

## SSPC: The Society for Protective Coatings

# SURFACE PREPARATION COMMENTARY for Metal Substrates

## 1. Introduction

This Surface Preparation Commentary (SP COM) is intended to be an aid for the coating specifier in selecting methods, materials, and standards for specifying the proper surface preparation for steel, and other metals (not including ductile iron pipe). The use of these standards in a coating specification will give direction to the contractor regarding what is required and give direction to the inspector on verifying compliance to the specification.

The SSPC standards, summarized in Table 1A, represent a broad consensus of users, suppliers, and public interest groups. Details of the methods used to verify many of the properties discussed in this SP COM are described in SSPC publication 03-14, "The Inspection of Coatings and Linings, A Handbook of Basic Practice for Inspectors, Owners, and Specifiers, 2nd Ed."

Table 1B includes similar standards published by the International Organization for Standardization (ISO)<sup>(1)</sup>. It should be noted that while the ISO and SSPC standards are similar and commonly deemed equivalent, they are not identical. Tables 3A, 3B, and 3C provide a comparison of the ISO and SSPC standards.

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<sup>(1)</sup> International Organization for Standardization (ISO), Case Postale 56, Geneva CH-1211, Switzerland. In the United States, ISO standards may be obtained from the American National Standards Institute (ANSI) at <<http://www.ansi.org>>

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- 13.2 SSPC-TR 2/NACE 6G198, "Joint Technical Report on Wet Abrasive Blast Cleaning"
- 13.3 SSPC-Guide 15, "Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates"
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## 3. Importance of Surface Preparation

Often, the surface preparation of steel for coating requires a three-step process: 1) initial pre-cleaning to remove deposits of grease, oil, dirt, and other surface contaminants; 2) cleaning with hand/power tools, pressurized water, chemicals, or abrasive blasting; 3) creation or verification of the specified anchor pattern profile. The life of a coating depends as much on the degree and quality of surface preparation as on the selected coating system, because most coating failures can be attributed to inadequate surface preparation or lack of coating adhesion. Surface preparation, therefore, should receive thorough consideration. The primary functions of surface preparation are:

- to remove surface contaminants that can induce premature coating failure
- to provide a clean surface with adequate profile for good coating adhesion

Where conventional abrasive blast cleaning is not allowed or is impractical, alternative abrasives or methods of cleaning the surface must be employed. Chemical stripping will remove coating and is relatively easy to contain. Hence, chemical stripping may be used around sensitive machinery or in densely populated areas. (Refer to SSPC-TU 6, "Chemical Stripping of Organic Coatings from Steel Structures.") Alternative abrasives such as sodium bicarbonate (baking soda) or dry ice ( $\text{CO}_2$ ) can sometimes be used in places where conventional abrasives cannot be used. A class of abrasives has been developed that surrounds each abrasive particle with an open-cell sponge matrix. The sponge contains the abrasive and facilitates cleanup and recycling.

When control of dust emissions is critical, wet blast cleaning methods are often employed. Wet blast cleaning methods may involve water alone, abrasive injected into the water stream, water injected into an abrasive air stream, or a water curtain surrounding an air/abrasive stream. Power tools with vacuum shrouds have also been proven effective in controlling dust emissions, particularly in removing lead-containing coatings. It is important to note that surface preparation methods used to control dust may not necessarily eliminate any hazards associated with disturbance of hazardous materials such as lead. In applications where the presence of soluble salts on the steel surface creates a serious problem, such as tank linings, it could be beneficial to incorporate water into the cleaning process.

The use of water alone (without abrasive media) at various pressures is a technique for surface preparation that will remove coatings and contaminants without altering the existing surface profile.

