

SSPC: The Society for Protective Coatings

SURFACE PREPARATION SPECIFICATIONS

Surface Preparation Commentary for Steel and Concrete Substrates

1. Introduction

This Surface Preparation Commentary (SP COM) is intended to be an aid in selecting the proper surface preparation method, materials, and specification for steel, other metals, and concrete. A compilation of standards, guides, and specifications related to concrete is available as SSPC publication #04-03 "Surface Preparation and Coating of Concrete." The SP COM is not part of the actual standards, but is included to provide a better understanding of the SSPC surface preparation standards. In addition, surface preparation standards other than those published by SSPC are referenced.

The SSPC standards, summarized in Table 1, represent a broad consensus of users, suppliers, and public interest groups. Details of the methods used to measure 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."

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3. Importance of Surface Preparation

Often, the surface preparation of steel for painting requires a three step process: 1) initial pre-cleaning to remove 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 paint 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

TABLE 1
SUMMARY OF CURRENT SSPC ABRASIVE AND
SURFACE PREPARATION STANDARDS AND SPECIFICATIONS

SSPC SPECIFICATION	DESCRIPTION
AB 1 Mineral and Slag Abrasives	Definition of requirements for selecting and evaluating mineral and slag abrasives used for blast cleaning.
AB 2 Cleanliness of Recycled Ferrous Metallic Abrasive	Cleanliness requirements for a recycled work mix and a description of the test procedures.
AB 3 Ferrous Metallic Abrasive	Requirements of chemical and physical properties of iron and steel abrasives.
SP 1 Solvent Cleaning	Removal of oil, grease, dirt, soil, salts, and contaminants by cleaning with solvent, vapor, alkali, emulsion, or steam.
SP 2 Hand Tool Cleaning	Removal of loose rust, loose mill scale, and loose paint to degree specified, by hand chipping, scraping, sanding, and wire brushing.
SP 3 Power Tool Cleaning	Removal of loose rust, loose mill scale, and loose paint to degree specified, by power tool chipping, descaling, sanding, wire brushing, and grinding.
SP 5/NACE No. 1 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. For very corrosive atmospheres where high cost of cleaning is warranted.
SP 6/NACE No. 3 Commercial Blast Cleaning	Blast cleaning until at least two-thirds of the surface is free of all visible residues with only staining permitted on the remainder. For conditions where a thoroughly cleaned surface is required.
SP 7/NACE No. 4 Brush-Off Blast Cleaning	Blast cleaning of all except tightly adhering residues of mill scale, rust, and coatings, while uniformly roughening the surface.
SP 8 Pickling	Complete removal of rust and mill scale by acid pickling, duplex pickling, or electrolytic pickling.
SP 10/NACE No. 2 Near-White Blast Cleaning	Blast cleaning nearly to White Metal cleanliness, until at least 95% of the surface is free of all visible residues with only staining permitted on the remainder. For high humidity, chemical atmosphere, marine, or other corrosive environments.
SP 11 Power Tool Cleaning to Bare Metal	Complete removal of all rust, scale, and paint by power tools, with resultant surface profile.

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SP 12/NACE No. 5 Surface Preparation and Cleaning of Metals by Waterjetting Prior to Coating	Defines four degrees of cleaning for visible contaminants (similar to SP 5, 6, 7, and 10) and three levels of flash rust and describes three levels of non-visible surface cleanliness for non-visible soluble salt contamination.
SP 13/NACE No. 6 Surface Preparation of Concrete	Description of inspection procedures prior to surface preparation, methods of surface preparation, inspection, and classification of prepared concrete surfaces.
SP 14/NACE No. 8 Industrial Blast Cleaning	Between SP 7 (brush-off) and SP 6 (commercial). The intent is to remove as much coating as possible, but contaminants difficult to remove can remain on 10 percent of the surface.
SP 15 Industrial Grade Power Tool Cleaning	Between SP 3 and SP 11. Removes all rust and paint but allows for staining; requires a minimum 1 mil (25 μ m) profile.
VIS 1 Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning	Standard reference photographs; recommended supplement to SSPC surface preparation standards SSPC-SP 5, 6, 7, 10, and 14.
VIS 2 Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces	A geometric numerical scale for evaluating degree of rusting of painted steel. Color photographs show staining while matching black and white images depict only rust. Three rust distributions, general, spot, and pinpoint, are depicted.
VIS 3 Guide and Reference Photographs for Steel Surfaces Prepared by Power- and Hand-Tool Cleaning	Standard reference photographs; recommended supplement to SSPC-SP 2, 3, 11, and 15.
VIS 4/NACE VIS 7 Guide and Reference Photographs for Steel Surfaces Prepared by Waterjetting	Standard reference photographs depict previously rusted steel (painted and unpainted) cleaned by water jetting. Photographs depict three levels of flash rusting. Recommended as a supplement to SSPC-SP 12.
VIS 5/NACE VIS 9 Guide and Reference Photographs for Steel Surfaces Prepared by Wet Abrasive Blast Cleaning	Standard reference photographs depict previously rusted unpainted steel cleaned by wet abrasive blast cleaning to SSPC SP 6 and SP 10. Photographs depict three levels of flash rusting. Recommended as a supplement to SSPC-SP 6 and SP 10 when wet blast cleaning methods are used.

such as sodium bicarbonate (baking soda) or dry ice (CO_2) can sometimes be used in places where conventional abrasives cannot be used. A class of abrasives has been developed where each abrasive particle is contained in a urethane sponge. The sponge contains the abrasive and facilitates cleanup and recycling. Alternative methods of surface preparation are discussed in more detail in Chapter 2.9 of the SSPC Painting Manual, Vol. 1.

An advantage of all wet blast methods is the control of dust emissions. Wet blast 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 paint. 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 may be beneficial to incorporate water into the cleaning process.

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 paint, 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 nonmetallic 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 as follows:

- New construction—steel not previously painted
- Maintenance—previously painted 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 references, namely, SSPC-VIS 1, SSPC-VIS 3, and SSPC-VIS 4, are as follows:

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

Rust 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 painted surfaces.

Condition E	Light-colored 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 painting system and on the extent of degradation of the surface to be painted. The amount of rusting on a surface is based on the numerical scale of 0 to 10 given in SSPC-VIS 2 (ASTM D 610), “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 percent 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. The SSPC Painting System Commentary will also help in estimating surface preparation requirements.

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 which 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 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 paint, removing unsound paint, 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 such as chlorides, sulfates, etc., paint chalk, and loose, cracked, or peeling paint.

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 resulting from the corrosion of steel 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. 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.

Ideally, these types of rust should be removed, even for the lowest degrees of hand and power tool cleaning, SSPC-SP 2 and SSPC-SP 3. However, a judgment must be made on each job 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. As a general rule, unless completely removed before painting, it will later 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 is erratic in its effect upon the performance of coatings. Tightly adhered or intact mill scale may not have to be removed for mild atmospheric exposure. If, however, the steel surface is to 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 or SP 11.

4.3.3 Grease and Oil: Even thin films of grease and oil, which may not be readily visible, can prevent tight bonding of high performance coatings. Oil paints may be tolerant of thin oil films. Visible deposits of grease and oil should 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, the power tools or abrasive blasting may spread the grease or oil over the surface without removing it.

4.3.4 Dirt and Dust: Dirt and dust can also prevent tight bonding of coatings, and should be removed completely. ISO 8502-3:1982, “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 painting.

4.3.5 Moisture: Steel surfaces must be dry before cleaning and painting. Moisture may either produce flash rusting before painting or accelerate underfilm corrosion after painting. Water can also prevent an organic coating from properly “wetting out”

the surface on metal or concrete surfaces, and may disrupt the curing of the coating.

4.3.6 Soluble Salts: Soluble salts are deposited from the atmosphere onto surfaces. If they remain on the surface after cleaning, they can attract moisture which can permeate the coating and cause a blister (osmotic blistering). Salts, particularly chlorides, may also accelerate the corrosion reaction and underfilm corrosion. Methods for measuring the amount of salt on the surface are described in SSPC-TU 4, “Field Methods for Retrieval and Analysis of Soluble Salts on Substrates.” In some circumstances it is desirable to remove soluble salts by power washing or other method 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.

Sometimes a maximum level of soluble salts is specified in the procurement documents (job specification.) Three commonly specified levels, as verified by field or laboratory analysis using reliable, reproducible test methods, are:

- The surface shall be free of detectable levels of soluble contaminants.
- The surface shall have less than $7 \mu\text{g}/\text{cm}^2$ (0.0007 grains/in²) of chloride contaminants, less than $10 \mu\text{g}/\text{cm}^2$ (0.001 grains/in²) of soluble ferrous iron levels, or less than $17 \mu\text{g}/\text{cm}^2$ (0.0017 grains/in²) of sulfate contaminants.
- The surface shall have less than $50 \mu\text{g}/\text{cm}^2$ (0.005 grains/in²) of chloride or sulfate contaminants.

The U.S. Navy has established maximum allowable levels of chloride as measured with an adhesive patch/conductivity meter method. Currently these requirements are $3 \mu\text{g}/\text{cm}^2$ for tanks and immersed surfaces and $5 \mu\text{g}/\text{cm}^2$ for topside and non-immersed surfaces. Similarly, the conductivity requirements are $30 \mu\text{S}/\text{cm}$ for immersed surfaces and $70 \mu\text{S}/\text{cm}$ for non-immersed applications.

4.3.7 Paint Chalk: The sun’s ultraviolet light causes all exterior organic coatings 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 before coating in order to avoid intercoat adhesion problems. It is often specified that, before topcoating, old paint must have a rating of no less than 8 in accordance with ASTM D 4214, “Test Method for Evaluating Degree of Chalking of Exterior Paint Films.”

4.3.8 Deteriorated Paint: All loose paint (can be removed with a dull putty knife and/or fails pre-established adhesion values) must be removed before maintenance painting. Before removing any old paint, it must be determined whether the paint contains significant amounts of lead or other toxic material. 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 coating failure. Other features of steel that are difficult to properly cover and protect include crevices, weld porosity, laminations, etc., 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. Some high solids coatings, often requiring plural component spray, have edge retentive properties that may lessen the effect of sharp edges.

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. 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 paint. NACE RP0178, "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, could have an influence on coating performance and may need to be removed (e.g., grinding, mechanical sanding, filing). Care should be taken to ensure that new sharp edges are not created during the removal operations.

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

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 painting.

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 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. Where possible, such deficiencies should be corrected by structural or design modification. Where this is not possible, filling, and/or special surface preparation and painting procedures may be needed.

