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# Standard Guide for Painting Inspectors (Metal Substrates)[1]

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## 1. Scope

1.1 This guide is intended as an information aid to painting inspectors in carrying out their task efficiently. It includes the key elements of surface preparation, coatings application, and final approval for both field and shop work. The items should be selected that are pertinent to the specification of a particular job.

NOTE 1—For additional helpful information, refer to the following documents:

*Manual of Coating Work for Light-Water Nuclear Power Plant Primary Containment and Other Safety-Related Facilities*[2]

*New Concepts for Coating Protection of Steel Structures*[3]

D 16 Terminology Relating to Paint, Varnish, Lacquer and Related Products[4]

D 4538 Terminology Relating to Protective Coatings and Lining Work for Power Generation Facilities[5]

SSPC-PA Guide 3 A Guide to Safety in Paint Application[6]

Steel Structures Painting Manual Vol 1 Good Painting Practice[6]

Steel Structures Painting Manual Vol 2 Systems and Specifications[6]

Manufacturers Specifications and Instructions (made available to the inspector for reference to special requirements for proper application)

Material Safety Data Sheets (needed to ensure that personnel take necessary precautions in handling hazardous materials). Available from Materials manufacturer.

1.2 Certain industries or owners may require certified inspection personnel. See Guide D 4537 for establishing procedures to certify inspectors for coatings work in nuclear facilities.[5]

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 This guide is arranged in the following order:



[1] This guide is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

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[2] ASTM, 1979.

[3] *ASTM STP 841*, ASTM, 1984.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

[5] *Annual Book of ASTM Standards*, Vol 06.02.

[6] Available from SSPC: The Society for Protective Coatings, 40 24th Street, Pittsburgh, PA 15222.

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products[4]

D 1186 Test Methods for Nondestructive Measurement of Dry-Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[4]

D 1212 Test Methods for Measurement of Wet Film Thickness of Organic Coatings[4]

D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Base[4]

D 1475 Test Method for Density of Liquid Coatings, Inks, and Related Products[4]

D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting[7]

D 2092 Guide for Treatment of Zinc-Coated (galvanized) Steel Surfaces for Painting[5]

D 2200 Pictorial Surface Preparation Standards for Painting Steel Surfaces[5]

D 3359 Test Methods for Measuring Adhesion by Tape Test[4]

D 4138 Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means[5]

D 4212 Test Method for Viscosity by Dip-Type Viscosity Cups[4]

D 4285 Test Method for Indicating Oil or Water in Compressed Air[5]

D 4414 Practice for Measurement of Wet Film Thickness by Notch Gages[4]

D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel[5]

D 4537 Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear Facilities[5]

D 4538 Terminology Relating to Protective Coatings and Lining Work for Power Generation Facilities[5]

D 4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers[5]

D 5064 Practice for Conducting a Patch Test to Access Coating Compatibility[5]

D 5162 Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metal Substrates[5]

2.2 *Occupational Safety and Health Administration (OSHA) Standard:*

29 CFR 1910.1200 Hazard Communication[8]

2.3 *SSPC Standards:*[6]

SSPC-SP 1 Solvent Cleaning

SSPC-SP 2 Hand Tool Cleaning

SSPC-SP 3 Power Tool Cleaning

SSPC-SP 5/NACE 1 White Metal Blast Cleaning

SSPC-SP 6/NACE 3 Commercial Blast Cleaning

SSPC-SP 7/NACE 4 Brush-off Blast Cleaning

SSPC-SP 10/NACE 2 Near-White Blast Cleaning

SSPC-SP 11 Power Tool Cleaning to Bare Metal

SSPC-SP 12/NACE 5 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating

SSPC-PA 1 Paint Application Specifications

SSPC-PA 2 Measurement of Paint Thickness with Magnetic Gages

SSPC-Vis 1-89 Pictorial Surface Preparation Standards for Painting Steel Surfaces

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

SSPC-Paint 27 Basic Zinc Chromate-Vinyl Butyral Wash Primer

SSPC-Guide 6 Guide for Containing Debris Generated During Paint Removal Operations

SSPC-Guide 7 Guide for the Disposal of Lead Contaminated Surface Preparation Debris

## 3. Significance and Use

3.1 This guide is intended as a reference for those concerned with the inspection of industrial coating work. Many of the details covered may be in a specification for a particular project. A specification for coating projects should include the coatings to be used. A checklist for use in the field is included as an appendix.

## 4. Preparation for Inspection

4.1 The guide describes the duties of the inspector and discusses inspection methods, both visual and instrumental,

[7] *Annual Book of ASTM Standards*, Vol 02.05.

[8] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402-9328.

that can be used to determine that the specification requirements have been met by the painting contractor.

4.2 Before painting is started the project engineer should provide the inspector with information from the official plans and specifications as to coating type, thinner to be used, mixing ratios to be used, specified application thickness, primer, tie coat, topcoat, time between coats, surface preparation, method of application, and any special precautions to be followed such as limits on ambient conditions. These details should be recorded in an inspector's record book to eliminate any misunderstanding between the inspector and the contractor.

4.3 The inspector should obtain copies of Materials Safety Data Sheets for all products that will be used on the project, review any hazard communications program in accordance with 29 CFR 1910.1200 that will apply to the project, and review other safety information related to the work that will be performed by the contractor. The inspector should examine these materials and be supplied with appropriate protective equipment and devices.

## 5. Surface Preparation Methods and Requirements

5.1 *Surface Preparation* is one of the most important factors affecting the performance of coatings. The specifier determine the proper level in accordance with the expected service life and type of coating specified.

5.1.1 *Pictorial Standard D 2200 (SSPC-Vis 1-89)* should be provided to the inspector on a job involving blast cleaning of structural steel. The standard is used by the inspector to assist in determining whether the degree of surface preparation specified in a contract has been attained by the contractor. For large jobs it is recommended that before work starts, an actual steel sample of adequate size be blasted to the satisfaction of the project engineer. This blasted surface should be protected by a clear acrylic coating or encased in plastic and used for reference purposes as the work progresses.

5.2 *Factors Affecting Coating Performance*—There are a number of factors that should be considered to ensure a proper painting job.

5.2.1 *Cleanliness*—Many materials, if not removed from the surface, will affect the life of the coating. These include oil, grease, soil, weld spatter, and slag, that make it impossible to obtain proper adhesion to the metal surface. Deposits of salt (such as chlorides and sulfates) should be removed, or long-term coating performance will be seriously affected. SSPC issues detailed surface preparation specifications that cover methods for solvent cleaning, hand and power tool cleaning, as well as the various methods of blast cleaning.

5.2.2 *Mill Scale*, the bluish-black oxide resulting from the hot-rolling process, is a constant source of trouble leading to coating failure. This scale is very brittle and can crack or loosen due to temperature changes (both in fabricating and weathering in the field) leading to failure of the coating.