**TABLE 1A**

**SUMMARY OF CURRENT SSPC ABRASIVE AND SURFACE PREPARATION STANDARDS**

| <b>SSPC STANDARD</b>                                                                                                        | <b>DESCRIPTION</b>                                                                                                                                                                                                                      |
|-----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SSPC-AB 1<br>Mineral and Slag Abrasives                                                                                     | Definition of requirements for selecting and evaluating mineral and slag abrasives used for blast cleaning                                                                                                                              |
| SSPC-AB 2<br>Cleanliness of Recycled Ferrous Metallic Abrasive                                                              | Cleanliness requirements for a recycled work mix and a description of the test procedures.                                                                                                                                              |
| SSPC-AB 3<br>Ferrous Metallic Abrasives                                                                                     | Requirements for chemical and physical properties of iron and steel abrasives.                                                                                                                                                          |
| SSPC-AB 4<br>Recyclable Encapsulated Abrasive Media                                                                         | Requirements for physical properties and cleanliness of abrasive media encapsulated in a compressible non-uniform cellular matrix.                                                                                                      |
| SSPC-PA 17<br>Conformance to Profile/Surface Roughness/<br>Peak Count Requirements                                          | A procedure suitable for shop or field use for determining compliance with specified profile ranges on a steel substrate.                                                                                                               |
| SSPC-SP 1<br>Solvent Cleaning                                                                                               | Removal of oil, grease, dirt, soil, salts, and contaminants by cleaning with solvent, vapor, alkali, emulsion, or steam.                                                                                                                |
| SSPC-SP 2<br>Hand Tool Cleaning                                                                                             | Removal of loose rust, loose mill scale, and loose paint to degree specified, by hand chipping, scraping, sanding, and wire brushing.                                                                                                   |
| SSPC-SP 3<br>Power Tool Cleaning                                                                                            | Removal of loose rust, loose mill scale, and loose paint to degree specified, by power tool chipping, descaling, sanding, wire brushing or wire impact tools, and grinding.                                                             |
| SSPC-SP 5/NACE No. 1<br>White Metal Blast Cleaning                                                                          | Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning by wheel or nozzle (dry or wet) using sand, grit or shot.                                                                                          |
| SSPC-SP 5 (WAB)/ NACE WAB-1*<br>White Metal Wet Abrasive Blast<br>Cleaning                                                  | Same level of cleanliness as SSPC-SP 5/NACE No. 1, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.                                             |
| SSPC-SP 6/NACE No. 3<br>Commercial Blast Cleaning                                                                           | Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning. Staining is permitted on no more than 33% of each 9 in <sup>2</sup> area.                                                                         |
| SSPC-SP 6 (WAB)/ NACE WAB-3<br>Commercial Wet Abrasive Blast Cleaning                                                       | Same level of cleanliness as SSPC-SP 6/NACE No. 3, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.                                             |
| SSPC-SP 7/NACE No. 4<br>Brush-Off Blast Cleaning                                                                            | Blast cleaning of all except tightly adhering residues of mill scale, rust, and coatings, while uniformly roughening the surface.                                                                                                       |
| SSPC-SP 7 (WAB)/ NACE WAB-4<br>Industrial Wet Abrasive Blast Cleaning                                                       | Same level of cleanliness as SSPC-SP 7/NACE No. 4, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.                                             |
| SSPC-SP 8<br>Pickling                                                                                                       | Complete removal of rust and mill scale by acid pickling, duplex pickling, or electrolytic pickling.                                                                                                                                    |
| SSPC-SP 10/NACE No. 2<br>Near-White Blast Cleaning                                                                          | Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning. Staining is permitted on no more than 5% of each 9 in <sup>2</sup> area of the cleaned surface.                                                   |
| SSPC-SP 10 (WAB)/NACE WAB-2<br>Near White Metal Wet Abrasive Blast Cleaning                                                 | Same level of cleanliness as SSPC-SP 10/NACE No. 2, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.                                            |
| SSPC-SP 11<br>Power Tool Cleaning to Bare Metal                                                                             | Complete removal of all rust, scale, and paint by power tools, with resultant minimum surface profile of 25 $\mu$ m (1 mil).                                                                                                            |
| SSPC-SP 14/NACE No. 8<br>Industrial Blast Cleaning                                                                          | Between SP 7 (brush-off) and SP 6 (commercial). The intent is to remove as much coating as possible, but tightly adherent rust, mill scale, and coating can remain on 10 percent of each 9 in <sup>2</sup> area of the cleaned surface. |
| SSPC-SP 14 (WAB)/NACE WAB-8<br>Industrial Wet Abrasive Blast Cleaning                                                       | Same level of cleanliness as SSPC-SP 14/NACE No. 8, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.                                            |
| SSPC-SP 15<br>Commercial Grade Power Tool Cleaning                                                                          | Between SP 3 and SP 11. Removes all rust and paint but allows for random staining on up to 33% of each 9 in <sup>2</sup> area of surface; requires a minimum 25 $\mu$ m (1 mil) profile.                                                |
| SSPC-SP 16 Brush-Off Blast Cleaning of<br>Coated and Uncoated Galvanized Steel,<br>Stainless Steels, and Non-Ferrous Metals | Requirements for removing loose contaminants and coating from coated and uncoated galvanized steel, stainless steels, and non-ferrous metals. Requires a minimum 19 $\mu$ m (0.75 mil) profile on bare metal substrate.                 |

|                                                                               |                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SSPC-SP WJ-1/NACE WJ-1<br>Waterjet Cleaning of Metals–Clean to Bare Substrate | Cleanest waterjetting level, requires the cleaned metal to be free of all visible oil, grease, dirt, rust and other corrosion products, previous coatings, mill scale, and foreign matter.                                                                                                                                                          |
| SSPC-SP WJ-2/NACE WJ-2<br>Waterjet Cleaning of Metals–Very Thorough Cleaning  | Requires the cleaned metal surface to be free of all visible oil, grease, dirt, rust, and other corrosion products except for randomly dispersed stains of rust and other corrosion products, tightly adherent thin coatings, and other tightly adherent foreign matter over no more than 5% of each 9 in <sup>2</sup> area of the cleaned surface. |
| SSPC-SP WJ-2/NACE WJ-3<br>Waterjet Cleaning of Metals–Through Cleaning        | Requires removal of all visible contaminants as in WJ-2 above. Randomly dispersed staining as described in WJ-2 is limited to no more than 33% of each 9 in <sup>2</sup> area of the cleaned surface.                                                                                                                                               |
| SSPC-SP WJ-4/NACE WJ-4<br>Waterjet Cleaning of Metals–Light Cleaning          | Requires removal of all visible oil, grease, dirt, dust, loose mill scale, loose rust and other corrosion products, and loose coating. Any residual material shall be tightly adhered to the metal substrate.                                                                                                                                       |