4.4.7 Concrete Defects: As is the case for steel, repair of surface defects on concrete is important for a successful coating application. Identification and repair of defects in concrete are discussed in Appendix A of SSPC-SP 13, "Surface Preparation of Concrete." Some specific defects that require repair prior to surface preparation and application of a coating or polymer overlay are: mechanical damage, exposed rebar, honeycombs, scaling, spalling, bugholes, pinholes, and generally unsound concrete. The surface must also be cleaned of organic contaminants such as moss, mildew, and algae.

4.5 RUST BACK: Rust back occurs when freshly cleaned steel is exposed to conditions of high humidity, moisture, or a corrosive atmosphere. The time interval between blast cleaning and rust back will vary greatly (from minutes to weeks) from one environment to another. Because of this factor, timeliness of inspection is of great importance. Inspection must be coordinated with the contractor's schedule of operation in such a way as to avoid delay. 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 painting.

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 painting, regardless of the time elapsed. (With wet abrasive blast cleaning or waterjetting, a certain level of flash rusting may be acceptable.) If visible rust occurs prior to painting, 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 document the quality of the cleaned surface before proceeding with application of the primer even if third-party inspection is required.

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.

Excessive weathering or exposure of bare steel to chemical 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 chlorides, sulfates, or other electrolytes on the steel surface may be harmful and, for some coatings, may cause premature coating failure.

Residual chemical contamination on the surface can cause the steel to rust back quickly. Painting immediately after blast cleaning before the rust back occurs will trap the contamination between the paint and the substrate. Even though the steel “looked” clean when it was painted, it is better to first remove the contamination that caused the rapid rust back before painting.

5. Summary of SSPC Surface Preparation Standards

Although these standards are primarily intended for heavy metal or plate, most are also suitable for light weight or thin section metal. Obviously, caution must be exercised when using methods such as abrasive blast cleaning or waterjetting on thin gage metal since damage by warping may occur from excessive peening of the surface or from the thrust of the water. Occasions will arise where these standards will not result in the type of cleaning desired. In such cases, the contract documents may need to modify the surface preparation standards to obtain the result desired. Regardless of which methods are used, adjacent equipment, pre-finished items, or surfaces that could be damaged from the method of surface preparation must be protected.

Occasionally in maintenance painting, a new paint used to make repairs is incompatible with the existing paint. Under these circumstances all paint, regardless of condition, will have to be removed. A minimum of SSPC-SP 6, “Commercial Blast Cleaning” is usually necessary.

“Good Painting Practice” (Volume 1 of the SSPC Painting Manual), devotes several chapters to mechanical surface preparation, and it also discusses special surface preparation requirements for shops, ships, highways, tanks, vessels, refineries, and various types of plants. Volume 1 should be consulted when choosing a surface preparation standard.

The “Commentary on Paint Specifications” (Chapter 4 of this volume) shows the minimum surface preparation required

for each of the SSPC specification paints. Similarly, the “Commentary on Painting Systems” (Chapter 3) shows the recommended minimum surface preparation for each paint system and for the various individual alternative primers within each system, in ten common types of exposure. The guides for each generic coating type discuss in some detail the required surface preparation. For example, SSPC-PS Guide 12.00, “Guide to Zinc-Rich Coating Systems” has a table showing the minimum surface preparation required for each type of zinc-rich coating in ten different environmental zones.

The SSPC surface preparation standards were numbered according to the chronological order in which they were adopted, not according to their degree of thoroughness of cleaning. For example, some time 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.

5.1 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.

Solvent cleaning is used primarily to remove oil, grease, dirt, soil, drawing compounds, and other similar organic compounds. Inorganic compounds such as chlorides, sulfates, weld flux, rust, and mill scale are not removed by cleaning with organic solvents.

TABLE 2
RELATIVE RANKING OF SSPC SURFACE PREPARATION STANDARDS FOR STEEL
BASED ON THOROUGHNESS OF CLEANING¹

Most Thorough Cleaning	Dry Abrasive Blast ²	Hand and Power Tools	Waterjetting
↑	SP 5		SP 12, WJ-1
	SP 10		SP 12, WJ-2
	SP 6	SP 11	
	SP 14	SP 15	SP 12, WJ-3
	SP 7		SP 12, WJ-4
			SP 3
		SP 2	

¹ This ranking is not meant to imply that different methods of cleaning on the same level are equivalent. For example, SP 14 is not the same as SP 15, nor are either of these the same as SP 12, WJ-3. If SP 14 is desired, but abrasive blast cleaning is not possible, then the closest alternatives would be SP 15 or SP 12, WJ-3.

² SSPC-SP 1, Solvent Cleaning, to remove oil and grease is a prerequisite to all abrasive blast and hand and power tool cleaning standards.

Many solvents are hazardous. Care must be taken when using solvents for solvent cleaning. 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.

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 cover a very wide range in composition and method of use. 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. Various solvent, alkaline, and detergent cleaning compounds are discussed in Volume 1 of the SSPC Painting Manual.

5.1.1 Petroleum Solvents and Turpentine: These types of solvents clean the metal by dissolving and diluting the oil and greases which contaminate the surface. All solvents are potentially hazardous and they should be used under such conditions that their concentration in air being breathed by workers is low enough for safety (see Table 3). When used in closed spaces where the safe concentration is exceeded, appropriate respiratory protection should be worn. The fresh air intake should be clear of carbon monoxide or other contaminants

TABLE 3. THRESHOLD LIMIT VALUES (TLV) FOR SOLVENTS⁴

	ACGIH Values				OSHA Industry Values	
	TLV-TWA ¹		TLV-STEL ²		TLV-TWA ¹	
	ppm	mg/m ³	ppm	mg/m ³	ppm	mg/m ³
Acetone	500	1780	750	2375	1000	
Benzene (Benzol)—Skin	0.5	30	2.5	75	1	—
Carbon Tetrachloride—Skin	5	31	10	63	10	—
Cyclohexane	100	334	—	—	300	1050
Epichlorohydrin—Skin	0.5		—	—	5	19
Ethyl Acetate	400	1440	—	—	400	1440
Ethanol (Ethyl Alcohol)	1000	1880	—	—	1000	1900
Ethylene Dichloride (1,2-Dichloroethane)	10	40	—	—	50	200
Ethylenediamine—Skin	10	25	—	—	10	25
Furfuryl Alcohol—Skin	10	40	15	60	50	200
Methanol (Methyl Alcohol)—Skin	200	—	250	—	200	260
Methylene Chloride (Dichloromethane)	50	174	—	—	25	—
VM & P Naphtha	300	1370	—	—	—	—
Perchloroethylene—Skin	25	170	100	685	100	—
Isopropyl Alcohol—Skin	400	—	500	—	400	980
Stoddard Solvent	100	525	—	—	500	2900
Toluene	50	188	—	—	200	750
Trichloroethylene	100	535	—	—	100	—
Turpentine	100	556	—	—	100	560
Xylene (Xylol)	100	434	150	651	100	435

¹ TLV-TWA (Threshold Limit Value—Time Weighted Average): The time-weighted average concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.

² TLV-STEL (Threshold Limit Value—Short Term Exposure Limit): The maximum concentration to which workers can be exposed for a short time without suffering from irritation, chronic or irreversible tissue damage, or narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded. Exposures above the TLV-TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There should be at least 60 minutes between successive exposures in this range.

³ In general, the aromatic hydrocarbon content will determine what TLV applies.

⁴ Values were obtained from www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html. These TLVs are revised periodically. Note that OSHA limits may be different from ACGIH recommendations.

from engine exhausts or other sources. The concentration of solvent in air should not exceed the lower limit of flammability as fire or explosion may result. Some solvents, especially aromatic solvents, will also dissolve the vehicle of paints so they can be removed. It is important that the last wash or rinse be made with clean solvent in every case or a film of oil or grease will be left on the surface when the solvent of the last washing evaporates. This film may interfere with the bond of the paint to the metal.

Petroleum base mineral spirits (aliphatics), with a minimum flash point of 38°C (100°F) should be used as the general purpose solvent for cleaning under normal conditions. In hot weather, or when the temperature is 25 to 35°C (80 to 95°F), high flash aliphatic mineral spirits with a minimum flash point of 50°C (122°F) should be used. In very hot weather, when the temperature is over 35°C (95°F), heavy mineral spirits with a flash point over 60°C (140°F) should be used. Gasoline and V.M. & P. Naphtha are too dangerous for use under ordinary conditions.

Aromatic solvents may be used where greater solvency is required, but they are more toxic and the solvents generally available have low flash points. Benzol (benzene) is the most toxic and should not be used, particularly in view of its low flash point and attendant fire and explosion hazard. Xylene (xylo), toluene (toluol), and high flash naphtha may be used when their concentration in air that is being breathed does not exceed the safe limit (see Table 3). If the concentration is greater, appropriate respiratory protection should be worn. Because of the low flash points of these solvents, fire and explosion hazards are inherent with their use and great caution should be taken to ensure safe working conditions.

Chlorinated hydrocarbons may be used. However, due to toxicity, chlorinated hydrocarbons are not recommended for general use except with special equipment and trained operators. Chlorinated hydrocarbons should never be used where they may affect stainless steel.

In general, solvents are satisfactory for use provided that they meet the flash point requirements above and that they are used under such conditions that the concentration of chlorinated hydrocarbons in air does not constitute a health hazard (see Table 3). NOTE: Always review the MSDS supplied with any solvent for proper safety/health and environmental precautions to be taken when using the solvent.

5.1.2 Alkaline Cleaners: These cleaners saponify certain oils and greases, and their surface active constituents wash away other types of contaminants, such as oil. They may be particularly effective in removing some coating types because the alkali saponifies the dried paint vehicle. Since the soaps formed are soluble in water, the contaminants are more easily removed by washing with water after saponification. Although alkaline cleaners pose no problems to a steel substrate, extended exposure will cause significant damage to aluminum, zinc, wood, or concrete.

The most commonly used alkaline cleaner is trisodium phosphate (TSP), but there are other alkalis which are used.

Some of these are mixtures with wetting agents and detergents. They are available as proprietary products and should be used in accordance with directions of the manufacturer. If not used properly, alkaline cleaners will damage oil-base coatings.

If no commercial alkaline cleaner is available, good results may be achieved by the use of 15 grams of trisodium phosphate (TSP) per liter of water (2 oz/gal), to which is also added soap or other suitable detergent at 8 to 15 grams per liter (1 to 2 oz/gal). This solution is best used hot; if used cold, it may be advisable to increase the concentration. This solution is suitable for spraying or scrubbing; if used in dip tanks, the concentration may be tripled. If not washed from the surface, this mixture will soften and eventually loosen many paints. Local sewer disposal regulations should be reviewed before using TSP.

