁹	<p>The steel surface shall be prepared so that the coating selected can achieve an even distribution at the required NDFT and have an adequate adhesion by removing sharp edges, grinding weld beads and removing weld spatter and any other surface contaminant.</p> <p>Edges shall be treated to a rounded radius of minimum 2 mm, or subjected to three pass grinding or at least equivalent process before painting.</p>
.2	Surface treatment ⁶	<p>Sa 2½ on damaged shop primer and welds.</p> <p>Sa 2 removing at least 70% of intact shop primer, which has not passed a pre-qualification certified by test procedures in 1.3.</p> <p>If the complete coating system comprising epoxy-based main coating and shop primer has passed a pre-qualification certified by test procedures in 1.3, intact shop primer may be retained provided the same epoxy coating system is used. The retained shop primer shall be cleaned by sweep blasting, high-pressure water washing or equivalent method.</p> <p>If a zinc silicate shop primer has passed the pre-qualification test of 1.3 as part of an epoxy coating system, it may be used in combination with other epoxy coatings certified under 1.3, provided that the compatibility has been confirmed by the manufacturer by the test in accordance with 1.7 of appendix 1 to annex 1 without wave movement.</p>

6 Reference standard: ISO 8501-1:1988/Suppl:1994. Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.

7 Reference standard: ISO 8503-1/2:1988. Preparation of steel substrate before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates.

8 Conductivity measured in accordance with ISO 8502-9:1998. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.

9 Reference standard: ISO 8501-3:2001 (grade P2). Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.

.3	Surface treatment after erection ⁶	Butts St 3 or better or Sa 2½ where practicable. Small damages up to 2% of total area: St 3. Contiguous damages over 25 m ² or over 2% of the total area of the tank, Sa 2½ shall be applied. Coating in overlap shall be feathered.
.4	Profile requirements ⁷	In case of full or partial blasting 30-75 µm, otherwise as recommended by the coating manufacturer.
.5	Dust ⁹	Dust quantity rating “1” for dust size class “3”, “4” or “5”. Lower dust size classes to be removed if visible on the surface to be coated without magnification.
.6	Water soluble salts limit equivalent to NaCl after blasting/grinding ⁸	≤ 50 mg/m ² of sodium chloride. .
.7	Oil contamination	No oil contamination.

4 Miscellaneous

.1	Ventilation	Adequate ventilation is necessary for the proper drying and curing of coating. Ventilation should be maintained throughout the application process and for a period after application is completed, as recommended by the coating manufacturer.
.2	Environmental conditions	Coating shall be applied under controlled humidity and surface conditions, in accordance with the manufacturer's specifications. In addition, coating shall not be applied when: .1 the relative humidity is above 85%; or .2 the surface temperature is less than 3°C above the dew point.
.3	Testing of coating ⁵	Destructive testing shall be avoided. Dry film thickness shall be measured after each coat for quality control purpose and the total dry film thickness shall be confirmed after completion of final coat, using appropriate thickness gauges (see annex 3).
.4	Repair	Any defective areas, e.g., pin-holes, bubbles, voids, etc., shall be marked up and appropriate repairs effected. All such repairs shall be re-checked and documented.

5 COATING SYSTEM APPROVAL

Results from prequalification tests (table 1, paragraph 1.3) of the coating system shall be documented and a Statement of Compliance or Type Approval Certificate shall be issued if found satisfactory by a third party, independent of the coating manufacturer.

⁵ Type of gauge and calibration in accordance with SSPC-PA2:2004. Paint Application Specification No.2.

⁶ Reference standard: ISO 8501-1:1988/Suppl:1994. Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.

⁷ Reference standard: ISO 8503-1/2:1988. Preparation of steel substrate before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates.

⁸ Conductivity measured in accordance with ISO 8502-9:1998. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.

⁹ Reference standard: ISO 8502-3:1993. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.

6 COATING INSPECTION REQUIREMENTS

6.1 General

6.1.1 To ensure compliance with this Standard, the following shall be carried out by qualified coating inspectors certified to NACE Coating Inspector Level 2, FROSIO Inspector Level III or equivalent as verified by the Administration.