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TABLE 1B

**SUMMARY OF INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)  
SURFACE PREPARATION STANDARDS**

| <b>ISO Standard 8501-1</b>                                                                                                                          | <b>Description</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sa 1 Light blast cleaning                                                                                                                           | Free of oil, grease and dirt and poorly adhering mill scale, rust, paint and foreign matter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Sa 2 Thorough blast cleaning                                                                                                                        | Free of oil, grease and dirt and most of the mill scale, rust paint and foreign has been removed                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Sa 2 ½ Very thorough blast cleaning                                                                                                                 | Free of oil, grease and dirt and from mill scale, rust and paint. Remaining traces of contamination will only be slight stains.                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Sa 3 Blast cleaning to visually clean steel                                                                                                         | Free of oil, grease, dirt, mill scale, rust, paint and foreign matter. Surface shall have a uniform metallic colour                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| St 2 Thorough hand and power tool cleaning                                                                                                          | Free of oil, grease and dirt and poorly adhering mill scale, rust, paint and foreign matter.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| St 3 Very thorough hand and power tool cleaning                                                                                                     | Same as St 2, but the surface shall be treated much more thoroughly to give a metallic sheen arising from the metallic substrate.                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>ISO Standard 8501-2<br/>Localized Removal of Previous Coatings</b>                                                                               | <b>Description</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| P Sa 2<br>Thorough localized blast cleaning                                                                                                         | Firmly adhering coatings are intact. Where coatings are removed, surface is free of visible contaminants, loose coating and most mill scale, rust and foreign matter.                                                                                                                                                                                                                                                                                                                                                                                                       |
| P Sa 2 ½<br>Very thorough localized blast cleaning                                                                                                  | Firmly adhering coatings are intact. Exposed substrate is free from visible contaminants and loose coating. Remaining traces of contaminants are visible as slight stains in form of spots or stripes.                                                                                                                                                                                                                                                                                                                                                                      |
| P Sa 3<br>Localized blast cleaning to visually clean steel                                                                                          | Exposed substrate is free of visible contaminants and mill scale, rust, and foreign matter. Surface shall have a uniform metallic color.                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| P St 2<br>Thorough localized hand- and power-tool cleaning of previously coated surfaces                                                            | Firmly adhering coatings are intact. Exposed substrate is free of loose coating, loose mill scale, loose visible foreign matter.                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| P St 3<br>Very Thorough localized hand-and power-tool cleaning of previously coated surfaces                                                        | Exposed substrate is free of coating, mill scale, foreign matter, and has a uniform metallic sheen.                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| P Ma<br>Localized machine cleaning                                                                                                                  | Firmly adhering coatings are intact. Exposed substrate is free of visible oil and grease, loose visible loose contaminants, loose coating, mill scale, and rust. Remaining traces of contaminants are visible as slight stains in form of spots or stripes.                                                                                                                                                                                                                                                                                                                 |
| <b>ISO Standards 8501-4<br/>Initial surface conditions, preparation grades and flash rust grades in connection with high-pressure water jetting</b> | <b>Description</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Wa 1 Light High Pressure Water Jetting                                                                                                              | When viewed without magnification, the surface shall be free from visible oil, grease, loose rust, and foreign matter. Any residual contamination shall be randomly dispersed and firmly adherent.                                                                                                                                                                                                                                                                                                                                                                          |
| Wa 2 Thorough High Pressure Water Jetting                                                                                                           | When viewed without magnification, the surface shall be free from visible oil, grease and dirt and most of the rust, previous paint, coatings, and foreign matter. Any residual contamination shall be randomly dispersed and can consist of firmly adherent coatings, firmly adherent foreign matter, and stains of previously existent rust.                                                                                                                                                                                                                              |
| Wa 2 ½ Very Thorough High Pressure Water Jetting                                                                                                    | When viewed without magnification, the surface shall be free from all visible rust, oil, grease, dirt, previous paint coatings and, except for slight traces, all foreign matter. Discoloration of the surface may be present where the original coating was not intact. The grey, brown/black discoloration observed on pitted and corroded steel cannot be removed by further water jetting. Note that this standard does not imply that the cleanliness is limited to Wa 2, but achieving a greater degree of cleanliness may involve disproportionate increase in time. |

To gain maximum benefit from a high-performance industrial coating, it is not prudent to cut back on the surface preparation. Surface preparation is important even when a “surface-tolerant” coating is used. When the manufacturer claims a particular coating will “tolerate” a given amount of rust, old coating, or other contamination on the steel surface, it is likely that the coating will perform even better if the surface is prepared to a higher level of cleanliness.

## 4. Surface Conditions

The initial condition of the surface to be cleaned will determine the amount of work, time, and money required to achieve any particular degree of surface cleanliness. It is more difficult to remove contaminants from rusty steel than from intact mill scale. Therefore, it is necessary to consider the surface condition prior to selecting the method of cleaning.

The initial condition of the steel may determine the choice of abrasive to be used. Steel shot is an economical and effective choice for removing intact mill scale. However, if the steel is rusted and/or pitted, a more angular abrasive such as steel grit or a non-metallic mineral abrasive will more effectively “scour out” the rust.

Although there are almost an infinite number of initial conditions, they can be broadly divided into three categories:

- new construction—steel not previously coated
- maintenance—previously coated steel
- contaminated surfaces—common to both new construction and maintenance.

**4.1 NEW CONSTRUCTION:** For new construction there are four surface conditions based upon the rust condition classifications. These initial conditions, defined in SSPC visual consensus guides, namely, SSPC-VIS 1, SSPC-VIS 3, and SSPC-VIS 4, are:

- **Condition A:** Steel surface covered completely with adherent mill scale; little or no rust visible
- **Condition B:** Steel surface covered with both mill scale and rust
- **Condition C:** Steel surface completely covered with rust; little or no pitting visible
- **Condition D:** Steel surface completely covered with rust; pitting visible

Conditions A, B, C, and D are also referred to as Rust Grades A, B, C, and D.

**4.2 MAINTENANCE:** The SSPC documents containing the consensus reference photographs also define conditions E, F, G, and H for previously coated surfaces.

- **Condition E:** Paint applied over a blast-cleaned surface, paint mostly intact.
- **Condition F:** 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 H:** Degraded painting system applied over steel; system thoroughly weathered, thoroughly blistered, or thoroughly stained.

In maintenance repainting, the degree of surface preparation required depends on the new coating system and on the extent of degradation of the surface to be coated. The amount of rusting on a surface is based on the numerical scale of 0 to 10 given in SSPC-VIS 2 (ASTM D610),<sup>(2)</sup> “Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces,” where a rating of 10 indicates no rust and a rating of 0 indicates more than 50% rusting. SSPC-PA Guide 4, “Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems,” suggests the minimum surface preparation needed for each degree of rusting.