A soap film left on the surface is just as damaging to the paint bond as is an oil or grease film; therefore the surface should be thoroughly washed (preferably with hot water under pressure) to remove this soap and other residue. Moreover, all alkali must be thoroughly removed from the surface or the new paint may be saponified and damaged by it. To test the effectiveness of the wash, universal pH test paper should be placed against the wet steel. The pH of the washed surface should be no greater than the pH of the wash water.

Alkaline cleaners must be used with caution since bad burns may result from contact with some solutions. Particular care should be paid to protecting the eyes of workers; safety goggles or eye shields should be worn. Rubber gloves should be worn if the solutions will contact workers' hands. Where alkaline cleaning compounds are sprayed, respirators should be worn.

5.1.3 Emulsion Cleaners: Emulsion cleaners usually contain oil soluble soaps or emulsifying agents along with kerosene or mineral spirits. They are usually supplied as a concentrate which may be thinned with kerosene or mineral spirits and sprayed on the surface to be cleaned. They are emulsified by the action of water under pressure and washed away along with oil, grease, and other contaminants. They may be diluted with water, emulsified, and used in that condition. In any event, the directions of the manufacturer should be followed.

A residue of emulsion is almost always left on the surface. This residue will leave a thin film of oil on the surface. If the paint to be applied cannot tolerate a slight amount of oil, the residue must be washed from the surface by steam, hot water, detergents, solvents, or alkaline cleaning compounds.

Alkaline emulsion cleaners, which combine the advantages of the alkaline cleaners and the emulsion cleaners, are available.

5.1.4 Steam Cleaning: Steam cleaning may utilize either steam, hot water under pressure, or both.

The steam and hot water, when used to clean the surface, are usually used with a detergent and sometimes also with an alkaline cleaner. The steam and hot water themselves tend

to remove the oils, greases, and soaps by thinning them with heat, emulsifying them, and diluting them with water. They can then be easily removed by further washing. When detergent is used, its higher affinity for the metal also causes the oil, grease, and, in some cases, even the paint to loosen, thereby increasing the rate of cleaning.

New paint will not adhere to the metal if any of the oil, grease, soap, detergent, or alkali is left on the surface. A final washing with clean water is therefore always necessary.

5.1.5 Threshold Limit Values: Threshold limit values (TLVs) of common cleaning solvents can be obtained from the OSHA web site www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html (see Table 3). The American Conference of Governmental Industrial Hygienists (ACGIH) also publishes a booklet listing their recommended TLVs and Biological Exposure Indices (BEIs). Note that OSHA limits may be different from ACGIH recommendations. These TLVs are revised periodically.

5.1.6 Paint Removal: Although not addressed in SSPC-SP 1, many of the cleaning methods may adversely affect existing paint. A strong solvent used in solvent cleaning may cause the existing paint to soften or disbond from the substrate. The adhesive nature of the old paint is reduced by chemical action on the paint. Where complete paint removal is the primary object, caustic soda (sodium hydroxide) or a commercial paint stripper may be used. Alkali cleaners remove oil base paint and solvent cleaners remove latexes and lacquers. Steam can be used to remove old paint by degrading the vehicle of the old paint by virtue of the high temperatures so that it loses its strength and its bonding to the metal. Information on chemical stripping can be found in the technology update SSPC-TU 6, "Chemical Stripping of Organic Coatings from Steel Structures," and in Volume 1 of the SSPC Painting Manual.

5.2 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 painting when using paints with good wetting ability. Hand cleaning will remove loose rust, loose paint, 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 paint into these areas.

The hand tool cleaning specification requires that oil and grease, along with any other visible contaminants, be removed as specified in SSPC-SP 1, "Solvent Cleaning" prior to hand tool cleaning. On welded work, particular care should be taken to remove as much welding flux, slag, and fume deposit as is possible since these are notorious in promoting paint failure on welded joints. All loose matter should be removed from the surface prior to painting. Blowing off with clean, dry, oil-free

compressed air, brushing, or vacuum cleaning are satisfactory removal methods.

5.2.1 Loose Rust, Mill Scale, and Paint: Determination of the degree of cleaning required to comply with SSPC-SP 2 is often very difficult. The problem is in establishing whether a residue is "adherent" or "loose." The standard considers the residue adherent if it cannot be lifted with a dull putty knife, a somewhat subjective criterion. Tightly adherent rust scale is discussed in Section 4.3.1.

One possible solution is for the contracting parties to establish a standard cleaning procedure in which the type of tool, force, speed, etc., are all stipulated.

Another possibility is for the contracting parties to agree on a sample area (sometimes called a "job standard") 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.

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 job standard, the actual production rate of cleaning is not in question. The job standard is of value in resolving differences of opinion as to whether the surface has been properly cleaned.

5.2.2 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 3 or other consensus reference photographs may be used to supplement the cleaning criteria of SSPC-SP 2. Table 4A gives the correlation between the SSPC and the ISO pictorial standards.

5.3 SSPC-SP 3, "POWER TOOL CLEANING": Similar to hand tool cleaning, power tool cleaning removes loose rust, loose mill scale, and loose paint. Intact materials may remain. Power tools use electrical and pneumatic equipment to provide faster cleaning. They include sanders, wire brushes or wheels, chipping hammers, scalers, rotating flaps (rotopeen), needle guns, hammer assemblies, and right angle or disk grinders. Some have high efficiency particulate air (HEPA) vacuum lines attached to reduce air pollution and collect debris produced in the cleaning operation. Power tools clean by impact, abrasion, or both. Cleaning of metal surfaces is less expensive using power tools than using hand tools. Less particulate contamination of the environment occurs with power tools as opposed to abrasive blasting. Thus, power tools are used frequently for spot cleaning of damaged coatings, where contamination of adjacent areas by abrasive is unacceptable, and when a surface-tolerant coating such as oil-based paint is to be used.

The power tool cleaning standard requires that oil and grease, along with any visible salts, be removed as specified in SSPC-SP 1, "Solvent Cleaning" prior to power tool cleaning. On welded work, particular care should be taken to remove as

**TABLE 4A
COMPARISON OF SSPC AND ISO SURFACE PREPARATION STANDARDS
FOR POWER- AND HAND-TOOL CLEANED STEEL**

Surface Preparation Standard		Initial Condition of Steel		Reference Photographs	
SSPC	ISO	Rust Condition	Description	SSPC-VIS 3 ¹	ISO 8501-1 ²
SP 11 Power Tool Cleaning to Bare Metal		A	intact mill scale	A SP 11	*
		B	partially rusted mill scale	B SP 11	*
		C	100% rusted, no pits	C SP 11	*
		D	rusted and pitted	D SP 11	*
		E	paint mostly intact	E SP 11, E SP 11/R	*
		F	zinc-rich paint	F SP 11, F SP 11/R	*
		G	deteriorated paint over mill scale	G SP 11	*
SP 15 Commercial Grade Power Tool Cleaning		A	intact mill scale	*	*
		B	partially rusted mill scale	B SP 15	*
		C	100% rusted, no pits	C SP 15	*
		D	rusted and pitted	D SP 15	*
		E	paint mostly intact	E SP 15	*
		F	zinc-rich paint	F SP 15	*
		G	deteriorated paint over mill scale	G SP 15	*
SP 3 Power Tool Cleaning	St 3	A	intact mill scale	A SP 3/PWB, A SP 3/SD	*
		B	partially rusted mill scale	B SP 3/PWB, B SP 3/SD	B St 3
		C	100% rusted, no pits	C SP 3/PWB, C SP 3/SD	C St 3
		D	rusted and pitted	D SP 3/PWB, D SP 3/SD	D St 3
		E	paint mostly intact	E SP 3/PWB, E SP 3/SD	*
		F	zinc-rich paint	F SP 3/PWB, F SP 3/SD	*
		G	deteriorated paint over mill scale	G SP 3/PWB, G SP 3/SD	*
SP 2 Hand Tool Cleaning	St 2	A	intact mill scale	A SP 2	*
		B	partially rusted mill scale	B SP 2	B St 2
		C	100% rusted, no pits	C SP 2	C St 2
		D	rusted and pitted	D SP 2	D St 2
		E	paint mostly intact	E SP 2	*
		F	zinc-rich paint	F SP 2	*
		G	deteriorated paint over mill scale	G SP 2	*

* = no photograph

¹ SSPC-VIS 3 contains photographs for SP 11, SP 15, SP 3, and SP 2.

² The United Kingdom Standard BS 7079 Part A1 is equivalent to ISO 8501-1 and depicts the degrees of cleanliness of unpainted steel. BS 7079 Part A2 is equivalent to ISO 8501-2 and depicts the same degrees of cleanliness of previously painted steel.

much welding flux, slag, and fume deposit as is possible since these are notorious in promoting paint failure on welded joints. All loose matter should be removed from the surface prior to painting. Blowing off with clean, dry, oil-free compressed air, brushing, or vacuum cleaning are satisfactory methods.

Care is necessary in the use of power tools to prevent excessive roughening of the surface, as ridges and burrs can contribute to paint failure because sharp edges may not be protected by adequate thickness of paint. Excessive power wire brushing can also be detrimental to the performance of the paint since the surface (particularly mill scale) is easily burnished to a smooth, slick finish to which paint will not adhere.

5.3.1 Loose Rust, Mill Scale, and Paint: Determination of the degree of cleaning required to comply with this standard is often very difficult. The problem is in establishing whether a residue is "adherent" or "loose." The standard considers the residue adherent if it cannot be lifted with a dull putty knife, a somewhat subjective criteria. Tightly adherent rust scale is discussed in Section 4.3.1.

One possible solution is for the contracting parties to agree on a standard cleaning procedure in which the type of tool, force, speed, etc., are all stipulated.

Another possibility is for the contracting parties to agree on a sample area (sometimes called a "job standard") 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.

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 job standard, the actual production rate of cleaning is not in question. The job standard is of value in resolving differences of opinion as to whether or not the surface has been properly cleaned.

5.3.2 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 3 may be used to supplement the cleaning criteria of this standard. Table 4 gives the correlation between the SSPC and the ISO pictorial standards.

5.4 SSPC-SP 4, "FLAME CLEANING OF NEW STEEL":
This standard was discontinued in 1982.

5.5 SSPC-SP 5/NACE No. 1, "WHITE METAL BLAST CLEANING": White Metal Blast Cleaning is generally used for exposures in very corrosive atmospheres and for immersion service where the highest degree of cleaning is required and a high surface preparation cost is warranted.

Blast cleaning to white metal will result in high performance of the paint systems due to the complete removal of all rust, mill scale, and foreign matter or visible contaminants from the

surface. In ordinary atmospheres and general use, white metal is seldom warranted.