6.1.2 Coating inspectors shall inspect surface preparation and coating application during the coating process by carrying out, as a minimum, those inspection items identified in section 6.2 to ensure compliance with this Standard. Emphasis shall be placed on initiation of each stage of surface preparation and coatings application as improper work is extremely difficult to correct later in the coating progress. Representative structural members shall be non-destructively examined for coating thickness. The inspector shall verify that appropriate collective measures have been carried out.

6.1.3 Results from the inspection shall be recorded by the inspector and shall be included in the CTF (refer to annex 2 (Example of daily log and non-conformity report)).

6.2 Inspection items

Construction stage	Inspection items
Primary surface preparation	1 The surface temperature of steel, the relative humidity and the dew point shall be measured and recorded before the blasting process starts and at times of sudden changes in weather.
	2 The surface of steel plates shall be tested for soluble salt and checked for oil, grease and other contamination.
	3 The cleanliness of the steel surface shall be monitored in the shop-primer application process.
	4 The shop-primer material shall be confirmed to meet the requirements of 2.3 of table 1.
Thickness	If compatibility with the main coating system has been declared, then the thickness and curing of the zinc silicate shop primer to be confirmed to conform to the specified values.
Block assembly	1 After completing construction of the block and before secondary surface preparation starts, a visual inspection for steel surface treatment including edge treatment shall be carried out. Any oil, grease or other visible contamination shall be removed.
	2 After blasting/grinding/cleaning and prior to coating, a visual inspection of the prepared surface shall be carried out. On completion of blasting and cleaning and prior to the application of the first coat of the system, the steel surface shall be tested for levels of remaining soluble salts in at least one location per block.
	3 The surface temperature, the relative humidity and the dew point shall be monitored and recorded during the coating application and curing.
	4 Inspection shall be performed of the steps in the coating application process mentioned in table 1.
	5 DFT measurements shall be taken to prove that the coating has been applied to the thickness as specified and outlined in annex 3.

Construction stage		Inspection items
Erection	1	Visual inspection for steel surface condition, surface preparation and verification of conformance to other requirements in table 1, and the agreed specification shall be performed.
	2	The surface temperature, the relative humidity and the dew point shall be measured and recorded before coating starts and regularly during the coating process.
	3	Inspection shall be performed of the steps in the coating application process mentioned in table 1.

7 VERIFICATION REQUIREMENTS

The following shall be carried out by the Administration prior to reviewing the Coating Technical File for the ship subject to this Standard:

- .1 check that the Technical Data Sheet and Statement of Compliance or Type Approval Certificate comply with this Standard;
- .2 check that the coating identification on representative containers is consistent with the coating identified in the Technical Data Sheet and Statement of Compliance or Type Approval Certificate;
- .3 check that the inspector is qualified in accordance with the qualification standards in paragraph 6.1.1;
- .4 check that the inspector's reports of surface preparation and the coating's application indicate compliance with the manufacturer's Technical Data Sheet and Statement of Compliance or Type Approval Certificate; and
- .5 monitor implementation of the coating inspection requirements.

8 ALTERNATIVE SYSTEMS

8.1 All systems that are not an epoxy-based system applied according to table 1 of this Standard are defined as an alternative system.

8.2 This Standard is based on recognized and commonly used coating systems. It is not meant to exclude other, alternative, systems with proven equivalent performance, for example non epoxy-based systems.

8.3 Acceptance of alternative systems will be subject to documented evidence that they ensure a corrosion prevention performance at least equivalent to that indicated in this Standard.

8.4 As a minimum, the documented evidence shall consist of satisfactory performance corresponding to that of a coating system which conforms to the coating standard described in section 4, a target useful life of 15 years in either actual field exposure for 5 years with final coating condition not less than "GOOD" or laboratory testing. Laboratory test shall be conducted in accordance with the test procedure given in annex 1 to this Standard.

ANNEX 1

TEST PROCEDURES FOR COATING QUALIFICATION FOR DEDICATED SEAWATER BALLAST TANK OF ALL TYPES OF SHIPS AND DOUBLE-SIDE SKIN SPACES OF BULK CARRIERS

1 Scope

These Procedures provide details of the test procedure referred to in 5 and 8.3 of this Standard.