In estimating rust percentages, photographs and schematic diagrams of the type shown in SSPC-VIS 2 can serve as practical aids. The Guide to SSPC-VIS 2 shows black-and-white schematics of actual rust patterns that serve as guides for judging the percentage of surface covered by rust (after removal of stains) or rust blisters. SSPC-VIS 2 shows three different configurations of rusting – general, pinpoint, and spot rust.

Comments on surface preparation for maintenance repainting are also given in SSPC-PA Guide 4, “Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems.” This guide includes a description of accepted practices for retaining old, sound coating, removing unsound coating, feathering, and spot cleaning.

**4.3 SURFACE CONTAMINANTS:** Typical contaminants that should be removed during surface preparation are rust, corrosion products, mill scale, grease, oil, dirt, dust, moisture, soluble salts containing anions, such as chlorides, sulfates (if present in detrimental quantities), paint chalk, and loose, cracked, or peeling coating.

**4.3.1 Rust, Stratified Rust, Pack Rust, and Rust Scale:** Rust consists primarily of iron oxides, the corrosion products of steel. Whether loose or relatively tightly adherent, rust must be removed for satisfactory coating performance. Rust is not a good base for applying coatings because it expands and becomes porous. So-called “over-rust primers” (also referred to as “rust converters”) do not perform as well as conventional coatings applied over clean steel, and the effectiveness of rust converters is unproven.

Stratified rust, pack rust, or rust scale occur when the iron oxides form in a definite shape rather than in grains or powder. Pack rust typically forms between mating surfaces (e.g., in crevice areas), whereas rust scale and stratified rust form on the surface of the steel (e.g., on steel plates, webs, and flanges). Stratified rust, pack rust, and rust scale can be dislodged from the surface in pieces or layers as large as several inches (centimeters) across. Some of this rust can adhere so tightly to the base metal that a power wire brush will not remove it. Even though it is considered “tightly adherent” because it cannot be lifted with a dull putty knife, it provides a very poor surface to paint over. Eventually the rust will loosen and dislodge from the surface leaving large areas unprotected.

<sup>(2)</sup> ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

Stratified rust, pack rust, and rust scale must be removed with impact tools such as chipping hammers, scabblers, needle guns, and rotary impact flap assemblies. High- and ultrahigh-pressure waterjetting also can be used to remove pack rust; then the crevices must be blown out by compressed air or dried to remove the water.

Ideally, these types of rust should be removed even when the lowest levels of hand and power tool cleaning, SSPC-SP 2 and SSPC-SP 3, are specified. However, a judgment must be made on each job as to whether the cost and effort required to remove the stratified rust, pack rust, and rust scale can be justified by the expected increase in the life of the coating system. Where these forms of rust are a problem, the contracting parties should come to an agreement on the extent of removal at the outset of the job.

**4.3.2 Mill Scale:** Mill scale is a bluish, somewhat shiny oxide residue that forms on steel surfaces during hot rolling. Although initially tightly adherent, it eventually cracks, pops, and disbonds. Unless completely removed before coating, mill scale will eventually cause the coatings to crack and expose the underlying steel. Steel is anodic to mill scale and so corrodes more rapidly in this combination of “dissimilar metals.”

Mill scale varies in its effects upon the performance of coatings. Tightly adhered or intact mill scale may not need to be removed for mild atmospheric service. If, however, the steel surface will be coated with primers with low wetting properties or exposed to severe environments, such as chemical exposures or immersion in fresh or salt water, then removal of mill scale by blast cleaning or power tool cleaning is necessary. Note that the effort required to remove all tightly adherent mill scale usually results in a surface that has less staining than the maximum 33% permitted by SP 6 or SP 15, but may have more staining than the maximum 5% permitted by SP 10.

**4.3.3 Grease and Oil:** Even thin films of grease and oil, which may not be visible to the unaided eye and therefore are not required to be removed by SSPC-SP 1, can prevent tight bonding of high-performance coatings. Oil paints and a few specific epoxy coatings may be tolerant of thin oil films. Visible deposits of grease and oil must be removed by solvent cleaning, SSPC-SP 1, prior to mechanical cleaning (e.g., power tool or abrasive blast cleaning). If this precleaning is not done, power tool or abrasive blast cleaning may spread the grease or oil over the surface without removing it. Other methods of precleaning include hot water (typically under pressure) with emulsifier or grease cutting chemicals. High- and ultrahigh-pressure waterjetting may also be capable of removing grease and oil. Most air driven power tools require a daily lubrication by the addition of oil in the air stream. This oil can be transmitted to the surface being cleaned. Although not visible, the specifier may require its removal by solvent cleaning prior to the application of the coating system. ASTM F22, “Standard Test Method for Hydrophobic Surface Films by the Water-Break Test,” can be used to determine the presence of non-visible oil on the surface. Ultraviolet (“black”) light can also be used to detect films of hydrocarbons on the surface.

Appropriate eye protection should be worn when using ultraviolet light to inspect surfaces.

**4.3.4 Dirt and Dust:** Dirt and dust can also prevent tight bonding of coatings, and should be removed completely. ISO 8502-3, “Preparation of steel substrates before application of paints and related products—Tests for the assessment of surface cleanliness—Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)” provides a method of determining the amount of dust on a surface prior to coating.

**4.3.5 Moisture:** Steel surfaces must be dry before cleaning and coating. Moisture may either produce new rust before coating is applied or accelerate underfilm corrosion after coating is applied. Water can also prevent an organic coating from properly “wetting out” (penetrating into the surface profile) on metal surfaces, and may disrupt the curing of the coating. Specialty coatings designed for application over damp or submerged surfaces or even underwater, are exceptions to this common rule.