The use of this grade of blast cleaning without rust back is particularly difficult in the environments where it is most needed as a preparation for painting; for example, in humid chemical environments. White Metal Blast Cleaning should be conducted at a time when no contamination or rusting can occur, and when prompt painting is possible. A good rule is that no more surface should be prepared for painting than can be coated the same day.

5.5.1 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 1 may be used to supplement the cleaning criteria of this standard. Table 4B gives the correlation between the SSPC and the ISO pictorial standards. When using consensus reference photographs, it should be recognized that the color or hue of the cleaned surface may appear different from the photographs due to the nature of the steel, the abrasives used, the presence of existing coatings, and other factors.

5.6 SSPC-SP 6/NACE No. 3, "COMMERCIAL BLAST CLEANING": Commercial Blast Cleaning should be employed for all general purposes where a high, but not perfect, degree of blast cleaning is required. It will remove all rust, all mill scale, and all other detrimental matter from the surface, but will permit a great deal of staining from rust, mill scale, or previously applied paint to remain. The surface will not necessarily be uniform in color, nor will all surfaces be uniformly clean. The advantage of Commercial Blast Cleaning lies in the lower cost for providing a degree of surface preparation that should be suitable for the majority of cases where blast cleaning is believed to be necessary. However, if it is possible that Commercial Blast Cleaning will result in a surface unsatisfactory for the service, SSPC-SP 10 (near-white) or SSPC-SP 5 (white metal) should be specified.

When a project specification includes maintenance painting, if it is intended that some of the existing coating be permitted to remain (e.g. because it is thin, well adherent, and compatible with the new coating system), the contract documents should stipulate the extent of the surface to be cleaned in accordance with this standard. SSPC-PA 1, "Shop, Field, and Maintenance Painting of Steel," and SSPC-PA Guide 4, "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems," cover additional maintenance painting procedures.

5.6.1 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 1 or other consensus reference photographs may be used to supplement the cleaning criteria of this standard. Table 4A gives the correlation between the SSPC and the ISO pictorial standards. When using consensus reference photographs, it should be recognized that the color or hue of the cleaned surface may appear different from the photographs due to the nature of the steel, the abrasives used, the presence of existing coatings, and other factors such as angle of lighting and profile depth.

**TABLE 4B
COMPARISON OF SSPC AND ISO SURFACE PREPARATION STANDARDS
FOR BLAST CLEANED STEEL**

Surface Preparation Standard		Initial Condition of Steel		Reference Photographs	
SSPC/NACE	ISO ¹	Rust Condition	Description	SSPC-VIS 1 ² /SSPC-VIS 5	ISO 8501-1
SP 5/NACE No. 1 White Metal Blast Cleaning	Sa 3	A	intact mill scale	A SP 5, A SP 5-N1, A SP 5-N2, A SP 5-N3 A SP 5-M1, A SP 5-M2, A SP 5-M3 ³	A Sa 3 ⁴
		B	partially rusted mill scale	B SP-5	B Sa 3 ⁴
		C	100% rusted, no pits	C SP-5	C Sa 3 ⁴
		D	rusted and pitted	D SP-5	D Sa 3
		G	deteriorated paint over mill scale	G ₁ SP 5, G ₂ SP 5, G ₃ SP 5, G ₁ SP 5 P, G ₁ SP 5 H, G ₁ SP 5 L, G ₁ SP 5 D, G ₃ SP 5 P, G ₃ SP 5 H, G ₃ SP 5 L, G ₃ SP 5 D	*
SP 10/NACE No. 2 Near-White Blast Cleaning	Sa 2 1/2	A	intact mill scale	A SP 10	A Sa 2 1/2
		B	partially rusted mill scale	B SP-10	B Sa 2 1/2
		C	100% rusted, no pits	C SP-10, C WAB-10 ⁵	C Sa 2 1/2
		D	rusted and pitted	D SP-10, D WAB-10	D Sa 2 1/2
		G	deteriorated paint over mill scale	G ₁ SP 10, G ₂ SP 10, G ₃ SP 10	*
SP 6/NACE No. 3 Commercial Blast Cleaning	Sa 2	A	intact mill scale	*	*
		B	partially rusted mill scale	B SP-6	B Sa 2
		C	100% rusted, no pits	C SP-6, C WAB-6	C Sa 2
		D	rusted and pitted	D SP-6, D WAB-6	D Sa 2
		G	deteriorated paint over mill scale	G ₁ SP 6, G ₂ SP 6, G ₃ SP 6	*
SP 14/NACE No. 8 Industrial Blast Cleaning		A	intact mill scale	*	*
		B	partially rusted mill scale	*	*
		C	100% rusted, no pits	*	*
		D	rusted and pitted	*	*
		G	deteriorated paint over mill scale	G ₁ SP 14, G ₂ SP 14, G ₃ SP 14	*
SP 7/NACE No. 4 Brush-Off Blast Cleaning	Sa 1	A	intact mill scale	*	*
		B	partially rusted mill scale	B SP-7	B Sa 1
		C	100% rusted, no pits	C SP-7	C Sa 1
		D	rusted and pitted	D SP-7	D Sa 1
		G	deteriorated paint over mill scale	G ₁ SP 7, G ₂ SP 7, G ₃ SP 7	*

* = no photograph

¹ ISO standards Sa 3, Sa 2 1/2, Sa 2, Sa 1, St 2 and St 3 approximate the corresponding SSPC standards.

² SSPC-VIS 1 contains photographs for SP 5, SP 6, SP 7, SP 10, and SP 14.

³ Alternate non-metallic abrasives: A SP 5-N1, A SP 5-N2, A SP 5-N3

Alternate metallic abrasives: A SP 5-M1, A SP 5-M2, A SP 5-M3

⁴ ISO 8501-1 photographs (1978 through 1989 printing) may not adequately illustrate the corresponding SSPC surface preparation ISO photograph illustrating B Sa 2 shows dark areas that could be interpreted as mill scale and, therefore, represents SSPC-SP 14 and does not represent SSPC-SP 6.

ISO photographs illustrating A Sa 3, B Sa 3 and C Sa 3 do not adequately illustrate the surface texture of typically blast cleaned steel. The United Kingdom Standard BS 7079 Part A1 is equivalent to ISO 8501-1 and depicts the degrees of cleanliness of unpainted steel. BS 7079 Part A2 is equivalent to ISO 8501-2 and depicts the same degrees of cleanliness of previously painted steel.

⁵ SSPC-VIS 5 photographs of wet abrasive blast cleaning are indicated by WAB.

5.7 SSPC-SP 7/NACE No. 4, “BRUSH-OFF BLAST CLEANING”: Brush-off blast cleaning should be employed when the environment is mild enough to permit tight mill scale, tight paint (if the surface was previously painted), and tight rust to remain on the surface. The surface resulting from this method of surface preparation should be free of all loose mill scale, loose paint, and loose rust. The small amount of rust remaining should be an integral part of the surface. The surface should be sufficiently abraded to provide a good anchor for paint. The low cost of this method may result in economical protection in mild environments.

It is not intended that brush-off blast cleaning be used for very severe surroundings. Brush-off blast cleaning is generally intended to supplant power tool cleaning where facilities are available for blast cleaning. With this method of surface preparation, as with any other, it is understood that the rate of cleaning will vary from one part of the structure to another depending upon the initial condition of the surface. Because of the high rate of cleaning, the cost is low relative to the higher grades of blast cleaning. Paints which are used should have a fair degree of wetting because of the material that is allowed to remain on the surface.

When a project specification includes maintenance painting, if brush-off blast cleaning of the entire surface is specified, the existing coating should be compatible with the new coating system and should be of adequate integrity to withstand the impact of the abrasive. If a substantial amount of the coating will be removed by this method, then a higher level of cleaning should be specified, e.g. SSPC-SP 14 (industrial) or SSPC-SP 6 (commercial). SSPC-PA 1, “Shop, Field, and Maintenance Painting of Steel,” and SSPC-PA Guide 4, “Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems,” cover additional maintenance painting procedures.

5.7.1 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 1 or other consensus reference photographs may be used to supplement the cleaning criteria of this standard. Table 4A gives the correlation between the SSPC and the ISO pictorial standards.

5.8 SSPC-SP 8, “PICKLING”: Pickling is considered a desirable method of removing rust and mill scale from structural shapes, beams, and plates when the cost of such removal is felt to be justified. Properly accomplished, pickling produces a surface that will promote long paint life with most coatings, but pickling is most commonly associated with hot dipped galvanizing.

Where production is sufficiently high to keep the equipment in use, pickling results in low cost shop preparation. It is impractical for field use.

Facilities are extremely limited for pickling of large fabricated members or large structural beams. However, there are a number of facilities for large steel plates and structural members that are not exceedingly long. Small-scale pickling facilities are widely available.

Hydrochloric acid dissolves scale faster than does sulfuric acid, but hydrochloric acid is seldom heated for greater action because of the greater amounts of toxic hydrogen chloride fumes emitted. Any acid used should contain an appropriate inhibitor to control the chemical action. Considerable use is made of the duplex type of pickling where sulfuric acid is used to remove the rust and scale, and phosphoric acid is used for a final phosphate treatment. Special precautions including fresh water rinsing are necessary to remove residues of unreacted sulfuric or hydrochloric acid.

Design of fabricated steel may require special consideration to eliminate pockets or crevices which trap acid during pickling. This may be avoided by pickling in phosphoric acid. Pickled steel, like blast cleaned steel, should be painted as soon as possible after cleaning. A more detailed discussion of pickling is available in Volume 1 of the SSPC Painting Manual.

5.9 SSPC-SP 9, “WEATHERING FOLLOWED BY BLAST CLEANING”: This standard was discontinued in 1971. Weathering prior to blast cleaning has been found to be a very harmful practice, especially in corrosive environments, since deleterious surface impurities are much more difficult to remove after weathering away of mill scale.

5.10 SSPC-SP 10/NACE No. 2, “NEAR-WHITE BLAST CLEANING”: In many exposures involving a combination of high humidity, chemical atmosphere, marine, or other corrosive environment, the use of SSPC-SP 5 “White Metal Blast Cleaning” was found to be overly expensive due to the disproportionately large amount of work required to remove the last vestiges of streaks and shadows. There are many applications in which these traces can be tolerated without appreciable loss in coating life. Therefore, the need for a grade of blast cleaning beyond that of SSPC-SP 6 but less than SSPC-SP 5 was demonstrated. The near-white blast cleaning standard was developed to fill this need.