5.2.3 *Surface Profile*—The texture of the metal surface has a significant effect on the performance of coatings, since it increases the surface area to which the coating can develop adhesion. In fact, the term "anchor pattern" is sometimes used to describe the depth of profile. Profile varies both with the type and size of the abrasive used. Coarser abrasives generally produce a coarser and deeper profile. Deep profiles are advantageous for adhesion, but require more coating to fill in the valleys and cover the peaks of the profile; they cannot be used with low-build coatings that do not cover the peaks even when several coats are applied. A general recommendation is that the surface profile should be one quarter to one third of the dry film thickness of the coating system. This recommendation does not apply if the resulting profile would be too great. The angularity (sharpness) and density of the profile may affect adhesion. Methods for measuring surface profile can be found in Test Methods D 4417.

5.3 *Cleaning Procedures*—Safety precautions are not addressed separately for each of the following cleaning methods. Each has its own safety-related hazards, and U.S. Occupational Health and Safety Administration regulations should be followed. Materials Safety Data Sheets (MSDS) for the solvents and cleaning compounds provided by the manufacturer should also be consulted for proper worker protection.

5.3.1 *Chemical Cleaning*—Solvents are used to remove oil, grease, and related materials. The solvent is applied to the surface by wiping or scrubbing with rags or brushes. The contaminants should be removed (not simply spread out) by a thorough wiping of the affected areas with cloths saturated with clean solvent. Contaminated cloths should not be dipped into clean solvent. The cleaning should be repeated with clean rags and fresh clean solvent. Emulsions, cleaning compounds, steam cleaning, or similar methods and materials may also be used. Where emulsion cleaners, soaps, or detergents are used, they should be removed completely by washing with clean hot water. SSPC SP-1 covers cleaning procedures using these materials.

5.3.1.1 *Solvent Vapor Cleaning* is a procedure that can be adapted to a production line or piecework operation. Vapor cleaning removes all soluble contaminants but does not disturb the natural oxide film. If this film should be removed, mechanical cleaning will be necessary as well. The part to be cleaned is placed in the saturated vapor above the heated solvent so that the solvent vapor condenses on the metal surface. Vapor degreasing does not remove particulate matter, so parts should be wiped to remove any insoluble soils. Vapor degreasing has the advantages over solvent wiping in that hot solvents are used and the solvent condensation removes oils without recontamination.

5.3.2 *Hand Tool Cleaning* is the method used for the removal of loose mill scale, loose rust, loose or otherwise defective coating, weld flux, slag and spatter from metal surfaces by hand brushing, hand sanding, hand chipping or scraping using wire, fiber or bristle brushes, sandpaper, steel wool, hand scrapers or chisels, and chipping hammers. Material is considered tightly adherent if it cannot be lifted with a dull putty knife. SSPC provides a detailed specification, SSPC-SP 2. A visual standard, SSPC-VIS3, may be used to assist in determining compliance.

5.3.2.1 Hand tool cleaning requires that all weld flux, tar, oil and grease, and other greasy contaminants be removed first by solvent cleaning (5.3.1).

5.3.2.2 Wire brushes should be rigid enough to clean the surface thoroughly, and shaped to penetrate into all corners and joints. Brushes should be kept free of all materials that may clog the wires of the brush.

5.3.2.3 Hand scrapers should be made of tool steel, tempered and ground to a sharp edge, and should be of the proper size and shape to enable cleaning to be done as specified. Scrapers should be kept sharp at all times.

5.3.3 *Power Tool Cleaning* is a method used for the removal of loose mill scale, loose rust, loose or otherwise defective coating, and weld flux from metal surfaces by power wire brushes, power impact tools, power grinders, power sanders, or by a combination of these methods. Material is considered tightly adherent if it cannot be lifted with a dull putty knife. SSPC-SP 3 is the detailed specification for power tool cleaning. A visual standard, SSPC-VIS3, may be used to assist in determining compliance.

5.3.3.1 *Power Tool Cleaning* requires that all oil, grease, weld flux, and other contaminants be removed first by solvent cleaning (5.3.1). Hand tool cleaning in accordance with 5.3.2 may be used prior to power tool cleaning.

5.3.3.2 All equipment should be suitable for the configuration of the work to be cleaned and maintained free of material that clogs the wire or disks making them ineffective. All impact tools should be kept sharp.

5.3.4 *Power Tool Cleaning to Bare Metal* is a method used for the total removal of coating, rust, and mill scale. It also requires a minimum of 1-mil anchor profile. Surface cleaning, power tools, and surface profile producing media are used to obtain the specified finish. Surface cleaning power tools consist of non-woven abrasive wheels and discs, coated abrasive discs or sanding pads, coated abrasive fly wheels, and coated abrasive bands. Surface profile producing media consist of rotary impact flap wheel assemblies and needle guns. SSPC-SP11 is the detailed specification for power tool cleaning to bare metal.

5.3.4.1 Depending on the initial condition of the surface and existing profile conditions, it may be necessary to use one or both of the types of power tools. All oil, grease, weld flux, and other contaminants should be removed first by solvent cleaning (5.3.1). Hand tool cleaning (5.3.2) or power tool cleaning (5.3.3) may be used prior to power tool cleaning to bare metal.

5.3.4.2 All equipment should be suitable for the configuration of the work to be cleaned and maintained free of material that clogs the wire or discs making them ineffective. Needle guns require 2-mm diameter needles to produce a suitable surface profile.

5.3.4.3 The finished surface should be bare, bright metal. Slight residues of rust and paint may remain in the lower portions of pits if the original surface was pitted. SSPC-Vis 3 is a visual standard to assist in determining compliance. Surface profile is determined by procedures in 6.1.1.

5.3.5 *Blast Cleaning* is used to remove coating, rust and mill scale from a metal surface and to provide a roughened surface by striking the surface with a stream of small, hard abrasive particles such as (dry) sand, grit, or shot.

5.3.5.1 One method utilizes compressed air, special blast nozzles, and abrasive. Water may be injected into the air stream to control dust. In another method used primarily in fabricating shop, wheels propel the abrasive centrifugally against the work. The minimum and maximum particle size of the abrasive may be specified as a means of controlling the surface profile.

5.3.5.2 Blast cleaning requires that all oil, grease, and weld flux be removed by solvent cleaning (5.3.1). The compressed air used for blast cleaning should be free of condensed water or oil by making certain that separators and traps are in working order. Test the compressed air supply in accordance with Test Method D 4285.

5.3.5.3 Blast-cleaning operations should be performed so that no damage is done to the completed portion of the work. Blast cleaning is often performed from the top to bottom of the structure and should only be carried on downwind from any recently painted areas. Dry blast cleaning operations should not be conducted on surfaces that will be wet after blasting and before painting. Dew point should be at least 3°C (5°F) above the steel temperature.

5.3.5.4 The degree of blast cleaning required should be at least equal to the appropriate surface preparation specification and the applicable visual standard. Standards from ASTM, SSPC, and National Association of Corrosion Engineers (NACE) are listed below in Table 1. Note that Pictorial Surface Preparation Standards D 2200 is divided into two methods. Method A describes photographic standards available from International Standards Organization (ISO) Pictorial Surface Preparation Standards. Method B describes photographic standards available from SSPC. The two sets of photographs are not directly comparable.