**4.3.6 Soluble Salts:** Steel surfaces are exposed to water-soluble salt deposition from many sources, including contact with contaminated water or cargo, or exposure in industrial or marine environments. If the salts remain on the surface after cleaning, they can attract moisture that can permeate the coating and may result in formation of blisters (osmotic blistering) as the water vapor finds its way to the salt crystals. Salts, particularly chlorides, may also accelerate the corrosion reaction and the formation of underfilm corrosion. Methods for measuring the amount of salt on the surface are described in SSPC-Guide 15, “Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates.” In some circumstances it is desirable to remove soluble salts by power washing or other methods prior to power tool or abrasive blast cleaning. In other circumstances, salt removal is more efficient after initial power tool or abrasive blast cleaning has been performed.

No industry standards currently exist for the maximum level of salts permitted on a steel surface prior to coating application. The results of tests to determine salt levels are affected by the condition of the substrate, the service environment for the coating, and the specific test method and test location selected. Individual coatings have different tolerance levels for various contaminants. The specifier should consult with a protective coating specialist and the manufacturer of the coating to be applied.

**4.3.7 Paint Chalk:** The sun’s ultraviolet light causes all organic coatings in exterior exposures to chalk to some extent. Chalk is the residue left after deterioration of the coating’s surface organic binder. All loose chalk must be removed prior to recoating in order to avoid intercoat adhesion problems. It is often specified that, before topcoating, old coating must have a rating of no less than 8 in accordance with ASTM D4214, “Test Method for Evaluating Degree of Chalking of Exterior Paint Films.”

**4.3.8 Deteriorated Coating:** All loose coating that can be removed with a dull putty knife or coating that fails to meet pre-established adhesion values must be removed before performing maintenance coating. Prior to removal, the coating should be tested for the presence of lead or other toxic materials. If toxic materials are found, special precautions must be taken to protect workers, others in the area, and the environment.

**4.4 SURFACE DEFECTS:** Coatings tend to draw thin and pull away from sharp edges and projections, leaving little or no coating to protect the underlying steel, thereby increasing the potential for premature coating failure. This results in poor coating film quality. Other features of steel that are difficult to properly cover and protect include crevices, weld porosity, laminations, etc. These considerations are discussed below. The high cost to remedy these surface imperfections requires weighing the benefits of remedial methods, such as edge rounding or grinding, versus a potential coating failure.

Poorly adhering contaminants, such as weld slag residues, loose weld spatter, and some minor surface laminations, may be removed by abrasive blast cleaning. Other surface defects, such as steel laminations, weld porosities, or deep corrosion pits, may not be evident until after abrasive blast cleaning is completed. Therefore, the timing of such surface repair work may occur before, during, or after preliminary surface preparation operations have begun.

**4.4.1 Welds and Weld Spatter:** Weld spatter should be removed prior to blast cleaning. Most weld spatter, except that which is very tightly adherent, can be readily removed using a chipping hammer, spud bar, or scraper. Tightly adhering weld spatter may require removal by grinding. Weld spatter that is not removed will result in a lower coating film thickness (as on sharp edges) and may disbond from the base metal, resulting in adhesion failure. Welds can also have sharp projections that may penetrate through the wet coating film. NACE SP0178, "Standard Recommended Practice, Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to Be Lined for Immersion Service," provides details on grinding welds.

**4.4.2 Weld Porosity:** Although it may be outside the scope of surface preparation for coating application, areas of porosity might warrant further investigation. Unacceptable porosity is defined in the American Welding Society standard AWS D1.1, "Structural Welding Code." Acceptable weld profiles, arc strikes, and weld cleaning are also addressed in Section 3 of AWS D1.1.

**4.4.3 Sharp Edges:** Sharp edges, such as those normally occurring on rolled structural members or plates, as well as those resulting from flame cutting, welding, grinding, etc., and especially shearing, have an influence on coating performance and may need to be removed (e.g., grinding, mechanical sanding, filing). During removal operations, care should be taken use proper grinding techniques to prevent the formation of new sharp edges. SSPC-PA Guide 11, "Guide to

Methods for Protection of Edges, Crevices, and Irregular Steel Surfaces." provides additional information to assist specifiers in determining how to treat edges. Some high solids coatings, often requiring plural component spray, have edge-retentive properties that may lessen the effect of sharp edges.

**4.4.4 Crevices:** Areas of poor design for corrosion protection, such as tack or spot welded connections, back-to-back angles, crevices, etc., may require special attention. When possible, such deficiencies should be corrected by structural or design modification. When this is not possible, filling or special surface preparation and coating procedures may be needed.

**4.4.5 Laminations, Slivers:** Rolling discontinuities (laps) may have sharp protruding edges and deep penetrating crevices. It is beneficial to remove such defects prior to coating. Various methods can be used to eliminate minor slivers (e.g., scraping and grinding), and filling may be necessary. Filling of indentations may also be necessary.

**4.4.6 Pits:** Deep corrosion pits, gouges, clamp marks, or other surface discontinuities may require grinding prior to coating. The surface may also require filling with weld material.

## 4.5 POST-CLEANING SURFACE CONDITIONS (RUST BLOOM, RUST-BACK, FLASH RUST)

It is important that the surface conditions do not change between the time of inspection for the specified visual cleanliness preparation level and the time immediately prior to coating application.

Section 4.3.1 describes forms of rust that are pre-existing on steel. Rust Bloom, Rust-Back, and Flash Rust are forms of rust that might develop between the time that the inspection is completed after surface preparation is accomplished and the time that coating is applied. Rust-back is general atmospheric rust contaminated with chemicals from the environment in which the metal has been exposed. In contrast, flash rust, formed while preparing surfaces by waterjetting using potable water, consists of pure iron oxide, which is actually a component of some coatings. The coatings industry treats Rust-Back and Flash Rust differently. Coatings are not normally applied over rust-back. Under some circumstances, however, coatings MAY be applied over light levels of flash rust if recommended by the coating manufacturer and allowed by the contract specification.