Near-white blast cleaning can be employed for all general purposes where a high degree of surface cleanliness is required. It will remove all rust, mill scale, and other detrimental matter from the surface but streaks and stains are permitted to remain. The surface will not necessarily be completely uniform in color, nor will all surfaces be uniformly clean. However, it is explicit in this standard that shadows, streaks, or discolorations, if any, be slight and be distributed uniformly over the surface—not concentrated in spots or areas.

The advantage of near-white blast cleaning lies in the lower cost for surface preparation that is satisfactory for all but the most severe service conditions. Depending upon the initial condition of the new or previously painted steel, it has been variously estimated that near-white blast cleaning can be carried out at a cost of 10 to 35% less than that of SSPC-SP 5. These numbers are estimates only and will not hold true in all cases.

The verbal description calling for at least 95% of the surface being equivalent to SSPC-SP 5 is based upon a large number of visual observations and a limited number of light reflectivity

measurements. It is hoped that the amount of surface impurity can be quantified by specific measurement technique, but efforts to date have been unsuccessful except on a laboratory basis. It is believed, however, that a visual estimate of the amount of residuals can be agreed upon between owner and contractor.

When a project specification includes maintenance painting, if it is intended that some of the existing coating be permitted to remain (e.g., because it is thin, well adherent, and compatible with the new coating system), the contract documents should stipulate the extent of the surface to be cleaned in accordance with this standard. SSPC-PA 1, "Shop, Field, and Maintenance Painting of Steel," and SSPC-PA Guide 4, "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems," cover additional maintenance painting procedures.

5.10.1 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 1 or other consensus reference photographs may be used to supplement the cleaning criteria of this standard. Table 4B gives the correlation between the SSPC and the ISO pictorial standards. When using consensus reference photographs, it should be recognized that the color or hue of the cleaned surface may appear different from the photographs due to the nature of the steel, the abrasives used, the presence of existing coatings, and other factors.

5.11 SSPC-SP 11, "POWER TOOL CLEANING TO BARE METAL": Power tool cleaning to remove tightly adherent material produces a surface that is visibly free from all rust, mill scale, and old coatings, and that has a surface profile of at least $25\mu\text{m}$ (1 mil). SSPC-SP 11 is the highest level of power tool cleaning. It produces a greater degree of cleaning than SSPC-SP 3 (which does not remove tightly adherent material) and SSPC-SP 15, "Commercial Grade Power Tool Cleaning" which allows substantial staining. SSPC-SP 11 may be considered for coatings requiring a bare metal substrate.

The surfaces prepared according to this standard are not to be compared to surfaces cleaned by abrasive blasting. Although this method produces surfaces that resemble near-white or commercial blast, they are not necessarily equivalent to those surfaces produced by abrasive blast cleaning as called for in SSPC-SP 10 (near-white) or SP 6 (commercial) due to characteristics of the profile.

The SSPC-SP 11 standard gives the specifier an opportunity to select a method of cleaning suitable for certain coatings in areas where wet or dry abrasive blasting or waterjetting is prohibited or not feasible. Examples of other circumstances where this standard may be applied are as follows:

- touch-up of welded or damaged areas of erection assemblies
- reducing volume of hazardous waste produced by abrasive blasting
- cleaning around sensitive equipment or machinery

5.11.1 Power Tools and Cleaning Media: A power tool cleaning system consists of a surface cleaning medium for abrading the surface and a powered tool for driving that medium. The standard distinguishes between media that clean the surface and those that produce a profile. Similarly, power tools are classified as surface cleaning type or profile producing type.

Surface cleaning power tools are those that drive two main classes of surface cleaning media: 1) non-woven abrasive wheels and discs; 2) coated abrasive discs, flap wheels, bands, or other coated abrasive devices.

Profile-producing power tools are described as those on which rotary impact or peening media are mounted, and those on which steel needles (needle guns) are mounted, although other tools and media that can produce the appropriate profile are acceptable. In instances where a profile already exists, such as on previously painted surfaces, only surface cleaning power tools and media may be required, if the appropriate degree of cleanliness is created without reducing the profile to less than 25 micrometers (1 mil). Where an existing profile is reduced to less than 25 micrometers (1 mil) in the process of cleaning, surface profiling power tools are required to restore the appropriate profile.

Where there is no existing profile, then both cleanliness and profile must be produced as specified. This may require using both kinds of tools and media, although in some cases a surface profiling tool/medium may adequately clean the surface without requiring a separate cleaning operation with surface cleaning tools/media. It should be noted that misuse of power tools on metals can produce a burnished rather than a textured surface that compromises coating adhesion.

Cleaning of metal surfaces is usually faster and less expensive using abrasive blasting than using power tools, without considering the cost of mobilization and containment for the control of dust and debris. However, power tools are used frequently for spot cleaning of damaged coatings where contamination of adjacent areas by abrasive is unacceptable. Less particulate contamination of the environment occurs than from abrasive blasting.

5.11.2: Power Tools With Vacuum Shrouds: Special power tools may also have high-efficiency particulate air (HEPA) vacuum lines attached to reduce air pollution and to contain the debris generated at the point-source during coating removal. The vacuum shroud surrounds only the tool itself, providing a localized containment of the debris at the point of generation.

The method of operation of vacuum shrouded tools is similar to that of non-vacuum shrouded tools. This is difficult when cleaning irregular surfaces. As a result, special custom shrouds can be fitted onto the ends of the tools. Some tools however, are not amenable to shrouds, and therefore the collection of debris is not as efficient. A surface can be cleaned to comply with SSPC-SP 3, SSPC-SP 15 "Industrial Grade Power Tool Cleaning," or SSPC-SP 11, using these vacuum shrouded tools.

5.11.3 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 3 or other consensus reference photographs may be used to supplement the cleaning criteria of this standard. Table 4A lists the SSPC-VIS 3 consensus reference photographs that correspond to various initial surface conditions. SSPC-VIS 1 and ISO 8501-1 are not suitable for assessing surfaces cleaned to bare metal by power tools.

5.12 SSPC-SP 12/NACE No. 5, "SURFACE PREPARATION AND CLEANING OF METALS BY WATERJETTING PRIOR TO COATING": As is the case with dry abrasive blast cleaning, high pressure waterjetting (HP WJ) and ultra-high pressure waterjetting (UHP WJ) can be used to prepare surfaces to various degrees of cleanliness. Waterjetting is used when abrasive blasting is not possible or not desired, or when it is necessary to remove a high percentage of soluble salt contamination. Waterjetting does not produce a profile. However, if a profile exists under old paint that is being removed, the original profile can be restored by waterjetting. SSPC-TR 2/NACE 6G198, "Wet Abrasive Blast Cleaning," discusses wet methods using abrasive.

Water cleaning uses pressures less than 70 MPa (10,000 psi) and high-pressure waterjetting (HP WJ) uses pressures above this value. Ultrahigh-pressure waterjetting (UHP WJ) uses pressures above 210 MPa (30,000 psi).

5.12.1 Surface Cleanliness: SSPC-SP 12 defines four degrees of VISUAL cleanliness which can be summarized as follows:

- WJ-1 Clean to the bare substrate; the most thorough level
- WJ-2 Very thorough or substantial cleaning; randomly dispersed visible stains of previously existing rust, tightly adherent thin coatings, and tightly adherent foreign matter is allowed on only 5 percent of the surface
- WJ-3 Thorough cleaning; randomly dispersed visible stains of previously existing rust, tightly adherent thin coatings, and tightly adherent foreign matter is allowed on only 33 percent of the surface
- WJ-4 Light cleaning; all loose material is removed.

These four conditions of waterjetting were originally meant to parallel the four degrees of abrasive blast cleaning (SSPC-SP 5, SSPC-SP 10, SSPC-SP 6, and SSPC-SP 7). However, SSPC-SP 12 has evolved to the point where WJ-2 and WJ-3 allow thin paint to remain, while the dry abrasive blast cleaning standards SSPC-SP 10 and SP 6 continue to allow only stains of paint.

One of the advantages of waterjetting is the removal of soluble contaminants. In an appendix, SSPC-SP 12 describes three levels of nonvisual surface cleanliness based on the amount of water-soluble chlorides, iron-soluble salts, and sulfates:

- NV-1 No salts detected
- NV-2 Less than 7 $\mu\text{g}/\text{cm}^2$ chloride ion contaminants, 10 $\mu\text{g}/\text{cm}^2$ ferrous ion, and 17 $\mu\text{g}/\text{cm}^2$ sulfate ion
- NV-3 Less than 50 $\mu\text{g}/\text{cm}^2$ chloride and sulfate contaminants

Methods for measuring the amount of salt on the surface are described in SSPC-TU 4, "Field Methods for Retrieval and Analysis of Soluble Salts on Substrates" (to be reissued in 2005 as SSPC-Guide 15). The choice of visual and nonvisual cleanliness is determined by the existing condition of the surface, the coating to be applied, and the exposure environment.

5.12.2 Flash Rusting: With any wet method of surface preparation, the cleaned surface will eventually exhibit a rust bloom or flash rust as the surface dries. Non-uniform rusting with areas of heavy rust usually indicates the presence of soluble salts on the surface. A uniform rust bloom may be an acceptable surface to paint. Visible flash rusting can be light, medium, or heavy. The coating manufacturer must be consulted to determine the extent of rust bloom that their coating can tolerate for the given exposure. Inhibitors can be added to the water to prevent flash rusting, but the coating manufacturer must be consulted to verify compatibility with the level of inhibitor used.

5.12.3 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 4 or other consensus reference photographs may be used to supplement the cleaning criteria of this standard. SSPC-VIS 4 contains photographs showing steel of original rust condition C cleaned to WJ-2 and WJ-3, each with light, medium, or heavy flash rusting. A parallel set of photographs is given for original rust condition D. In addition, there are four different painted surfaces each cleaned to the four degrees of waterjetting, WJ-1 through WJ-4. When using the consensus reference photographs, it should be recognized that the color or hue of the cleaned surface may appear different from the photographs due to the nature of the steel, the presence of existing coatings, and other factors.

5.13 SSPC-SP 13/NACE NO. 6, "SURFACE PREPARATION OF CONCRETE": This standard gives requirements for surface preparation of concrete by mechanical, chemical, or thermal methods prior to the application of bonded protective coating or lining systems. The requirements of this standard are applicable to all types of cementitious surfaces including cast-in-place concrete floors and walls, precast slabs, masonry walls, and shotcrete surfaces.

An acceptable prepared concrete surface should be free of contaminants, laitance, loosely adhering concrete, and dust, and should provide a sound, uniform substrate suitable for the application of protective coating or lining systems. When required, a minimum concrete surface strength, maximum moisture content, and surface profile range should be specified in the procurement documents.