2 Definitions

Coating specification means the specification of coating systems which includes the type of coating system, steel preparation, surface preparation, surface cleanliness, environmental conditions, application procedure, acceptance criteria and inspection.

3 Testing

Coating specification shall be verified by the following tests. The test procedures shall comply with appendix 1 (Test on simulated ballast tank conditions) and appendix 2 (Condensation chamber tests) to this annex as follows:

- .1 for protective coatings for dedicated seawater ballast tanks, appendix 1 and appendix 2 shall apply; and
- .2 for protective coatings for double-side spaces of bulk carriers of 150 m in length and upwards other than dedicated seawater ballast tanks, appendix 2 shall apply.

APPENDIX 1

TEST ON SIMULATED BALLAST TANK CONDITIONS

1 Test condition

Test on simulated ballast tank conditions shall satisfy each of the following conditions:

- .1 The test shall be carried out for 180 days.
- .2 There are to be 5 test panels.
- .3 The size of each test panel is 200 mm x 400 mm x 3 mm. Two of the panels (Panel 3 and 4 below) have a U-bar welded. The U-bar is welded to the panel in a 120 mm distance from one of the short sides and 80 mm from each of the long sides.



The panels are to be treated according to this Standard, table 1.1, 1.2 and 1.3, and coating system applied according to table 1, paragraphs 1.4 and 1.5. Shop primer to be weathered for at least 2 months and cleaned by low pressure washing or other mild method. Blast sweep or high pressure washing, or other primer removal methods not to be used. Weathering method and extent shall take into consideration that the primer is to be the foundation for a 15 year target useful life system. To facilitate innovation, alternative preparation, coating systems and dry film thicknesses may be used when clearly defined.

- .4 The reverse side of the test piece shall be painted appropriately, in order not to affect the test results.
- .5 As simulating the condition of actual ballast tank, the test cycle runs for two weeks with natural or artificial seawater and one week empty. The temperature of the seawater is to be kept at about 35°C.
- .6 Test panel 1: This panel is to be heated for 12 h at 50°C and cooled for 12 h at 20°C in order to simulate upper deck condition. The test panel is cyclically splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The interval of splashing is 3 s or faster. The panel has a scribe line down to bare steel across width.
- .7 Test panel 2: This panel has a fixed sacrificial zinc anode in order to evaluate the effect of cathodic protection. A circular 8 mm artificial holiday down to bare steel is introduced on the test panel 100 mm from the anode in order to evaluate the

effect of the cathodic protection. The test panel is cyclically immersed with natural or artificial seawater.

- .8 Test panel 3: This panel is to be cooled on the reverse side, in order to give a temperature gradient to simulate a cooled bulkhead in a ballast wing tank, and splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The gradient of temperature is approximately 20°C, and the interval of splashing is 3 s or faster. The panel has a scribe line down to bare steel across width.
- .9 Test panel 4: This panel is to be cyclically splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The interval of splashing is 3 s or faster. The panel has a scribe line down to bare steel across width.
- .10 Test panel 5: This panel is to be exposed to dry heat for 180 days at 70°C to simulate boundary plating between heated bunker tank and ballast tank in double bottom.