**4.5.1 Rust Bloom:** Rust Bloom is defined by NACE/ASTM G193-12D, "Standard Terminology and Acronyms Relating to Corrosion,"<sup>(3)</sup> as discoloration indicating the beginning of rusting. This is new rust. Rust bloom is usually visible as somewhat uniform rust spread evenly over a large section of the surface. This condition can occur on both wet or dry blast cleaned steel and can take days to develop. Both flash rust and rust-back could look like rust bloom. In a case where carbon steel is cleaned by wet methods and then left for longer periods

<sup>(3)</sup> NACE/ASTM G193-12D, "Standard Terminology and Acronyms Relating to Corrosion," NACE International, 1585 Park Ten Place, Houston, TX 77082, (713) 242-7000.

of time before coating is applied, the new rust bloom could consist of a mixture of flash rust and rust back. In this case, the party doing the work (coating contractor) should consult with the owner to inquire whether this rust bloom should be coated, or remediated before coating is applied.

**4.5.2 Rust-Back (dry blast methods or atmospheric rusting):** Rust-back (re-rusting) is rusting that occurs when freshly cleaned steel is exposed to conditions of high humidity, moisture, or a corrosive atmosphere. It is the term used when steel cleaned by dry abrasive blast cleaning or power tool cleaning, for example, begins to rust after the steel surface has completely dried, and there is no visible moisture or condensation on the substrate. Rust-back is different from Flash Rust. New rust that is very localized and dark, almost black, is caused by microscopic salt crystals on the surface or in the crevices, pits, and craters. Very dark, localized, splotchy rust spots that appear to be isolated in localized areas usually indicate that spots of non-visible salt contaminants are left in pits, under metal lips, or in crevices. These non-visible salt contaminants, depending on their levels, may be found to be detrimental to coating performance.

The time interval between blast cleaning and rust-back will vary greatly (from minutes to weeks) from one environment to another. Residual chemical contamination on the surface can cause the steel to rust-back quickly. Because of this factor, timeliness of inspection is of great importance. Inspection must be coordinated with the contractor's schedule of operation to avoid delays in production. Acceptance of the prepared surface must be made prior to application of the prime coat, because the degree of surface preparation cannot be readily verified after coating. Coating immediately after blast cleaning before the rust-back occurs will trap any remaining contamination between the coating and the substrate. Even though the steel "looked" clean when it was coated, it is better to first remove the contamination that caused the rapid rust-back to acceptable levels before coating.

Rust-back is addressed in the SSPC surface preparation standards in the non-mandatory notes. Re-rusting of dry abrasive blasted steel, as there is little moisture present in the preparation process, can be a sign that non-visual salt contaminants have been left on the steel, which is generally not acceptable to the coatings manufacturers.

Under normal mild atmospheric conditions it is best to coat a blast-cleaned surface within 24 hours after blast cleaning. Under no circumstances should the steel be permitted to rust-back before coating, regardless of the time elapsed. If visible rust develops prior to coating, surfaces must be re-cleaned to meet contract cleaning requirements (e.g. SSPC-SP 10). It is incumbent upon the contractor to verify (using recognized quality control tests) and to document the quality of the cleaned surface before proceeding with application of the primer.

Moisture condenses on any surface that is colder than the dew point of the surrounding air. It is therefore recommended that final dry blast cleaning should not be conducted when the steel surface is less than 3 C° (5 F°) above the dew point. Sometimes, dehumidification is used to control the humidity during surface preparation to prevent formation of rust bloom,

rust-back or flash rust. This is commonly referred to as "holding the blast." SSPC-TR 3/NACE 6A192, "Dehumidification and Temperature Control During Surface Preparation, Application and Curing for Coatings/Linings of Steel Tanks, Vessels, and Other Enclosed Spaces," contains additional information on the use of dehumidification.

After blast cleaning, even when dehumidification is used to "hold the blast," unacceptable levels of invisible soluble salt contamination may exist on the blast-cleaned steel, especially if such contaminants were not removed to acceptable levels before blasting. Physical evidence of such contamination can be masked by the dehumidification process because visual evidence of the soluble salts doesn't manifest itself due to the low humidity. Testing for such contamination may be prudent after blast cleaning even though the steel surface is visibly clean. Excessive weathering or exposure of bare steel to water soluble contaminants such as chlorides and sulfates prior to blast cleaning should be avoided since pitting of the steel may increase cleaning costs and makes removal of contaminants difficult. After blast cleaning, even slight residues of water-soluble contaminants such as chlorides, sulfates, or other electrolytes on the steel surface may adversely affect coating performance if left on surface above acceptable levels and, for some coatings, result in premature coating failure.

Residual chemical contamination on the surface can cause the steel to rust-back quickly. Coating immediately after blast cleaning before the rust-back occurs will trap the contamination between the coating and the substrate. Even though the steel "looked" clean when it was coated, it is better to first remove the contamination that caused the rapid rust-back before coating.

**4.5.3 Flash Rust (Wet Methods):** Flash rust is an oxidation product that forms as a wetted carbon steel substrate dries. This is different from rust-back. Flash rust may appear as rust spots on the surface of newly cleaned steel during the drying phase. Flash rust is an additional consideration when a carbon steel substrate is subjected to waterjet or wet abrasive blast cleaning. Gray or brown-black discoloration remaining in the pits of waterjet cleaned carbon steel is not the same as flash rust. The four SSPC/NACE Joint Standards for Water Cleaning of Metals (WJ-1, WJ-2, WJ-3 and WJ-4) contain descriptions of three levels of flash rusting: Light, Moderate, and Heavy, as well as sample specification language that an owner could use to specify the maximum level of flash rust permitted on a steel substrate immediately prior to coating application. These same levels are also described in the five SSPC/NACE joint standards for wet abrasive blast cleaning (see discussion in Section 9.3).