SSPC-SP 13/ NACE No. 6 contains sections on definitions, inspection procedures before surface preparation, the methods of surface preparation, inspection, and acceptance criteria for light service and for severe service.

5.14 SSPC-SP 14/NACE No. 8, "INDUSTRIAL BLAST CLEANING": Industrial blast cleaning is used when the objective is to remove most of the coating, mill scale, and rust, but the extra effort required to remove every trace of these materials is determined to be unwarranted. Industrial blast cleaning provides a greater degree of cleaning than SSPC-SP 7 but less than SSPC-SP 6.

The difference between an industrial blast and a brush-off blast is that the objective of a brush-off blast is to allow as much of an existing coating to remain as possible, while the objective of the industrial blast is to remove most of the coating. The industrial blast allows defined mill scale, coating, and rust to remain on less than ten percent of the surface and allows defined stains to remain on all surfaces. A commercial blast provides a higher level of cleaning, and the surface is free of mill scale, rust, and coatings, allowing only random staining to remain on no more than 33 percent of each 9 in² (60 cm²) increment of the surface.

5.14.1 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, VIS 1 or other consensus reference photographs may be used to supplement the cleaning criteria of this standard. Table 4A gives the correlation between the SSPC and the ISO pictorial standards. When using the photographic standards, it should be recognized that the color or hue of the cleaned surface may appear different from the photographs due to the nature of the steel, the abrasives used, the presence of existing coatings, and other factors.

5.15 SSPC-SP 15, "Commercial Grade Power Tool Cleaning": A surface cleaned with power tools to commercial grade is visibly free from all rust, mill scale, and old coatings; and it has a surface profile of at least 25 μm (1 mil). SSPC-SP 15 provides a higher level of cleanliness than SSPC-SP 3, "Power Tool Cleaning" in that all paint, rust, and mill scale are removed. SSPC-SP 15 provides a lesser level than SSPC-SP 11, "Power Tool Cleaning to Bare Metal" because staining is permitted on 33 percent of the surface. Both SSPC-SP 15 and SSPC-SP 11 require a minimum 25 μm (1 mil) profile.

The surfaces prepared according to this standard are not to be compared to surfaces cleaned by abrasive blasting. Although this method produces surfaces that resemble commercial blast cleaned surfaces, they are not necessarily equivalent to those surfaces produced by abrasive blast cleaning to SP 6. After power tool cleaning to SP 15, slight residues of rust and paint may remain in the bottoms of pits if the original surface is pitted. Commercial blast cleaning (SP 6) allows only staining of the surface, and does not permit residue to remain in pit bottoms.

SSPC-SP 15 helps to bridge the gap between the marginal surface preparation described in SP 3, "Power Tool Cleaning" and the more thorough cleaning described in SP 11, "Power Tool Cleaning to Bare Metal." It gives the specifier an opportunity to select a method of cleaning suitable for certain coatings in areas where the added expense of going to SP 11 is not justified by an anticipated increase in coating life. Examples of circumstances where this standard may be applied are as follows:

- touch-up of welded or damaged areas of erection assemblies
- reducing volume of hazardous waste produced by abrasive blasting
- cleaning around sensitive equipment or machinery
- cleaning where abrasive blasting is not permitted.

5.15.1 Consensus Reference Photographs: If mutually agreed upon or if specified in the procurement documents, SSPC-VIS 3 or other consensus reference photographs may be used to supplement the cleaning criteria of this standard. Table 4A lists the SSPC-VIS 3 photographs that correspond to various initial surface conditions. SSPC-VIS 1 and ISO 8501-1 are not suitable for assessing surfaces cleaned to commercial grade by power tools.

6. Selection of Abrasives, Blast Cleaning Parameters, and Equipment

The selection of the size and type of abrasive which will most effectively and economically produce the desired surface finish is not an exact science because of the many variables involved. These variables include the following at a minimum:

- The nature of the steel being cleaned, i.e., the hardness and the degree of rusting which may have developed prior to blast cleaning.
- The basic purpose for blast cleaning, which may include either new construction or maintenance and repair programs.
- The type of surface finish desired, i.e., degree of cleanliness and height of profile required to meet the specification or requirement of the paint to be applied. See SSPC report, "Surface Profile for Anti-Corrosion Paints," (SSPC 74-01).
- The type of blast cleaning systems which may be employed, e.g., centrifugal wheel or air blast recirculating abrasive systems, or open nozzle airblasting with expendable abrasives.

In general, select the smallest size abrasive that will produce the desired cleaning results. Usually, this will give the fastest, most economical cleaning operation.

Non-traditional blast cleaning media may be expendable or recyclable. Such materials include sponge, dry ice, sodium bicarbonate and ice crystals. All require specialized equipment and may or may not create a surface profile.

General information concerning the chemical and physical properties of cast steel shot and grit, and the physical properties of various non-metallic abrasives along with information on their usage, are presented in the following sections.

6.1 ABRASIVE CHARACTERISTICS: Selecting the appropriate type of abrasive for the job is important because the type of abrasive can have a significant influence on the

appearance of the blast cleaned surface, productivity, and subsequent clean-up. Abrasives vary in hardnesses, particle size distribution, shape, bulk density, friability, waste generation, and recyclability. The following is a discussion of these characteristics and how they influence abrasive performance. Some physical data on non-metallic abrasives are given in Table 5.

**TABLE 5
PHYSICAL DATA ON NON-METALLIC ABRASIVES**

	Hardness (Mohs)	Shape	Specific Gravity	Bulk Density		Color	Free Silica (wt %)	Degree of Dusting	Reuse
				lb/ft ³	kg/m ³				
Naturally Occurring Abrasives									
Silica Sand	5	Rounded	2 to 3	100	1600	White	90+	High	Poor
Heavy Mineral Sand	5 to 7	Rounded	3 to 4	125	2000	Variable	<5	Medium	Good
Flint	6.5 to 7	Angular	2 to 3	80	1300	Lt. Gray	90+	Medium	Good
Garnet	7 to 8	Angular	4	145	2300	Pink	Nil	Medium	Good
Zircon	7.5	Cubic	4.5	185	3000	White	Nil	Low	Good
Kieserite	3.5	Angular	2.6	90	1400	White	Nil	Medium	Poor
Novaculite	4	Angular	2.5	100	1600	White	90+	Low	Good
By-Product Abrasives									
Boiler Slag	7	Angular	2.8	85	1400	Black	Nil	High	Poor
Copper Slag	8	Angular	3.3	110	1800	Black	Nil	Low	Good
Nickel Slag	8	Angular	2.7	85	1400	Green	Nil	High	Poor
Walnut Shells	3	Cubic	1.3	45	720	Brown	Nil	Low	Poor
Peach Shells	3	Cubic	1.3	45	720	Brown	Nil	Low	Poor
Corn Cobs	4.5	Cubic	1.3	30	480	Tan	Nil	Low	Good
Manufactured Abrasives									
Silicon Carbide	9	Angular	3.2	105	1700	Black	Nil	Low	Good
Aluminum Oxide	8	Blocky	4.0	120	1900	Brown	Nil	Low	Good
Glass Beads	5.5	Spherical	2.5	100	1600	Clear	67	Low	Good
Crushed Glass	6 to 8	Irregular	2.5	63 to 91	1000-1500	Gray	67	Low	Poor
Sodium Bicarbonate	2.5	Powder	2.2	60	960	White	Nil	None	Poor
Sponge	0.016	Granular	0.29-1.45	5 to 25	80 to 400	Various	Nil	Low	Good
Plastic Beads	3.5	Blocky		55	880	Various	Nil	Low	Fair
Dry Ice	Nil	Cylinder	62.4	50	800	White	Nil	Low	Poor

6.1.1 Hardness: Metallic abrasive hardness is measured on the Rockwell C scale while non-metallic abrasive hardness is measured on the Mohs scale. Hardness is important because the harder an abrasive, the deeper the profile it is likely to generate.

6.1.2 Size: Specifications may include abrasive sieve size designation, because particle size plays a major role in productivity and in the subsequent profile generated. The role of abrasive size will be discussed in more detail under the section dealing with productivity.

6.1.3 Shape: Abrasive particles range from spherical to sharply angular. Spherical to rounded particles clean by impact, producing a peened surface. Angular to irregularly shaped particles clean by scouring or cutting the surface, producing an etched surface.

6.1.4 Bulk Density: The bulk density of an abrasive is a measure of an abrasive's weight per unit volume and is usually expressed in kilograms per cubic meter or pounds per cubic foot. For example, the bulk density of sand is approximately 1600 kg/m³ (100 lb/ft³) whereas for steel grit abrasives, it is typically 4000 kg/m³ (250 lb/ft³). Bulk density is important when lifting abrasive filled bulk containers. Using the bulk density values for sand and steel shown above, a 2.8 m³ (100 ft³) container filled with sand weighs 4500 kg (5 tons), whereas the same container filled with steel grit weighs 11,000 kg (12.5 tons).

6.1.5 Friability/Waste Generation: Abrasive friability is a measure of an abrasive's resistance to breakdown on impact. The more friable an abrasive, the greater the tendency for the abrasive to breakdown on impact, thereby generating more waste and dust.

6.1.6 Recyclability: Recyclability is a property of an abrasive that allows it to be reused many times without excessive breakdown. In order to meet the strict cleanliness requirements for recycling, the abrasive must also be able to withstand the rigorous cleaning process for removal of contaminants from the abrasive mix. Most mineral and byproduct abrasives can be recycled 1 to 3 times, but they have difficulty meeting the strict cleanliness requirements for recycling. Metallic abrasives, on the other hand, show the lowest friability, generate the least amount of waste, can be recycled many times, and meet the strict cleanliness requirements for recycling. Usually, the greater the hardness of a metallic abrasive, the more quickly it breaks down and the fewer times it can be recycled.

6.2 FACTORS AFFECTING SURFACE PROFILE: Surface profile is a measure of surface roughness resulting from abrasive blast cleaning. The height of the profile produced on the surface is measured from the bottoms of the lowest valleys to the tops of the highest peaks.

The thickness and generic type of paint to be applied determines the allowable minimum and maximum profile height. The abrasive size is then chosen to achieve that profile. SSPC-AB 1, "Mineral and Slag Abrasives," defines five abrasive grades yielding profile heights from 13 to 150 micrometers (0.5 to 6.0 mils).