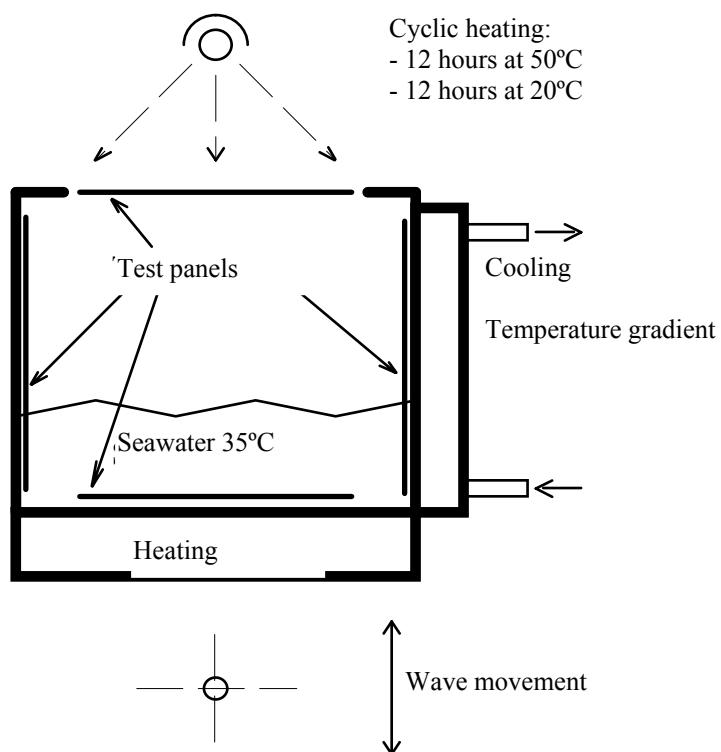


Figure 1
Wave tank for testing of ballast tank coatings

2 Test results

- 2.1 Prior to the testing, the following measured data of the coating system shall be reported:

- .1 infrared (IR) identification of the base and hardener components of the coating;
 - .2 specific gravity¹⁰ of the base and hardener components of the paint; and
 - .3 number of pinholes, low voltage detector at 90 V.
- 2.2 After the testing, the following measured data shall be reported:
- .1 blisters and rust;¹¹
 - .2 dry film thickness (DFT) (use of a template);¹²
 - .3 adhesion value;¹³
 - .4 flexibility¹⁴ modified according to panel thickness (3 mm steel, 300 µm coating, 150 mm cylindrical mandrel gives 2% elongation) for information only;
 - .5 cathodic protection weight loss/current demand/disbondment from artificial holiday; and
 - .6 undercutting from scribe. The undercutting along both sides of the scribe is measured and the maximum undercutting determined on each panel. The average of the three maximum records is used for the acceptance.

3 Acceptance criteria

- 3.1 The test results based on section 2 shall satisfy the following criteria:

Item	Acceptance criteria for epoxy-based systems applied according to table 1 of this Standard	Acceptance criteria for alternative systems
Blisters on panel	No blisters	No blisters
Rust on panel	Ri 0 (0%)	Ri 0 (0%)
Number of pinholes	0	0
Adhesive failure	> 3.5 MPa Adhesive failure between substrate and coating or between coats for 60% or more of the areas.	> 5 MPa Adhesive failure between substrate and coating or between coats for 60% or more of the areas.

¹⁰ Reference standard: ISO 2811-1/4:1997. Paints and varnishes. Determination of density.

¹¹ Reference standards: ISO 4628/2:2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 2. ISO 4628:2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of common types of defect – Part 3: Designation of degree of rusting.

¹² Nine equally distributed measuring points are used on panel's size 150 mm x 150 mm or 15 equally distributed measuring points on panel's size 200 mm x 400 mm.

¹³ Reference standard: ISO 4624:2002. Pull-off test for adhesion.

¹⁴ Reference standards: ASTM D4145:1983. Standard Test Method for Coating Flexibility of Preprinted Sheet.

Item	Acceptance criteria for epoxy-based systems applied according to table 1 of this Standard	Acceptance criteria for alternative systems
Cohesive failure	≥ 3 MPa Cohesive failure in coating for 40% or more of the area.	> 5 MPa Cohesive failure in coating for 40% or more of the area.
Cathodic protection current demand calculated from weight loss	< 5 mA/m ²	< 5 mA/m ²
Cathodic protection; disbondment from artificial holiday	< 8 mm	< 5 mm
Undercutting from scribe	< 8 mm	< 5 mm
U-bar	Any defects, cracking or detachment at the angle or weld will lead to system being failed.	Any defects, cracking or detachment at the angle or weld will lead to system being failed.

3.2 Epoxy-based systems tested prior to the date of entry into force of this Standard shall satisfy only the criteria for blistering and rust in the table above.

3.3 Epoxy-based systems tested when applied according to table 1 of this Standard shall satisfy the criteria for epoxy-based systems as indicated in the table above.

3.4 Alternative systems not necessarily epoxy-based and/or not necessarily applied according to table 1 of this Standard shall satisfy the criteria for alternative systems as indicated in the table above.