Steel that is cleaned with water can rust rapidly. The rate of re-rusting will depend on the purity of the water, the amount of oxygen dissolved in the water, the amount and type of ions (chloride, sulfate, etc.) left on the surface, the temperature, and the drying time. The major factor is the length of time for drying. The amount of flash rust can be significantly reduced by drying the cleaned surface with forced air, squeegeeing water from the surface, or using a vacuum shroud on the cleaning head.

that does not allow the water to remain on the surface. The use of low-conductivity water with the removal of most salts will reduce the amount of flash rust. Soluble salt removers and/or inhibitors are generally not added when doing high-pressure or ultra-high pressure waterjet cleaning. However, during the cleaning process, they can be added to a secondary pressure washer to reduce the potential of flash rusting if soluble salts are considered to be a problem (see Section 9.3).

The terms “flash rust” and “rust bloom” are often used interchangeably. However, not all rust bloom is flash rust. The distinguishing feature of flash rust is that it occurs within minutes of cleaning while the water is drying and will quickly change the initial appearance of the surface. It is not the rust itself, but the source of the re-rusting, that is of concern, as inert iron oxides (rust) are used as pigments. A light, easily removed rust bloom is considered inert and a sign of general steel oxidation. Coating manufacturers have concerns about performance when their coatings are applied over loose dust or loose rust. The level of flash rust that can be tolerated in a given environment is normally contained in the coating manufacturer’s product data sheets, but must be approved by the facility owner. Flash rusting is not addressed in the dry abrasive blast cleaning standards. Flash rusting by water is addressed in SSPC-VIS 4/ NACE VIS 7, “Guide and Consensus Reference Photographs for Steel Surfaces Prepared by Waterjetting.” The consensus reference photographs depict steel with light, medium, or heavy flash rusting prior to re-coating. Depending on the particular coating and exposure environment, the coating manufacturer may allow flash rusting at one of these levels. The SSPC report, “Maintenance Coating of Weathering Steel,” found that coatings can perform quite well over a blasted surface that has a uniform rust bloom.

The National Shipbuilding Research Panel has also prepared an illustrated set of photographs “Recommended Guidelines for Evaluating Flash Rust,” which is available from SSPC. This guide contains a field method for evaluating the

amount of flash rust removed from a surface by brushing a white cloth wrapped around a paintbrush across the surface. The amount and color of the rust on the cloth determines the level of flash rust.

## 5. Tools for Specifying Surface Preparation

**5.1 WRITTEN STANDARDS:** The SSPC surface preparation standards are numbered according to the chronological order in which they were issued, not according to the degree of cleaning thoroughness each represents. For example, after SSPC-SP 5, “White Metal Blast Cleaning” and SSPC-SP 6, “Commercial Blast Cleaning” were issued, a need arose for a standard between these two. Hence, the standard for Near-White Blast Cleaning was developed, but the next available number was SSPC-SP 10. Similarly, despite the numbering, SSPC-SP 14, “Industrial Blast Cleaning,” is a degree of cleaning between SSPC-SP 7 “Brush-Off Blast Cleaning” and SSPC-SP 6. Most recently, SSPC-SP 15, “Commercial Grade Power Tool Cleaning” falls between SSPC-SP 3, “Power Tool Cleaning” and SSPC-SP 11, “Power Tool Cleaning to Bare Metal.” Table 2 lists the SSPC surface preparation standards in order of thoroughness of cleaning.

**5.2 REFERENCE PHOTOGRAPHS:** SSPC has developed four sets of reference photographs through a consensus process to illustrate levels of cleanliness of coated and uncoated steel substrates prepared using different cleaning methods. It is recommended that reference photographs be used to supplement the cleaning criteria of the written standard. However, it is important to remember that in case of a dispute, the written requirements of the standard take precedence. Reference photographs give only an approximation of the final surface condition, because they are based on one

TABLE 2

### RELATIVE RANKING OF SSPC SURFACE PREPARATION STANDARDS FOR STEEL BASED ON THOROUGHNESS OF CLEANING<sup>1</sup>

| Most Thorough Cleaning                                                              | Dry Abrasive Blast <sup>2</sup> | Wet Abrasive Blast              | Hand and Power Tool | Waterjetting               |
|-------------------------------------------------------------------------------------|---------------------------------|---------------------------------|---------------------|----------------------------|
|  | SSPC-SP 5                       | SSPC-SP 5 (WAB)/<br>NACE WAB-1  |                     | SSPC-SP WJ-1/<br>NACE WJ-1 |
|                                                                                     | SSPC-SP 10                      | SSPC-SP 10 (WAB)/<br>NACE WAB-2 | SSPC-SP 11          | SSPC-SP WJ-2/<br>NACE WJ-2 |
|                                                                                     | SSPC-SP 6                       | SSPC-SP 6 (WAB)/<br>NACE WAB-3  |                     | SSPC-SP WJ-3/<br>NACE WJ-3 |
|                                                                                     | SSPC-SP 14                      | SSPC-SP 14 (WAB)/<br>NACE WAB-8 | SSPC-SP 15          |                            |
|                                                                                     | SSPC-SP 7                       | SSPC-SP 7 (WAB)/<br>NACE WAB-4  |                     | SSPC-SP WJ-4/<br>NACE WJ-4 |
|                                                                                     |                                 |                                 | SSPC-SP 3           |                            |
|                                                                                     |                                 |                                 | SSPC-SP 2           |                            |

<sup>1</sup> This ranking is not meant to imply that different methods of cleaning on the same level are equivalent. For example, SP 10 is not the same as SP 11, nor are either of these the same as WJ-2.