6.2.1 PROFILE HEIGHT: SSPC studies have shown that metallic abrasives larger than those which will pass through a 16 mesh sieve (ASTM E 11) may produce a profile which is too deep to be adequately covered with a single coat of primer. Accordingly, it is recommended that the use of larger abrasives be avoided whenever possible. However, when heavy mill scale or rust are present, abrasives of a larger size may be needed. In these cases two coats of primer may be needed instead of the usual one coat. Alternatively, if the nozzle pressure is

**TABLE 6
APPROXIMATE PROFILE HEIGHT OF BLASTED STEEL
USING DIFFERENT SIZE ABRASIVES***

ABRASIVE	Profile Height				
	25 μ m 1 mil	37 μ m 1.5 mil	50 μ m 2 mil	63 μ m 2.5 mil	75-100 μ m 3-4 mil
Silica Sand	30/60 mesh	16/35 mesh	16/35 mesh	8/35 mesh	8/20 mesh
Steel Grit	G80	G50	G40	G40	G25
Steel Shot	S110	S170	S280	S280	S330
Garnet	80 mesh	36 mesh	36 mesh	16 mesh	16 mesh
Aluminum Oxide	100 grit	50 grit	36 grit	24 grit	16 grit

* These profile heights are typical if the nozzle pressure is between 620 and 700 kPa (90 and 100 psi).

increased, a smaller size abrasive may remove heavy paint or scale more effectively than a larger abrasive at the lower pressure. Higher nozzle pressures may still produce larger profiles.

Table 6 gives the range of maximum and average maximum profile heights to be expected under normal good operating conditions (wheel and nozzle). At nozzle pressures in excess of 760 kPa (110 psi), the profile may be significantly higher.

Profile comparators are available to aid in estimating the average maximum profile of surfaces blasted with sand, steel grit, and steel shot. Surface profile can also be measured by use of replica tape. Methods for measuring profile are described in ASTM D 4417, "Test Method for Field Measurement of Surface Profile of Blast Cleaned Steel" and in NACE RP0287, "Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using a Replica Tape." A report, "Surface Profile for Anti-Corrosion Paints," (SSPC 74-01), is available from SSPC describing methods of measuring profile and relating profile to blast cleaning conditions and to coating performance.

When the abrasive media impacts the surface it creates surface profile. It is this profile (or "anchor pattern") that is necessary for most coating systems to adhere to the substrate. The depth of the profile is controlled by the following parameters:

- Abrasive Size: The larger the abrasive, the larger the profile.
- Abrasive Type: Angular abrasives create a deeper profile than round abrasives of the same size.
- Hardness: The harder the abrasive the deeper the profile.
- Blast Nozzle Air Pressure: The higher the nozzle pressure the deeper the profile.
- Type of Blast Nozzle: A venturi nozzle generates a deeper profile than a straight bore nozzle with the same diameter opening.
- Distance of Blast Nozzle to Surface: The closer to the work the deeper profile.
- Angle of Blast Nozzle to Surface: The greater the angle from the perpendicular to surface, the less the profile.

Altering any of these parameters during the blasting operation could affect profile and surface cleanliness. To avoid undesirable changes in profile and surface cleanliness, blasting trials are recommended before changing any of the parameters noted above.

A small abrasive can produce larger profiles if the impact velocity is increased by either increasing the wheel speed or increasing nozzle pressure. If a small abrasive is used, there will be more impacts per pound of abrasive than if a larger abrasive is used. The abrasive must be large enough to remove the rust and mill scale present. The rule of thumb is to use the smallest abrasive that will do the job.

6.2.2 PROFILE TEXTURE (ROUGHNESS): A 2 mil profile produced by a round abrasive (steel shot) will have a different texture than a 2 mil profile produced by an angular abrasive

(steel grit). Similarly, a surface blasted with a small abrasive at a high pressure may have the same profile height as a surface blasted with a large abrasive at a lower pressure, but the small abrasive will produce more peaks. Coating systems may have measurably different performance characteristics over these two types of surface. For example, the angular profile produced by grit is required for metallizing (see SSPC-CS 23.00/AWS C2.23/NACE No. 12).

Shot produces a surface composed of rounded craters. Grit produces a more irregular surface with many smaller peaks between adjacent large peaks. It is only the tallest peaks and lowest valleys that determine the profile height. Nonmetallic abrasives create profiles with the maximum amount of roughness.

The surface roughness can be measured quantitatively with a stylus instrument (e.g., a profilometer). This is a device that drags a needle across about an inch (2.5 cm) of the surface and electronically computes the distance between the highest peak and the lowest valley, the number of peaks, and the average peak height. Laser versions are also available.

The rougher the profile (the more peak/valleys) the more metal/paint interface is available for bonding. However, if the valleys are too deep and narrow, the coating may not be able to penetrate to the bottom of the valleys, thereby leaving a void at the bottom of the pits. Rough surfaces can be advantageous if the coating is able to completely wet the surface.

6.3 PARAMETERS THAT AFFECT PRODUCTIVITY:

Factors such as initial steel condition, specified degree of cleaning, and accessibility are job specific. Eleven controllable parameters that affect the productivity of abrasive blast cleaning are described below.

6.3.1 Particle Size: Decreasing abrasive particle size can dramatically increase cleaning rate. Increasing abrasive particle size may be necessary to remove heavy coatings and scale. The general rule is to use the smallest size abrasive that will do the job.

6.3.2 Hardness: Generally, the harder the abrasive, the better it will perform. However, very hard abrasives shatter on impact expending most of their energy in particle breakdown and dust generation. As with selecting abrasive size, the general rule is to select the minimum abrasive hardness that will effectively do the job.

6.3.3 Shape: Rounded particles are most effective in removing brittle coatings such as mill scale, whereas angular or irregular shaped particles are more effective in removing softer coatings such as rust and paint.

6.3.4 Specific Gravity: The higher the specific gravity, the more energy a given size abrasive particle will impart to the surface on impact, thereby increasing productivity. Generally, a higher specific gravity implies a higher bulk density.

6.3.5 Nozzle Pressure: The higher the nozzle pressure the more productive the blast operation. For example, for each 7 kPa (1 psi) increase there is a 1.5 percent increase in productivity. Most equipment for dry abrasive blasting has a practical upper limit of 1000 kPa (150 psi).

6.3.6 Nozzle Type: It is important to choose the right nozzle for the job. For example, straight bore nozzles give a tight blast pattern that is best suited for blast cleaning small areas such as hand rails, spot blasting, weld seams, etc. Venturi bore nozzles create a wide blast pattern and are best suited for large area blast cleaning. Venturi bore nozzles increase nozzle velocity by as much as 100% and therefore are 35% more efficient compared to straight bore nozzles of the same diameter.

6.3.7 Nozzle to Surface Distance: For optimum cleaning rate the nozzle to surface distance is around 46 cm (18 in). However, this distance can vary depending on the type of surface contamination being removed, nozzle pressure, abrasive type, and nozzle type.

6.3.8 Impact Angle: An 80 to 90 degree angle is best suited for removing mill scale or heavy rust and for cleaning pitted areas; a 45 to 60 degree angle is best for peeling heavy layers of paint or rust; a 60 to 70 degree angle is recommended for general cleaning. Operator technique in controlling the motion of the nozzle determines the impact angle at any instant.

6.3.9 Abrasive Metering: Each abrasive type has a different optimum flow rate through the metering valve. Before starting any blast cleaning job, it is important to conduct a test blast with the metering valve set at lean, moderate, and high abrasive flow rates to find the optimum flow for the given abrasive.

6.3.10 Abrasive Cleanliness: A clean, dry, dust-free abrasive is essential for optimum productivity. Check the abrasive before starting a job and regularly thereafter for foreign matter, moisture, and dust.

6.3.11 Embedment: Some abrasive products, particularly non-metallics, tend to embed in the blast cleaned surface. Conduct a test blast with the abrasive and evaluate the blast cleaned surface to be sure the amount of embedment does not exceed the job specification requirements.

6.4 ABRASIVE TYPES: Abrasives, the material in the blasting operation that does the work, can be divided into two major categories: metallic, generally ferrous, abrasives and non-metallic abrasives. The non-metallic abrasives can be further subdivided into naturally occurring, by-product, or manufactured abrasives.

6.4.1 Metallic Abrasives: Steel shot consists of nearly spherical particles of steel obtained by granulating a molten

stream of metal with water, air, or other methods. Steel shot will generally conform to SSPC-AB 3 "Ferrous Metallic Abrasive" in terms of hardness, chemical composition, size, and microstructure.

Cast steel grit consists of angular particles produced by crushing steel shot (SAE J827). Steel grit is available in a wide range of hardness, from 30 to 66 on the Rockwell C scale (R_c), produced by varying the tempering time cycles to which the grit is subjected. Generally, three hardness ranges are most commonly produced: 40 to 50 R_c , 55 to 60 R_c , and 60 to 66 R_c . The first two hardness ranges are used for structural steel, and the latter is used primarily for selective application where deep, consistent, sharp etched finishes are required, or where moderate etches on extremely hard surfaces are needed.

In addition to steel shot and grit, iron grit may also conform to SSPC-AB 3. Iron abrasive is characterized by high carbon content and hardness typically over 55 R_c . The particle shape requirements for iron grit are less stringent than those for steel grit.

Iron abrasive cannot be recycled as many times as steel abrasive, but it can be recycled many more times than non-metallic abrasives. Iron abrasive is less costly to purchase than steel abrasive. In situations where full recovery is not possible, such as a bridge containment, iron abrasive has an economic advantage over steel abrasive. Steel abrasive is more cost effective in centrifugal wheel machines in a shop.

Metallic shot will produce a peened surface texture whereas grit produces more of an etched surface texture. The etch becomes more pronounced with increasing abrasive hardness.

Typical applications of various steel abrasives, referring to rust condition classifications described in Section 4.1 are:

- Shot: Commonly used on new steel (rust conditions A and B) to remove mill scale using centrifugal wheel machines
- Grit (40-50 R_c): Most effective on rust conditions C and D, but also commonly used for rust conditions A and B
- Shot/Grit Mixture (Shot 40-50 R_c /Grit 55-60 R_c): Used on new steel to remove both mill scale and rust. Shot/grit mixes demand careful attention and close control of abrasive additions by the operator to maintain the shot/grit ratio.

6.4.2 Non-Metallic Abrasives: Non-metallic abrasives can be categorized as naturally occurring, by-product, or manufactured. Naturally occurring abrasives include silica sand, olivine sands, staurolite and other minerals, flint, garnet, zirconium, and novaculite. Byproduct abrasives include those from smelters (nickel or copper slag) and utility generators (coal or boiler slag) and those from agricultural products (walnut shells, peach shells, or corncobs). Manufactured abrasives include silicon carbide, aluminum oxide, and glass beads.