4 Test report

The test report shall include the following information:

- .1 name of the manufacturer;
- .2 date of tests;
- .3 product name/identification of both paint and primer;
- .4 batch number;
- .5 data of surface preparation on steel panels, including the following:
 - .5.1 surface treatment;
 - .5.2 water soluble salts limit;
 - .5.3 dust; and
 - .5.4 abrasive inclusions;

- .6 application data of coating system, including the following:
 - .6.1 shop primed;
 - .6.2 number of coats;
 - .6.3 recoat interval;¹⁵
 - .6.4 dry film thickness (DFT) prior to testing;¹⁵
 - .6.5 thinner;¹⁵
 - .6.6 humidity;¹⁵
 - .6.7 air temperature;¹⁵ and
 - .6.8 steel temperature;
- .7 test results according to section 2; and
- .8 judgment according to section 3.

¹⁵ Both of actual specimen data and manufacturer's requirement/recommendation.

APPENDIX 2**CONDENSATION CHAMBER TEST****1 Test condition**

Condensation chamber test shall be conducted in accordance with applicable standards.¹⁶

- .1 The exposure time is 180 days.
- .2 There are to be 2 test panels.
- .3 The size of each test panel is 150 mm x 150 mm x 3 mm. The panels are to be treated according to the Performance Standard, table 1, paragraphs 1, 2 and 3 and coating system applied according to table 1, paragraphs 1.4 and 1.5. Shop primer to be weathered for at least 2 months and cleaned by low pressure washing or other mild method. Blast sweep or high pressure washing, or other primer removal methods not to be used. Weathering method and extent shall take into consideration that the primer is to be the foundation for a 15 year target life system. To facilitate innovation, alternative preparation, coating systems and dry film thicknesses may be used when clearly defined.
- .4 The reverse side of the test piece shall be painted appropriately, in order not to affect the test results.

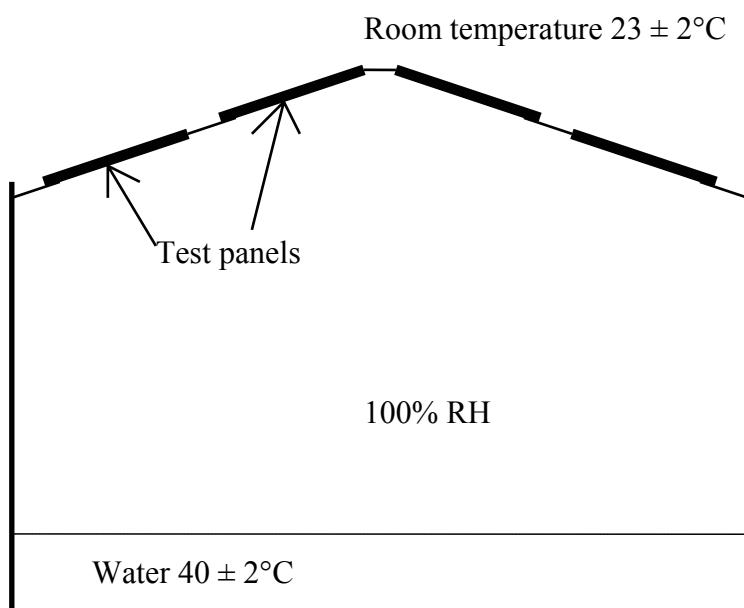


Figure 2
Condensation chamber

¹⁶ Reference standard: ISO 6270-1:1998 Paints and varnishes – Determination of resistance to humidity – Part 1: Continuous condensation.

2 Test results

According to section 2 (except for 2.2.5 and 2.2.6) of appendix 1.

3 Acceptance criteria

3.1 The test results based on section 2 shall satisfy the following criteria:

Item	Acceptance criteria for epoxy-based systems applied according to table 1 of this Standard	Acceptance criteria for alternative systems
Blisters on panel	No blisters	No blisters
Rust on panel	Ri 0 (0%)	Ri 0 (0%)
Number of pinholes	0	0
Adhesive failure	> 3.5 MPa Adhesive failure between substrate and coating or between coats for 60% or more of the areas.	> 5 MPa Adhesive failure between substrate and coating or between coats for 60% or more of the areas.
Cohesive failure	> 3 MPa Cohesive failure in coating for 40% or more of the area.	> 5 MPa Cohesive failure in coating for 40% or more of the area.