If SP 10 is desired, but abrasive blast cleaning is not possible, then the closest alternatives would be SP 11 or WJ-2.

<sup>2</sup> SSPC-SP 1, “Solvent Cleaning,” to remove all visible oil and grease is a prerequisite to all abrasive blast and hand and power tool cleaning standards.



specific set of steel conditions and cleaning operations. These conditions will not be identical to the conditions faced on other projects; however, the reference photographs are a valuable aid in establishing the general appearance described by the surface preparation standards, and are especially useful in depicting the relative differences between the various levels of cleanliness.

SSPC has consensus reference photographs for degrees of blast cleaning (SSPC-VIS 1); for the amount of rust on a coated surface (SSPC-VIS 2); for hand and power tool cleaning (SSPC-VIS 3); for waterjetting (SSPC-VIS 4); and for wet abrasive blast cleaning (SSPC-VIS 5). Some SSPC consensus reference photographs are jointly issued with NACE International (SSPC-VIS 4 and VIS 5) or ASTM International (SSPC-VIS 2). Other associations, such as ISO, as well as individual companies, have reference photographs.

Tables 3A, 3B, and 3C provide the correlation between the SSPC, joint SSPC/NACE, and ISO reference photographs for power and hand-cleaned steel, blast cleaned steel, and waterjet cleaned steel.

**5.3 JOB REFERENCE STANDARDS (JRS):** Determining the degree of cleaning required to comply with some standards is often very difficult. Prepared steel will often appear different from the photographic standards due to metallurgy of the steel, variations in initial surface conditions, abrasives being used, profile required, angle and amount of light, etc. An alternative to the use of photographs as visual aids is to prepare a sample area (sometimes called a "Job Reference Standard" or "JRS") that shows the standard of cleanliness for a particular job. The sample area should be representative of the surface to be cleaned, and may be a separate specimen or a designated flat portion of the actual surface. After the contracting parties agree on the cleanliness desired, the surface is protected and retained for comparison through the duration of the project.

It is emphasized that this practice establishes a standard of cleanliness, but not a production rate. As long as the cleaned surface is as clean as the JRS, the actual production rate of cleaning is not in question. The JRS is of value in resolving differences of opinion as to whether or not the surface had been properly cleaned.

## 6. Summary of SSPC Surface Preparation Standards for Metals

**6.1 SSPC-SP 1, "SOLVENT CLEANING:"** This solvent cleaning standard includes simple organic solvent wiping, immersion in solvent, solvent spray, vapor degreasing, alkaline cleaning, emulsion cleaning, and steam cleaning. The 2015 revision of SSPC-SP 1 defines "solvent" as "any liquid or vapor, permitted by the owner of the item being cleaned and used in compliance with all health, safety and environmental regulations applicable at the job site, that will dissolve or emulsify visible deposits of contaminants on the surface." Examples of solvents include water, emulsion or alkaline cleaners, and hydrocarbons." In SP-1, the term "visible" means detectable with normal or corrected normal vision without the use of additional equipment.

Solvent cleaning is used primarily to remove visible oil, grease, dirt, soil, drawing compounds, and other similar organic compounds. Detergent/water cleaning is a very gentle method of solvent cleaning. Aqueous solutions of household detergents may be effective in the removal of light deposits of grease and oil. They seldom have adverse effects on substrates.

Alkaline cleaning compounds are available in a wide range of compositions. It is important that residues of alkaline compounds do not remain on the surface after cleaning. The cleaned surface may be tested with litmus paper or universal indicating paper to see that it is neutral or at least no more alkaline than the rinse water that is used.

Though not specifically mentioned in SP-1, pressure washing with emulsifier or detergents, high and ultra-high pressure waterjet cleaning are methods frequently used to remove oil and grease. These methods may also reduce levels of soluble salts on the surface.

Many solvents are hazardous and care must be taken when using them. Special safety precautions must be followed with regard to ventilation, smoking, static electricity, respirators, eye protection, and skin contact. Used solvents should always be recycled or disposed of according to applicable environmental regulations. Consult an industrial hygienist or certified safety professional before specifying a solvent.

The SSPC SP-1 standard requires visual verification of the removal of contaminants. Supplementary tests for verification of removal of contaminants, the areas subject to testing, and the acceptance criteria should be included in the project specification.

The SSPC surface preparation standards require the removal of visible deposits of oil and grease using solvent cleaning prior to performing mechanical cleaning, and again following mechanical cleaning and prior to coating application. Normally, a dust-free surface is not required prior to mechanical surface preparation, since the mechanical preparation itself will create dust. After performing blast cleaning, visible deposits of oil, grease, and other soluble contaminants are to be removed from the surface in accordance with SSPC-SP 1. The surface must also be free of visible dust and dirt immediately prior to coating application.

**6.2 SSPC-SP 2, "HAND TOOL CLEANING:"** Hand tool cleaning is a method of surface preparation often used for normal atmospheric exposures, for interiors, and for maintenance coating when using coatings with good wetting ability. Hand cleaning will remove loose rust, loose coating, and loose mill scale but will not remove all residue of rust or intact mill scale. For cleaning small, limited areas prior to maintenance priming, hand cleaning will usually suffice.

Care in hand tool cleaning is also especially important if the prime coat is to be applied by spray, because a sprayed coating may bridge gaps and crevices, whereas brushing works the coating into these areas.

The hand tool cleaning standard requires that visible deposits of oil and grease, along with any other visible contaminants, first be removed as specified in SSPC-SP 1, "Solvent Cleaning." On welded work, particular care should be