**TABLE 1 Comparison of Surface Preparation Standards**

| Preparation Guide | SSPC | ASTM D 2200 | | NACE |
|---|---|---|---|---|
| | | Method A[A] | Method B[B] | |
| Blast clean to white metal | SSPC-SP 5 | Sa 3 | SP 5 | 1 |
| Blast clean to near-white metal | SSPC-SP 10 | Sa 2½ | SP 10 | 2 |
| Commercial blast cleaning | SSPC-SP 6 | Sa 2[C] | SP 6 | 3 |
| Brush-off blast cleaning | SSPC-SP 7 | Sa 1 | SP 7 | 4 |

[A]Method A is ISO/Swedish Standard.
[B]Method B is SSPC Vis 1-89.
[C]Pictorial Standard Sa 2 shows mill scale and conflicts with SSPC definition of commercial blast (SP 6), which does not allow mill scale.

5.3.5.5 Blast cleaned surfaces should be examined for any traces of oil, grease, or smudges; where present, the contaminants should be removed by solvent cleaning (5.3.1). Surfaces that have been dry blasted should be brushed with clean brushes, blown with compressed air free of oil and moisture, or vacuum cleaned to eliminate any traces of blast products, dust, or dirt from the surface. This also serves to remove abrasive from pockets and corners.

5.3.5.6 Blast cleaned surfaces should be further treated, primed or painted on the same day they are blasted, preferably within 8 h, or in any event before any visible flash rusting occurs. Reblasting will be necessary on any surface if rust bloom forms before coating can be applied.

5.3.6 *Pressurized Water Cleaning*—A high pressure water blast using potable water, either with or without an abrasive injected into the stream, is used as an alternative to open blasting, since it reduces the release of dust into the atmosphere. Pressures over 137 900 KPa (20 000 psi) are needed to achieve total coating removal when using only water. Pressurized water alone will not remove mill scale efficiently, or impart an anchor profile. Inhibitors may be added to the water to prevent flash rusting. The surface should be dried or allowed to dry before coating. SSPC-SP 12/NACE5 defines the various levels of cleanliness that can be achieved with pressurized water.

5.4 *Cleaning and Preparation of Various Surfaces*—Before application of any coating, all surfaces to be coated should be thoroughly cleaned and properly prepared to the requirements of the specification. All dust, dirt, oil, grease, moisture, soot, tar, or other contaminants should be removed from unpainted surfaces. Previously painted surfaces should be similarly cleaned of all foreign matter; all deteriorated coating should be removed as well. Mortar or cement drippings from earlier repairs should be removed by mechanical or chemical means. Tree limbs or other growth obstructing the structure should be cut away to provide ready access.

5.4.1 *Steel Surfaces*—Removal of rust and scale should be done in the manner and to the degree specified, that is, hand, power tool, or blast cleaned.

5.4.1.1 On complex structures, all dirt and debris should be removed from pockets, crevices, obstructed areas such as gusset plates and connections, and tops of horizontal surfaces. Blasting debris that accumulates on horizontal surfaces should be removed. Special attention should be placed on examining hard to reach areas, the back side of nuts and bolts, sides of members in close proximity to other members or walls, and undersides of members.

5.4.2 *Galvanized Surfaces* that are to be painted should be cleaned and then treated in accordance with the specified method in Guide D 2092. Alternatively, the surface may be allowed to weather a minimum of 6 months before cleaning and painting.

5.4.3 *Aluminum Surfaces*:

5.4.3.1 Complete removal of oil and grease and, for unanodized aluminum, treatment is essential. Vapor degreasing or immersion in an alkaline or acid cleaning solution are commonly used in shop work. In the field, water wash followed by solvent, steam or detergent cleaning is a good starting point.

5.4.3.2 Vinyl wash primer is one of the metal pretreatments commonly used on unanodized aluminum. The material is described in Practices D 1730, Type B, Method 8 and is covered by SSPC in Paint 27. Lead pigmented primers should never be used over aluminum surfaces. The minimum treatment for aluminum is Type B, Method 3 of Practices D 1730, which describes the use of an alcoholic phosphoric acid cleaner.

5.4.4 *Precautions in Preparing Unpainted and Previously Painted Surfaces*—Cleaning should proceed by sections, bays, or other readily identifiable parts of the work. The cleaning of each section, bay, or part of the work should be entirely completed, inspected, and accepted before any coating is applied. The specification should contain limits on the amount or area that can be cleaned and painted at one time. The system of alternately cleaning and painting short sections by one workman is not good practice since this can lead to surface or intercoat contamination.

5.4.4.1 If traffic, or any other source, produces an objectionable amount of dust, it is customary to control the dust by using tarpaulins, etc., for a sufficient distance around the structure and take any other precaution necessary to prevent dust and dirt from coming into contact with the cleaned or freshly painted surfaces. It may sometimes be necessary to clean newly coated surfaces using some of the specified methods between the various coats.

5.4.4.2 Some areas to be painted or repainted may be exposed to chemical fumes and, if so, should be washed with water before painting. Washing may also be necessary between coats of paint.

5.4.4.3 Residual contaminants present on pitted steel can be a problem. Chloride from deicing salts or a marine environment, and sulfate contamination from air pollution have been recognized as main factors in premature breakdown of existing coating systems. High-pressure water blasting is often used to remove these contaminants.

5.4.4.4 Current regulations require containment and collection of surface preparation debris for disposal. When the existing coating contains regulated heavy metals such as lead or chromium, or other regulated compounds such as organotin, special precautions and handling of debris may be necessary. Inspection of contaminant and disposal requirements, especially site storage requirements, are part of a Coating Inspector's activities. SSPC 6(CON)[6] and 7(DIS)[6] present information useful to the inspector and sections of these guides may be referenced in the specification. On lead removal projects, inspectors should be familiar with OSHA requirements for their own health and safety.

5.5 *Inspection of Surfaces Prior to Field Painting*:

5.5.1 *New Construction*—It should be emphasized that the first coat should be applied to the cleaned surfaces before any soiling or deterioration can occur. If painting is done outside, the cleaned areas should receive the first protective coat well before nightfall brings lower temperatures and possible moisture condensation on the surfaces. When surface preparation and painting are carried on indoors, overnight delays between coating and painting may be permissible except on blast-cleaned surfaces.

5.5.1.1 Shop-coated steel that has been shipped to the erection site should be stored on blocks to prevent contact with the ground, and where it is least likely to be marred, scratched, or subjected to harmful contamination by grease, oil, salt, etc. Insofar as practicable, the steel should be stored to avoid the formation of waterholding pockets. If outdoor storage lasts for several months, the inspector should check the integrity of the coating from time to time and verify that deficiencies are corrected in accordance with the contract document. The length of time between shop priming and erection and subsequent topcoating should be kept to a minimum to avoid the problem of intercoat adhesion.

5.5.1.2 Immediately before applying the first field coat, the shop-coated surfaces should be cleaned of dust. If necessary to remove grime and oil substances, they can be wiped, steam cleaned, power washed with detergents or cleaned with solvents selected so as not to soften the film appreciably. Miscellaneous scratches and breaks in the shop coat, including those occasioned by field welds, bolts, or rivets, should be cleaned, feathered and touched-up as specified before the steel receives the first overall field coat.