3.2 Epoxy-based systems tested prior to the date of entry into force of this Standard shall satisfy only the criteria for blistering and rust in the table above.

3.3 Epoxy-based systems tested when applied according to table 1 of this Standard shall satisfy the criteria for epoxy-based systems as indicated in the table above.

3.4 Alternative systems not necessarily epoxy-based and/or not necessarily applied according to table 1 of this Standard shall satisfy the criteria for alternative systems as indicated in the table above.

4 Test report

According to section 4 of appendix 1.

ANNEX 2

EXAMPLE OF DAILY LOG AND NON-CONFORMITY REPORT

DAILY LOG

Sheet No:

Ship:	Tank/Hold No:	Database:							
Part of structure:									
SURFACE PREPARATION									
Method:	Area (m ²):								
Abrasive:	Grain size:								
Surface temperature:	Air temperature:								
Relative humidity (max):	Dew point:								
Standard achieved:									
Rounding of edges:									
Comments:									
Job No.:	Date:	Signature:							
COATING APPLICATION:									
Method:									
Coat No.	System	Batch No.	Date	Air temp.	Surf temp.	RH%	Dew point	DFT* Meas.*	Specified
* Measured minimum and maximum DFT. DFT readings to be attached to daily log									
Comments:									
Job No:	Date:	Signature:							

NON-CONFORMITY REPORT

Sheet No:

Ship:	Tank/Hold No:	Database:
Part of structure:		
DESCRIPTION OF THE INSPECTION FINDINGS TO BE CORRECTED		
Description of findings:		
Reference document (daily log):		
Action taken:		
Job No.:	Date:	Signature:

ANNEX 3

DRY FILM THICKNESS MEASUREMENTS

- 1 The following verification check points of DFT are to be taken:
- .1 one gauge reading per 5 m^2 of flat surface areas;
 - .2 one gauge reading at 2 to 3 m intervals and as close as possible to tank boundaries, but not further than 15 mm from edges of tank boundaries;
 - .3 longitudinal and transverse stiffener members:

One set of gauge readings as shown below, taken at 2 to 3 m run and not less than two sets between primary support members;

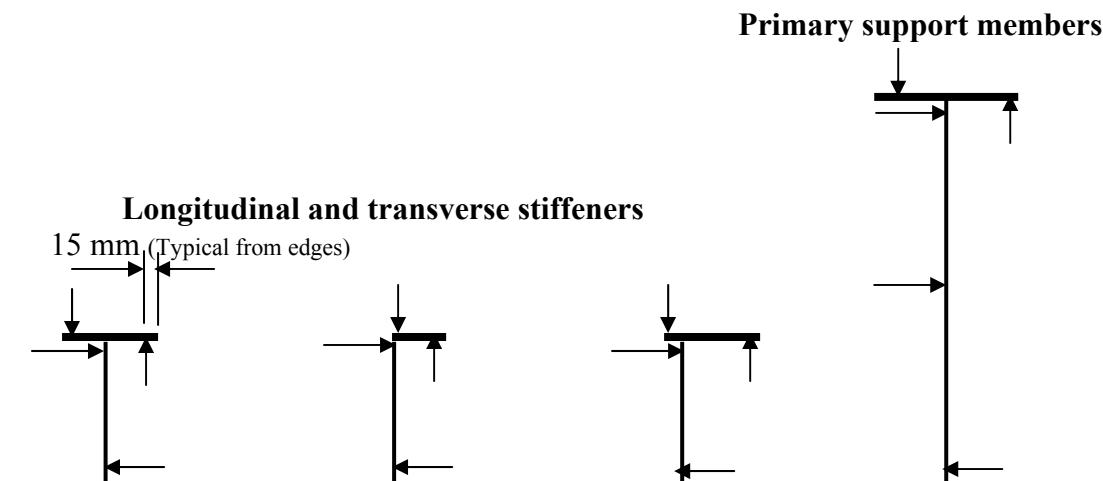


Figure 3

Note: Arrows of diagram indicate critical areas and should be understood to mean indication for both sides.