5.5.1.3 The inspector should ensure that field rivets have been cleaned of slag and weld spatter. It is important that every coat of the system be applied over dry, soil-free surfaces, and that all previous coats be free of mechanical damage. Great care should be exercised to prevent trapping corrosive salts under or between coats.

5.5.1.4 The inspector should determine whether the specifications are being followed with reference to the painting or prohibition of painting of contact surfaces in bolted or riveted surfaces of construction. He should ensure that surfaces not in contact but that will be made inaccessible by assembly or erection, have received the full number of specified coats before they become inaccessible.

5.5.2 *Maintenance Repainting*—In most cases, maintenance repainting will consist of spot-cleaning and priming of small isolated areas of deterioration, followed by application of one overall new finish coat to all surfaces of the structure. The inspector of maintenance repainting should be alert for several conditions not encountered in the painting of new work.

5.5.2.1 Sound coating not intended to be removed should not be damaged by cleaning operations on adjacent areas. This is particularly important with spot-blast cleaning.

5.5.2.2 The junctions between sound coating and spot-cleaned areas should present a smooth, feathered appearance. The application of coating to spot-cleaned areas should overlap the old, adjacent coating to a slight extent to ensure full coverage of the cleaned areas. Before the overall finish coat is applied, the inspector should ensure that oil, grime, dust, and other contaminants are cleaned from the old coating surfaces.

5.5.2.3 Adhesion of the newly applied coat to the old coating should be carefully checked. Practice D 5064 presents the procedure for evaluating adhesion of maintenance coatings.

5.5.2.4 Under the direction of the engineer, the inspector may explore beneath the surface of the existing or new coating film for covered-over rust or loosening of the old film, and where he discovers such conditions, require that the surface be cleaned and repainted.

5.5.2.5 The effect of the newly applied coating on the old underlying coating should be noted. Any coating that shows curling, lifting, or wrinkling should be reported to the engineer immediately since it may have to be removed and the area repainted. If the defects are general, rather than existing in a few isolated areas, use of a different type of coating may be necessary.

## 6. Coating Storage and Handling

6.1 *Storage of Coating and Thinner*— All coatings and thinners should be stored in areas or structures that are well-ventilated and not subject to excessive heat, open flames, electrical discharge, or direct rays of the sun. Storage should be in compliance with applicable regulations and the manufacturer's written instructions. Materials susceptible to damage at low temperatures should be stored to prevent freezing, such as in heated areas. Too high a storage temperature reduces the shelf life of the coating. If a coating is stocked for a considerable length of time (several months), it is desirable to invert the containers at monthly intervals. This will prevent hard settling and thus make mixing quicker and easier when the coating is to be used.

6.1.1 Coating containers should remain unopened until needed, and the oldest should be used first. The manufacturer's written instructions should be followed regarding shelf life. Coatings that have livered, gelled, or otherwise deteriorated during storage should not be used. If a particular material is in question, do not use it until it has been tested by the manufacturer or independent laboratory and found to be satisfactory.

6.1.2 Where a skin has formed in the container, the skin should be cut loose from the sides of the container, removed, and discarded. If it is felt that the skins are thick enough to have a practical effect on the composition, the remaining paint should not be used until it has been tested and found to be satisfactory.

6.2 *Mixing of Coatings*—All coatings should be thoroughly and completely mixed in clean containers before use. Where there is noticeable settling, and mixing is done either by power agitators or by hand, most of the vehicle should be poured off into a clean container. The pigment is then lifted from the bottom of the container with a clean, broad, flat paddle, lumps broken up and the pigment thoroughly mixed with the vehicle present. The poured-off vehicle should returned slowly to the original container with simultaneous agitation. It is also useful at this point to mix or pour repeatedly from one container to another (boxing) until the composition is uniform. The bottom of the original container should be inspected for the unmixed pigment. Two component paints should be mixed by agitation only, and not with boxing. After the individual components are homogenous, they are intermixed with agitation in the order stated in the manufacturer's instructions, that is, add Part B to Part A. The coating should not be mixed or kept in suspension by means of an air stream bubbling under the coating surface.

6.2.1 Some coatings may require straining after mixing, to ensure homogeneity and to remove skins and foreign matter. The strainers should be of a type to remove only skins, etc., but not to remove pigment. For example, a 297- µm (50-mesh) strainer is normally satisfactory for most coatings, unless some specific size is required in the specification. Containers should be covered when not in use, to reduce volatile losses and skinning.

6.2.2 Coatings should be agitated enough during application to ensure homogeneity. Some materials may even require constant agitation during use.

6.3 *Thinning*—Some specifications permit field thinning of laboratory-accepted coatings while others do not. This section describes some commonly accepted procedures when thinning is permitted.

6.3.1 *Initial Samples*—When thinning on the job site is permitted and unless other arrangements have been made, (for example using manufacturer-supplied thinner from unopened containers and complying with the manufacturer's written thinning instructions), the painting inspector may need to submit to an agreed-upon testing laboratory a 1-L (1-qt) sample from each batch to be thinned, together with a 1-qt sample of the thinner to be used, using clean sample containers in both cases. A request is submitted with these samples for advice on the proper thinning rate for the conditions prevailing and the consistency limits of the thinned coating.

6.3.2 *Thinning of Coating*—All additions of thinner should be made in the presence of the inspector, and only amounts or types of thinner permitted by the specification or manufacturer, or both, should be added. Thinning is carried out by pouring about half of the thoroughly mixed coating into an empty, clean container. The required thinner is then added and the two portions are remixed to obtain a homogenous mixture.

6.3.3 *Sampling of Thinned Coating*—During the work, additional samples need not be submitted for testing unless a deviation is noted in the coating consistency, or if it is suspected that there has been a change in the thinner.

6.3.3.1 When an inspector is qualified and has the necessary equipment available at the field office, arrangements may be made for on-site inspection of thinning and of the thinned coating. This speeds acceptance of a coating. The inspector should keep a record of all paint modifications, amount of thinning, weight per gallon, and viscosity. Where dry-film thickness is specified, the inspector should verify the new wet film thickness necessary to obtain the desired dried thickness with the thinned coating. He should make frequent checks of wet-film thickness as work progresses with the thinned coating. However, compliance with the specification should be based on dry-film thickness when specified.

6.3.3.2 To estimate the wet-film thickness of the thinned coating required to obtain the specified dried-film thickness, the percent volume of the nonvolatile (solids) in the original coating must be known. This figure is readily obtained from the manufacturer. With this information the calculation may be made as follows:

$$W = \frac{D(1.0 + T)}{S} \quad (1)$$

where:

$W$ = wet-film thickness,
$D$ = desired dry-film thickness,
$S$ = percent by volume (expressed as a fraction) of coating solids, and
$T$ = percent by volume (expressed as a fraction) of thinner added.

6.4 *Heating of Coating*—Coating as delivered in the manufacturer's containers and mixed thoroughly are ready for use unless the specification permits on-site thinning of high-viscosity material. When the temperature of the liquid coating is low (below 10°C (50°F)) the consistency (viscosity) may increase to the point that application is difficult. When thinning is not permitted, the coating may be heated. Should the contractor wish to reduce the viscosity by heating, to make application easier, the containers may be warmed in hot water, on steam radiators, by storing in a warm room, or by other acceptable indirect heating processes. In-line heaters are also available for application equipment. Direct application of flame to the containers is forbidden by fire regulations. It should be noted, however, that heating of the coating alone will not compensate for ambient or surface temperatures, or both, if they are below the minimum specified for that material.

## 7. Weather Considerations

7.1 *Drying*—It is well known that most coatings, particularly those for structures, will not dry properly at low temperatures and high relative humidities, nor will they perform well if applied over wet surfaces.

7.2 *Low Temperature*—Many specifications indicate temperature limits between which painting may be undertaken. The typical minimum temperature (air, material and surface) is usually 5°C (40°F), but may be as low as −18°C (0°F) for "cold-curing" one or two component systems or 10°C (50°F) for conventional two component systems. The requirements may state further that painting should not be undertaken when the temperature is dropping and within 3°C (5°F) of the lower limit. However, some authorities believe that some coatings may be applied at (or below) 0°C (32°F) without adverse effects. Within the limitations of the composition of the coating, this may be satisfactory, depending upon the type of coating and providing the surface is dry. Painting over ice or frost will result in early adhesion failure of the coating.

7.3 *High Temperature*—The maximum reasonable surface temperature for application is 50°C (125°F) unless clearly specified otherwise. A surface that is too hot may cause the coating solvents to evaporate so fast that application is difficult, blistering takes place, or a porous film results. To keep the temperature down it may be desirable, where practical, to paint under cover at a shop or to protect the surface from the sun with tarpaulins, or schedule painting operations to avoid seasonal or daily high temperatures.

7.4 *Moisture*—Painting should not be performed in rain, snow, fog, or mist, or when the temperature of the surface is less than 3°C (5°F) above the dew point. This is especially true in spring and fall when days are warm and nights are cool. Wet surfaces should not be painted unless the coatings are specifically designed for that condition. Relative humidity is usually an indicator of condensing conditions and specifications often contain an 85 % upper limit. High humidity can also affect the cure of some coatings. If it is suspected that the temperature and humidity conditions are such that moisture is condensing upon the surface, measure the relative humidity and dew point as described in 10.2.1.2.

7.4.1 When coatings must be applied in damp or cold weather, the substrate should be painted under cover, or protected from the surrounding air, and the steel heated to a satisfactory temperature. The steel should remain under cover until the applied coating is dry or until weather conditions permit its exposure in the open.

7.4.2 Newly applied coatings improperly exposed to freezing temperatures, excessive humidity, rain, snow, or condensation should be removed, the surface again prepared and painted with the same number of coats as the undamaged area.

7.5 *Wind*—The wind direction and velocity should be considered when applying coatings in areas where airborne overspray could damage automobiles, boats, and structures nearby. Heavy winds result in considerable loss of coating and excessive drying of the droplets reaching the surface. This results in an inability of the film to flow together (dry spray). If uncorrected, dry spray may create holidays, leading to poor performance, and it can interfere with adhesion of the applied or subsequent coat. Thinning with slower evaporating solvents may reduce or eliminate dry spray and produce a smooth surface. These problems can be avoided by utilizing brush or roller application methods instead of spray, scheduling the work at the less windy times of day, changing materials to the fast-dry types that do not adhere or damage adjacent property, or scheduling the work when the wind is blowing in a direction where dry spray will not cause damage.

## 8. Coating Application

8.1 *Residual Contaminants*—Visually inspect the surface immediately prior to painting to ensure that spent abrasive, dust, and debris have been completely removed. Dust removal should be considered satisfactory when the path left by a gloved hand wiped over the surface is barely discernable when viewed from a distance of 1 m (3 ft). During the inspection, also ensure that any oil or grease contamination that may have become deposited on the surface is completely removed. This is accomplished by solvent, steam, or detergent cleaning in accordance with SSPC-SP 1.

8.2 *Quality Assurance*—The inspector should consult the manufacturer's product data sheet and ensure that ( *1*) coatings received meet the description of the products acceptable under the requirements of the specification; (*2*) they are properly mixed and thinned (where allowed); (*3*) colors match a visual standard provided; (*4*) that proper precautions have been taken to prevent damage to adjacent areas from cleaning and painting operations; (*5*) working practices are so scheduled that damage to newly applied coating is minimized; (*6*) application equipment (brushes, spray) is acceptable for type, cleanliness, and usability; (*7*) weather conditions are acceptable under the requirements of the specification; (*8*) field-testing equipment on hand is in satisfactory working order ready for use; and (*9*) only the methods of application permitted under the specification are used, and that their use is in accordance with 8.3-8.7. SSPC-PA 1 is a specification for application of coating.

8.2.1 *Film Defects*—All coats should have nearly smooth surfaces relatively free of dry spray, overspray, orange peel, fish eyes, pinholes, craters, bubbles, or other significant defects. Bleed-through, insufficient hiding, skips, and misses are not acceptable. Runs and sags should be brushed out during application or removed by sanding if the coating has cured. Abrasive, dirt, or other debris that becomes embedded in the paint film should be removed prior to the application of subsequent coats.

8.3 *Brush Application*—Painting by brush should be done in a neat, workmanlike manner to produce a smooth coat as uniform in thickness as possible. The technique is from dry to wet, with the coating applied to the surface and spread back to the wet edge of the previous strokes. Coating should be worked into all irregularities in the surface, crevices, and corners. Runs, sags, or curtains should be brushed out. Surfaces that are inaccessible for painting with brushes and on which spraying is not permitted should have coating applied by means of sheepskin daubers. The specification may require "stripe coating" to provide adequate film thickness on places prone to premature breakdown. Edges and corners of all metal work, nut heads, bolts and nuts, and all individual members, bars, shapes, and plates should be striped by brush painting in advance of the application of coating to other parts.

8.3.1 Brushes should be of good quality, with pliable bristles that are compatible with the coating, and of suitable size to match the area being coated. They should not exceed 4 in. (100 mm) in width, and bristle length should be no less than 3½ in. (90 mm). The brushes should be kept in a clean, acceptable condition when not in use. The inspector should prohibit the use of any brush not in an acceptable condition.

8.4 *Spray Application*—Spray application may or may not be allowed. Often it is acceptable in fabricating shops, but because of the possibility of damaging surrounding property or coating films overspray, it may not be permitted in the field. The inspector should be familiar with the different kinds of spraying, which are compressed air spray, airless spray, air-assisted airless spray, electrostatic spray, and high-volume low-pressure spray.

8.4.1 The equipment should be suitable for the intended purpose, capable of properly atomizing the coating to be applied, and be equipped with suitable pressure regulators and gages. The equipment should be kept in a suitably clean condition to permit proper coating application without depositing dirt, dried coating, and other foreign materials in the film. The air supply for conventional and hot spray application should be free of moisture or oil. This can be verified by performing the white blotter test in accordance with Test Method D 4285. Airless spray equipment should be properly grounded. Any solvents left in the equipment should be completely removed before applying coating to the surface being painted.