- .4 3 gauge readings for each set of primary support members and 2 gauge readings for each set of other members as indicated by the arrows in the diagram;
- .5 for primary support members (girders and transverses) one set of gauge readings for 2 to 3 m run as shown in figure 3 above but not less than three sets;
- .6 around openings one gauge reading from each side of the opening;
- .7 five gauge readings per square metre (m^2) but not less than three gauge readings taken at complex areas (i.e., large brackets of primary support members); and
- .8 additional spot checks are to be taken to verify coating thickness for any area considered necessary by the coating inspector.

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
CIP Level 2	NACE Coating Inspector Level 2—Certified
CIP Levels 1, 2 and Peer Review Examination	NACE-Certified Coating Inspector—Level 3

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

This example illustrates how this information can be used by a **NACE-Certified Coating Inspector—Level 3**:

John Smith
NACE-Certified Coating Inspector—Level 3, 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: _____

CIP Work Experience Assessment Procedure

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 in order to be sent to a review board for verification and approval. 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 levels of the CIP. 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 two (2) CIP training courses.
3. Thirty-six (36) field-related work experience points are strongly recommended before you take the Peer Review and receive 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.

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	

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:

$$\begin{aligned}
 24 \text{ months} \times 1.5 \text{ points per month} \times 80\% &= 28.8 \text{ points for work as a painter} \\
 12 \text{ months} \times 2.0 \text{ points per month} \times 100\% &= \underline{24.0} \text{ points for inspection work} \\
 \text{Total Work Points} &= 52.8
 \end{aligned}$$

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 directions, and look over the sample forms, before proceeding.
2. Make as many copies of Form 2: Individual Job Documentation as you need to document the 36 work experience points you need to take the Peer Review.

NOTE: For the purpose of these forms, **job** is defined as **a position in which you are regularly employed for a period of time**. For example: *I had a job for AAA Painters for two years as a helper, then for two years as a painter; then I had a job for 3 years with ZZZ Inspection as a coating inspector.*

3. Completely fill out one copy of Form 2 for each job you want included in your work experience assessment. 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.
4. Summarize the information from each copy of Form 2 you completed onto Form 1: Summary of Protective Coatings-Related Work Experience.
5. Arrange your forms in order of most recent experience first, followed by less recent experience. Number pages consecutively. If you have 12 pages of forms, the first page is page 1, and the other pages should be numbered 2 through 12.
6. Write only on one side of each page.
7. Read and sign the Affirmation and Attestation.
8. Make and keep a copy of your forms for your records.
9. When your forms are complete, send them to:

NACE Education Division	Phone:	281/228-6244
Attention: Carol Steele	FAX:	281/228-6344
1440 South Creek Drive	E-Mail:	Carol.Steele@nace.org
Houston, TX 77084-4906 USA		

Note: You do not need to return the instructions or sample copies, only your completed forms.

10. If you require assistance, contact NACE at the above address or phone.

Your forms must be received at NACE Headquarters not less than 60 days from the first day of the Peer Review you plan to attend.

S A M P L E

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:

Name: A. Sample

Phone: 409/111-4321

Company: ZZZ Coating Inspection Inc.

Fax: 409/111-1234

Address: 987 Gage Avenue

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		

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: _____

Date: _____

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. Applications 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.

JOB INFORMATION:

Job Title:	Painter	
AAA Painters		
From:	Month <u>1</u>	Year <u>92</u>
To:	Month <u>1</u>	Year <u>95 (present)</u>
Who can NACE contact to verify this experience?		
Name:	Bob Roberts	
Company:	AAA Painters	
Address:	123 Coating St.	
City:	Paintersville	
State/Province:	<u>TX</u>	Zip/Postal Code <u>77123</u>
Country:	USA	
Phone:	409/123-4567	
Fax:	409/123-7654	

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 1.5

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.

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: _____

Date: _____

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:

Name: _____

Phone: _____

Company: _____

Fax: _____

Address: _____

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: _____

MAKE A COPY OF ALL PAGES OF THIS APPLICATION FOR YOUR RECORDS

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. Applications 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.

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: _____

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: _____

PLEASE DESCRIBE IN DETAIL what are/were your specific coating-related 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: _____

MAKE A COPY OF ALL PAGES OF THIS APPLICATION FOR YOUR RECORD