8.4.2 Coating ingredients should be kept properly mixed in spray pots or containers during coating application, either by continuous mechanical agitation or by intermittent agitation. Coating should be applied in a uniform layer, with overlapping at the edge of the spray pattern. The spray pattern should be adjusted so that the coating is deposited uniformly. During application the gun should be held at right angles (perpendicular) to the surface (not arced or fanned) and at a distance that will ensure that a wet layer of coating is deposited on the surface. The trigger of the gun should be released at the end of each stroke. Poor spray technique resulting in excessive overspray (a sand-like finish) should not be tolerated. All runs, sags, or curtains should be brushed out immediately or sanded out if the coating has cured.

8.4.3 Brush striping of edges and other vulnerable locations may be specified. Brush or sheepskin daubers are used to coat all areas inaccessible to the spray gun and brushes are used to work coating into cracks, crevices, and blind spots that cannot be adequately spray painted.

8.4.4 Particular care should be observed with respect to type and amount of thinner, coating temperature, and operating techniques in order to avoid depositing coating that is too viscous, too dry, or too thin when it reaches the surface.

8.5 *Roller Application*—Rollers that are clean and of a material not soluble in the coating to be applied should be used. Roller covers are available in a variety of diameters, lengths, types of fabric, and fiber lengths. The nap (length) used on metal surfaces, generally varies from ¼ to ¾ in. (6 to 19 mm). The longer fibers hold more coating but do not provide as smooth a finish. Therefore their use is generally restricted to rougher surfaces such as the substrate and faster drying coatings. Short nap rollers give a smoother finish and are generally used for applying the top coat. There are also specialized rollers available for use on pipes and fences, and even pressure rollers that continually feed the coating to the roller cover.

8.5.1 The roller cover should be dipped into the coating until it is saturated and then rolled along the tray ramp until the coating is completely wetted in. The first load of coating on the roller should be applied to scrap material to force out air bubbles trapped in the nap. Proper roller technique requires application in the form of a *V* or *W* depending on the size of the area involved. The coating should then be cross-rolled to fill in the square created by the boundaries of the initial application. Only moderate pressure should be used, as heavy pressure can cause foaming and possible cratering by entrapped air. Application should be finished with light perpendicular strokes in one direction (usually vertical) to provide the smoothest, most uniform finish.

8.6 *Miscellaneous Methods*—Methods such as pads, mitts, and squeegees or trowels are used for specialized products or in situations where the conventional methods are not suitable due to the location or configuration of the work.

8.6.1 Painter's pads generally consist of a roller-type synthetic fabric attached to a foam pad. The size is generally 100 by 175 mm (4 by 7 in.) and the fiber length is 5 mm (3⁄16 in.). Application technique with a pad on large surface areas is similar to that used with a roller.

8.6.2 Painter's mitts are lamb skin gloves that are dipped into the coating and are rubbed across the surface. They are ideal for application of coatings to small, odd-shaped surfaces such as pipes and railings.

8.6.3 Squeegee or trowel application is generally used for heavy-bodied thick-film coatings.

8.7 *Rate of Application*—Properly written specifications require certain minimum and maximum dry-film thicknesses for each coat. The requirements should be augmented with wet-film thickness figures calculated from the composition of the coating so that the proper dry-film thickness is obtained. (Equation shown in 6.3.3.2.) Wet-film thickness measurements are useful to check as the work progresses to determine reasonably well that the desired amount of coating is being applied. Later, when the films are dry, the inspector may make spot checks with a dry-film measuring gage to ascertain acceptability of the coatings. Film thickness measurements are more informative than visual inspection, which may show only obvious nonuniform application. Instruments for measuring film thickness and the procedures for their use are described in 10.2.5 and 10.2.6. Nondestructive dry-film thickness gages and measurements are preferred, and applicable to metal substrates only.

8.7.1 Thickness or coverage requirements apply to the whole structure, not some specific part. It is important to note that the painting inspector check all areas and determine the film thickness for each coat. For instance, if the "shop coat" requires a minimum of 50 µm (2 mils) dry-film thickness, the inspector should ensure that it is obtained within the tolerance permitted in SSPC-PA 2. The areas tested should be identified and recorded so that the dry-film thickness of added coating can also be determined. With nondestructive measuring instruments a 15-m (50-ft) long and 1.8-m (6-ft) high I-beam can be tested in 30 min, and low areas if any, properly marked and recorded in the inspector's book. Because the shop prime coat inspector may not be the person doing the field coat application inspection, it is very important to record test results and send a copy to the field inspector in order to better determine thicknesses of subsequently applied coats.

## 9. Additional Considerations

9.1 *Ventilation*—It is essential when performing surface preparation or painting in enclosed spaces that adequate ventilation is provided for removal of dust and solvents.

9.2 *Shopcoat Repair*—Normally after erection work, such as riveting, bolting, welding, straightening, etc., has been completed satisfactorily, areas of the shopcoat will be found to have been damaged. Damaged or bare areas should be thoroughly cleaned, prepared, feathered and repainted with one new coat of shop or field primer. In addition, crevices and small cracks should be thoroughly cleaned and spot-primed. After drying, the crevices and cracks can be filled with an acceptable caulking compound as required by the specification. The specified field coats should then be applied over the entire structure.

9.3 *Painting Schedule*—As indicated in 5.4.4, painting should proceed by sections, bays, or parts of the work, and each coat in each section should be applied entirely and accepted by the inspector before a succeeding coat is applied. Except for any shop coat touch-ups made necessary by welding, etc., none of the metal that will be exposed to view in the completed structure should be field-painted until all associated concrete has been placed. Care should be taken by the contractor during painting operations to protect adjacent surfaces from being stained by the coating being applied. Any stained surface will need to be restored to its original condition without damage to that surface.

9.4 *Film Integrity*—Each coat should be applied as a continuous film of uniform thickness, free of holidays and pores. Any thin spots or areas missed in the application should be repainted and permitted to dry before the next coat is applied.

9.5 *Recoat Time*—Each coat should be dried throughout the full thickness of the film before application of the next succeeding coat. Some coatings are considered dry for recoating when the next coat can be applied without the development of any detrimental film irregularities such as wrinkling, lifting, or loss of adhesion of the previous coat. For most coatings the time to dry for recoat, even under optimum conditions varies with their composition and that of the subsequent coat. Thus, an oil-based coating may take 2 to 3 days to harden sufficiently to be overcoated with a coating of the same type. However, it may take 3 or 4 months to harden to be satisfactorily overcoated with a vinyl coating or other type of coating containing strong solvents. Some coatings have maximum recoat times. The coating manufacturer's written instructions should be followed for recoat times.

9.6 *Coating System Failure*—Failure of completed coating work may be the result of several factors. Most obvious is noncompliance with the specifications indicating insufficient inspections of the surface preparation, coating quality, coating application, or conditions during application and dying/curing. On the other hand, failure may be due to improper specification of coatings for intended use. Defective coatings should be removed in their entirety, the surface recleaned, and the specified coatings, or their alternatives, applied.

## 10. Inspection Equipment

10.1 *General*—Visual observation is the most important part of inspecting the coating application. There are, however, instruments and mechanical aids that help the inspector. They make the painter aware that his work can be checked during progress and even after completion. The different instruments that can be used are described in this section.

10.1.1 *Surface Profile Gages*—The inspector can determine the surface profile of blast-cleaned steel substrates using Test Method D 4417 to ensure the proper profile is obtained for the specified material. Some of the common instruments are:

10.1.1.1 Surface profile comparator for visual comparisons of the profile against a reference disk for sand, grit, and shot blast-cleaned steel.

10.1.1.2 Depth micrometres with conical points to project into the valleys to determine profile depth.

10.1.1.3 Tape, to create an exact replica of the profile on a special material. The tape is measured in the field using a spring micrometer to determine average maximum profile height.

10.1.2 *Adhesion of Existing Coating*—The inspectors should carry a pocket knife that can be used to determine the soundness of existing paint where there might be blistering underfilm corrosion. This is a subjective test and its value depends upon the inspector's experience. The cross-cut test, Test Method D 3359, is more reproducible.

10.1.3 *Portable Pull-Off Adhesion Testers* are available as described in Test Method D 4541. The testers measure the force required to remove a metal stud that has been cemented to the coated surface.

10.2 *Field Inspection Equipment* in good working order should be available to the inspector so that he may perform his function properly.

10.2.1 *Drying and Curing Times*—These are both important considerations, since dry time and cure time can both be affected. Minimum temperatures are required for reactive and water-borne coatings while too high a temperature can make application difficult or cause film defects such as pinholing. Inorganic zinc-rich primers and moisture-cure urethanes require certain minimum humidity conditions for proper cure. The manufacturer's recommendations should be followed.

10.2.1.1 *Thermometers*—The paint inspector may need several types of thermometers and should have at least an accurate pocket thermometer with a range from about −18 to 65°C (0 to 150°F) for measuring the air temperature. The same thermometer or a floating dairy thermometer may be used to determine the temperature of liquid coating, solvent, etc. Flat surface-temperature thermometers are also available for measuring the substrate temperature.

10.2.1.2 *Relative Humidity and Dew Point*— A psychrometer containing a wet and dry-bulb thermometer for determining relative humidity and a dew point chart is a useful inspection tools. Hand-held sling or electrical types are available as well as a direct-reading digital type. Atmospheric conditions, including air temperature, relative humidity, dew point, and surface temperature should be measured and recorded at the location where work is being performed.

10.2.2 *Coating Consistency* is an important characteristic since durability is related to film thickness and whether a film of the proper thickness can be applied is partly controlled by consistency.

10.2.2.1 *Consistency Cups*—There are occasions, such as on-site thinning, when it is necessary to check paint consistency during field application. While giving only partial information about the viscosity of the coating, the Zahn cup is a portable device for checking quickly the approximate consistency of coatings and other liquids. It consists of a bullet-shaped, stainless steel cup with an orifice in the bottom. Attached to the cup is a looped handle with a small opening at the top to align the cup in a vertical position when withdrawing it from the liquid being tested. Complete instructions for the procedure are given in Test Method D 4212.

10.2.3 *Weight-per-Gallon Cup*—There are times when the inspector may wish to check the weight-per-gallon of the paint in the field. If the value is low compared to the paint specification or manufacturer's data sheets, it indicates that the material may not have been properly manufactured or that unauthorized thinning may have been done, while differing values from the same container show that the coating has not been thoroughly mixed for application. The weight-per-gallon cup holds a given volume when filled at 25°C (77°F) or other specified temperature. It has a closely fitted lid with a small hole in it. In use, the cup is filled with a liquid slightly below the specified temperature. As the contents warm up, the excess escapes through the hole and is removed. The filled cup is wiped clean on the outside and weighed. A relatively inexpensive balance having a sensitivity of 0.1 g provides sufficient accuracy. The difference between the full and the empty weights divided by 10 is the weight in pounds of 1 gal of the paint. Multiply by 119.8 to convert to grams per litre. Complete instructions for the procedure are given in Test Method D 1475.

10.2.4 *Wet-Film Thickness Gages*—This type of instrument is used to measure the thickness of a wet film of paint *immediately* after it is applied to a surface. Note that erroneous readings may result when using the gage on fast-drying paints such as inorganic zinc or vinyl. If a wet-film gage is used to determine the thickness of coats subsequent to the first, great care must be taken that partially hardened undercoats are not indented by the gage, thus giving high readings. If the coat being measured has an appreciable softening effect on the previous coat, a wet-film thickness gage cannot be used with accuracy. It is very important to record and retain test results.

10.2.4.1 *Interchemical Gage*—This instrument is rolled over the newly applied wet film on a *smooth* flat portion of the surface and the thickness read directly in mils (micrometers). Complete details are given in Method A of Test Methods D 1212.

10.2.4.2 *Notched Gage*—This device has a series of calibrated steps for measuring thin to heavy coats. This gage with the proper face is placed squarely on the fresh, wet film. It is then withdrawn perpendicularly *without a sliding movement*. The true wet-film thickness lies between the highest step coated and the next highest, which was not coated. The procedure is described in Practice D 4414.

10.2.5 *Dry-Film Thickness Gages*—Dry-film thickness measurements are of great importance because the protection of the substrate is directly related to the thickness of the coating. There are two ways of making the measurements, nondestructively or destructively. Nondestructive dry-film thickness gages are preferred, as they do not damage the coating. Destructive gages involves penetrating or cutting through the film to the substrate with a needle or blade and measuring by some means the distance between the top and bottom of the film. This type of gage destroys the film, necessitating touch up with primer and finish to prevent corrosion at these spots. One kind of cutting device is described in 10.2.5.4.

10.2.5.1 *Nondestructive Film Thickness Gages* are widely used for field and shop inspection. For ferrous metals they are based on magnetism, and for nonmagnetic metals on inductance and eddy currents. All of the different types require calibration with standards, the thickness of which is known and in the same range as the coating to be measured. The calibration should be made on metal of the same kind, temper, thickness, and contour as that beneath the coating. Test Methods D 1186 and D 1400 describe procedures. Measurements on relatively rough surfaces, such as a surface blasted to a high profile, may be misleading unless the instrument is calibrated on an identical surface.

10.2.5.2 *Magnetic-Type Gages* use either an electromagnet requiring a permanent power supply or a permanent magnet. The principle of the method is that a nonmagnetic coating changes the magnetic force between the magnet and the magnetic base or the magnetic flux between the poles of the magnet. As the change is a function of distance from the metal, the gage can be made to read film thickness directly. Magnetic gages may be affected by the mass of the steel, or if electric welding is being carried out on a structure, for example, a ship's hull, at the time of measurement. Test Methods D 1186 describe the procedure for using magnetic gages. The method is also described in SSPC-PA 2, which includes instructions on the number of measurements for different areas and tolerances on the required film thickness.

10.2.5.3 *Eddy-Current-Type Gages* are based on inductance and eddy current techniques, and are described in Test Method D 1400.

10.2.5.4 *Gage*—This inspection gage is designed to measure coating film thickness by microscopic observation of a cut into the film. The tungsten carbide cutting tip is specially shaped to slice a precise narrow groove through a film into the substrate at an angle to the surface. Thickness of coating on any type of stable substrate may be determined, and individual coats may be measured separately providing they are distinguishable, for example, by color. The coating cannot be too brittle or soft, otherwise the cutting tip will tear rather than precisely cut through the coating, making accurate readings impossible. Test Methods D 4138 presents the procedure for using this type of gage.

10.2.6 *Holiday Detectors*—Pinholes and holidays are discontinuities in a coating film that may be invisible to the naked eye. They allow moisture to penetrate to the substrate. Holiday testing is usually performed on coatings intended for immersion service. Holiday testing is performed before final cure of the coating has occurred so that a successful repair can be made if any are detected. Pinhole and holiday detectors are either low voltage or high voltage. Their use and operation is presented in Practice D 5162.

10.2.6.1 Low voltage holiday detectors consist of a sponge attached to a battery and alarm. A ground wire is attached to the bare substrate. The sponge is wetted and moved across the entire surface. If a pinhole or holiday is present, an electrical circuit is completed and the alarm sounds. When a holiday is found, it should be marked, then wiped dry of any moisture to avoid telegraphing back to this holiday. Low voltage holiday detectors are suitable on coatings up to 508 µm (20 mil) in thickness.

10.2.6.2 High voltage holiday detectors function on the same operating principle as low voltage holiday detectors except a sponge is not used. The electrode is moved over the surface and a spark jumps from the electrode to the substrate at pinholes, holidays, or excessively thin areas. High voltage holiday detectors are capable of producing various voltage outputs. The voltage used is usually 3.9 *V* per micrometre (100 *V* per mil), unless otherwise specified by the coatings manufacturer. High voltage holiday testing is suitable for coating systems greater than 508 µm (20 mil).

## 11. Keywords

11.1 industrial structures; metal substrates; painting

## APPENDIX

### (Nonmandatory Information)

### X1. INSPECTION CHECKLIST

X1.1 The checklist in Fig. X1.1 lists the key elements to be used for inspection of industrial coating work. Many of the details covered may be in a specification for a particular project. A job specification for painting should include the coatings to be used. The various items are explained in detail in the text of this guide.

| TASK | | | |
|---|---|---|---|
| I | *Surface Condition Examination:*<br>1. Condition of edges, weld splatter<br>2. Grease or oil, or both<br>3. Chalk, mildew<br>4. Protective coverings in place | *Test Method/Equipment:*<br>1. Visual observation and touch<br>2. Visual observation and clean white rag<br>3. Visual observation and magnifying glass<br>4. Visual observation | *Comments:*<br>Many materials if not removed from the surface will affect the life of the coating. These include oil, grease, soil, weld splatter, and slag, which make it impossible to obtain proper adhesion to the metal surface (5.2.1, 5.4) Careful observation is the key to making certain that a sound surface is available for painting. |
| II | *Environmental Conditions:*<br>1. Air temperature<br>2. Surface temperature<br>3. Wind direction, velocity<br>4. Dew point, RH<br>5. Visible moisture | *Test Method/Equipment:*<br>1. Air thermometer<br>2. Surface thermometer<br>3. Wind gage<br>4. Sling psychrometer<br>5. Direct observation | *Comments:*<br>Environmental conditions must be within specified limits to obtain adhesion and proper film formation. |
| III | *Safety on the Job:*<br>1. Protective clothing<br>2. Respirator<br>3. Safety glasses<br>4. Ear protection | *References:*<br>1. OSHA Hazard Communication Standard<br>2. Product MSD sheets<br>3. Municipal and state regulations | *Comments:*<br>There are a number of hazards associated with any painting operation; safety regulations should be observed and unsafe conditions or practices should be, reported promptly to management (1.2, 5.3). |
| IV | *Blast Cleaning:*<br>1. Type and size abrasive<br>2. Clean and dry abrasive<br>3. Recycled abrasive test<br>4. Compressed air check<br>5. Nozzle air pressure | *Test Method/Equipment:*<br>1. Sieve analysis and visual observation<br>2. Visual observation<br>3. Water test<br>4. White blotter<br>5. Pressure gage | *Comments:*<br>Blast cleaning is used to remove foreign materials from the surface to provide a roughened surface by means of a dry sand, grit, or shot blast impinging the surface with hard abrasive particles impelled by air (5.3.4). Precautions should be taken that blasting equipment is operated properly (5.3). |
| V | *Surface Preparation:*<br>1. Dust and abrasive removal<br>2. Degree of cleanliness<br>3. Profile measurement<br>4. Magnetic base reading | *Test Method/Equipment:*<br>1. Visual observation<br>2. Written definitions and pictorial standards<br>3. Replica tape or surface profile comparator<br>4. Magnetic thickness gage (6.2.6) | *Comments:*<br>Surface preparation is one of the most important factors affecting the performance of paint. The specifier will determine the proper level according to the expected service life of the structure and type of paint specified (5.1). *Surface Profile* —The texture of the metal surface has a significant effect on the performance of coatings since it increases the surface area to which the coating can develop adhesion. |
| VI | *Coatings Application:*<br>1. Time from surface preparation to application<br>2. Coating viscosity<br>3. Compressed air check<br>4. Protective coverings in place<br>5. Time application began<br>6. Surrounding air cleanliness<br>7. Continue to monitor temperature and humidity conditions<br>8. Correct coating and mixing procedure<br>9. Induction time observed<br>10. Proper percent agitation<br>11. Film thickness—wet<br>—dry<br>12. Recoat Times observed<br>13. Intercoat Cleanliness<br>14. Film defects, voids, etc. | *Test Method/Equipment:*<br>1. Record<br>2. Dip-type viscosity cup Test Method D 4212<br>3. White blotter<br>4. Visual observation<br>5. Record<br>6. Visual observation<br>7. Psychrometer<br>8. Record coatings batch numbers mixing procedure<br>9. Visual observation<br>10. Visual observation<br>11. Film thickness gages<br>12. Record time application completed<br>13. Visual observation<br>14. Holiday detector | *Comments:*<br>Many factors are important in ensuring proper application of coatings. The details are covered in this guide ( 8). In particular, note: Dry-film thickness measurements are of great importance because the protection of the substrate is directly related to the thickness of the coating. There are two ways of making the measurements, nondestructively or destructively (10.2.5). |
| VII | *Recordkeeping:*<br>1. Record all details<br>Applicator<br>Manufacturer<br>Batch #'s<br>Container condition<br>2. Record observations from Sections I, II, IV, V and VI | *Test Method/Equipment:*<br>1. Inspector's log book | *Comments:*<br>Maintenance of record book containing all transactions between the inspector and the contractor is essential to eliminate contract disputes. Details of the many steps involved in proper coatings application should be recorded (Section 4). |

**FIG. X1.1 Inspection Checklist**