Commonly used non-metallic abrasives for surface preparation of steel to be painted include silica sand, coal and smelter slags, staurolite, olivine, and garnet. Some countries have banned the use of abrasives with a high free-silica content

because of possible health hazards. The U.S. Navy specification MIL-A-22262, "Abrasive Blasting Media, Ship Hull Blast Cleaning," allows the maximum crystalline silica content of the abrasive to be 1.0 percent by weight. This level of silica corresponds to a Class A abrasive as described in SSPC-AB 1, "Mineral and Slag Abrasives."

6.5 BLAST EQUIPMENT: For the most economical production, the appropriate blast cleaning equipment must be used.

6.5.1 Conventional Blasting: Air abrasive blasting equipment has five basic components: air compressor, air hose, blasting machine (sand pot), blast hose, and nozzle. The compressor must be large enough to supply the volume of air needed at the correct pressure, and this depends on factors such as nozzle size, number of nozzles, and length and size of air hose. Nozzles are available in several lengths, designs, sizes of openings, and lining materials. Nozzle lengths of 13 to 20 cm (5 to 8 inches) are generally used for removing tightly adhering rust and scale. Shorter nozzles 8 cm (3 in) or less are more appropriate for use behind beams and in other areas difficult to access using full range of motion.

Where shop cleaning of steel is possible, centrifugal wheel blasting units using recyclable steel abrasive are the most economical. Both centrifugal wheel and air blasting are discussed in detail in Volume 1 of the SSPC Painting Manual.

6.5.2 Vacuum Blasting: Vacuum blast cleaning is less productive than conventional blast cleaning and therefore is typically used for small localized areas. Vacuum blast cleaning can achieve the highest levels of surface preparation while minimizing worker exposure to emissions of dust and debris. The tools must be properly operated and fitted with the appropriate shroud in order to maintain the seal between the blast nozzle and the substrate. Compressed air is used to propel abrasive particles against the surface to be cleaned. The blast nozzle is fitted into a localized containment assembly (surrounding the nozzle only) which is equipped with a vacuum. Dust, abrasive, and old paint are sent to a recycler. The cleaned abrasive is returned for re-use. Aluminum oxide or metallic abrasives such as iron or steel grit or steel shot are commonly used.

6.5.3 Abrasive Blast Cleaning Above 760 kPa (110 psi): Over the last several years many blast cleaning operators have been developing techniques that will allow them to blast clean at nozzle pressures greater than 760 kPa (110 psi). The primary driving force has been dramatic increases in productivity. For every 7 kPa (1 psi) increase in nozzle pressure there is a 1.5 percent increase in productivity. For example, going from 690 to 760 kPa (100 to 110 psi) is a 10 percent increase in nozzle pressure but a 15 percent increase in productivity. Going from 690 to 860 kPa (100 to 125 psi) results in a 38 percent increase in productivity.

Another important advantage of higher nozzle pressures is the ability to use finer abrasives to achieve a given profile. Using finer abrasives means more abrasive impacts per unit time, which translates into faster cleaning and higher productivity. Steel or iron abrasives are recommended for high pressure blasting because they do not break down at these elevated pressures. When using non-metallic abrasives at elevated pressures, much of the energy imparted to the abrasive particles is dissipated in the pulverizing of the abrasive particles, thus, reducing cleaning efficiency and dramatically increasing dust levels.

7. Summary of SSPC Abrasive Standards

7.1 SSPC-AB 1, "MINERAL AND SLAG ABRASIVES":

This standard defines the requirements for selecting and evaluating nonmetallic mineral and slag abrasives used for blast cleaning steel and other surfaces for painting. The standard defines two types: 1) natural mineral abrasives, including sand, flint, garnet, staurolite, and olivine; and 2) slag abrasives, including coal slag, copper slag or nickel slag. The abrasives covered by the standard are primarily intended for one-time use without recycling.

The abrasives are also classified based on the crystalline silica content and the profile produced by the abrasive. The surface profile is determined by a blasting test conducted on 60 cm x 60 cm (2 ft by 2 ft) steel plates. Other properties stipulated include specific gravity, hardness, weight change on ignition, water-soluble contaminants, moisture content, and oil content.

For a given abrasive type, the surface profile is determined by the size and shape of the abrasive particles. The abrasive supplier is required to furnish a representative sieve analysis of the abrasive used in the profile determination. This sieve analysis then becomes the typical particle size distribution for subsequent delivery of the abrasive. Additional information on physical properties of non-metallic abrasives is given in Table 5.

7.2 SSPC-AB 2, "CLEANLINESS OF RECYCLED FERROUS METALLIC ABRASIVES":

This standard gives the cleanliness requirements for recycled work mix ferrous metallic abrasives. The limits and test methods are given for non-abrasive residue, lead content, water-soluble contaminants, and oil content.

7.3 SSPC-AB 3, "FERROUS METALLIC ABRASIVE":

This standard defines the physical and chemical requirements for steel and iron abrasives. Abrasive size is determined by sieve analysis. Abrasive shape, divided into shot or grit, is determined by the percentage of round and elongated particles in a sample. The minimum specific gravity is 7.0 for steel abrasive and 6.8 for iron abrasive. A specified percent of the abrasive must be retained on the appropriate take-out screen after 100 cycles in a durability test. Properties include requirements for carbon, manganese, and phosphorous content as well as conductivity and cleanliness.

8. Wet Abrasive Blast and Waterjetting Methods

Methods of coating removal that involve water may or may not include abrasive. Several wet abrasive blast methods are described in SSPC-TR 2/NACE 6G198, "SSPC/NACE Joint Technical Report, Wet Abrasive Blast Cleaning." The standard for waterjetting without abrasives is the joint surface preparation standard SSPC-SP 12/NACE No. 5, "Surface Preparation and Cleaning of Metals by Waterjetting Prior to Coating." The joint consensus reference photographs are contained in SSPC-VIS 4/NACE VIS 7, "Guide and Consensus reference Photographs for Steel Surfaces Prepared by Waterjetting." SSPC and NACE restrict the terms "blast" or "blasting" to refer to processes that involve abrasives. If no abrasives are present, the preferred terms are cleaning or jetting.

In the past, the term "water blasting" has generically referred to the use of 34 to 170 MPa (5,000 to 25,000 psi) water for cleaning where abrasives may or may not be added. Currently in SSPC, the term "water blasting" indicates that an abrasive has been added to the water stream; it is not used as a defined term in either wet abrasive blast or waterjetting documents.

8.1 WATER CLEANING AND WATERJETTING (WITHOUT ABRASIVE): Contaminants can be removed from a surface with water at pressures from 0.1 to over 300 MPa (15 psi to 45,000 psi). Water cleaning in its most general sense is simply removal of surface contaminants such as dirt, soil, and salts from a surface with liquid water. The definitions of low, high, and ultra-high pressure and the use of "cleaning" compared to "jetting" are based on the nozzle pressure and are related to the water velocity. Pressures below 34 MPa (5,000 psi) are defined as low; pressures above 34 MPa (5,000 psi) are defined as high pressure. The term "jetting" is used when the velocity of the water exceeds 335 m/s (1100 ft/s). That condition occurs around 70 MPa (10,000 psi). The reader is cautioned that different sectors may use the terms "low, medium, or high" at other levels or velocities; for example ASTM E 1575 (Standard Practice for Pressure Water Cleaning and Cutting) uses the term "high" for anything above 6.9 MPa (1000 psi). See Table 7.

8.1.1 Degrees of Cleaning: Joint surface preparation standard SSPC-SP 12/NACE No. 5 (waterjetting) defines four degrees of visual cleaning based on the amount of VISIBLE contaminants remaining on the surface. SSPC-SP 12/NACE

No. 5 does not relate water pressure nor volume to the degree of visual cleaning.

The appearance of a surface cleaned by water can differ from that of a surface cleaned by abrasive blasting. If the coating to be removed is intact, the resultant surface will look like the original blasted surface, but darker and dull. If the coating is breached or there is rust to be removed, the surface can be mottled or very non-uniform. Every defect is revealed. The surface can show variation in texture, shade, color, tone, pitting, or flaking. A brown-black discoloration of ferric oxide can remain as a tightly adherent thin film on corroded or pitted steel.

Because water cleaning and waterjetting are used in maintenance cleaning, not on new steel, the coating manufacturer should be contacted for details of coating performance over residual paint, rust, and mill scale.

Water cleaning and waterjetting can remove soluble salts. Salts can adversely affect coating performance by causing underfilm corrosion or osmotic blistering. Some claim it may be useful to add a salt remover or rinse aid to achieve the desired nonvisual cleanliness. It is necessary to rinse from the surface any product used in cleaning to achieve the desired level of cleanliness. In all cases, it is recommended that surfaces be tested for nonvisible contaminants after washing and prior to coating to ensure compliance with recommended guidelines or specified limits. A corrosion inhibitor may be added to prevent the formation of flash rust.

8.1.2 Profile: Because waterjetting does not provide an anchor pattern needed for coating adhesion, water cleaning or waterjetting is used primarily for recoating or relining projects where there is an adequate preexisting profile. Water alone, under various pressures, can be used to remove coating materials, deleterious amounts of water-soluble surface contaminants, rust, shotcreting spatter, and surface grease and oil. It can not efficiently remove tight mill scale or tightly adherent magnetite. An existing profile under the paint or rust can be restored down to the bottom of the pits.

8.1.3 Water Consumption: Low pressure water cleaning (LP WC) is often called pressure washing or power washing. Pressure washing of an existing coating is done to remove salts and surface contaminants (chalk, dirt, etc.) prior to "cleaning" the surface for painting. Cleaning steel for coatings can be achieved with water pressures as great as 300 MPa (45,000 psi) or above and water volumes of only 6 to 55 liters (1.5 to 15

**TABLE 7
SSPC DEFINITIONS OF WATER CLEANING AND WATERJETTING**

Low-Pressure Water Cleaning (LP WC)	Less than 34 MPa (less than 5,000 psi)
High-Pressure Water Cleaning (HP WC)	34 to 70 MPa (5,000 to 10,000 psi)
High-Pressure Waterjetting (HP WJ)	70 to 210 MPa (10,000 to 30,000 psi)
Ultrahigh-Pressure Waterjetting (UHP WJ)	Over 210 MPa (30,000 psi)

gallons) per minute. While pressures up to 700 MPa (100,000 psi) are used commercially under controlled situations, in 2004 an upper limit of 340 MPa (50,000 psi) is being used in field cleaning equipment designed for the coatings industry. Caution must be maintained with water cleaning or waterjetting to avoid injuries to personnel and structures.

8.1.4 Equipment: The pumps, nozzles, and access equipment have evolved tremendously since 1990. Vacuum shrouds, remote controls, filtration, and collection, in both manual and non-manual systems, are available. The water stream can be combined with a vacuum system to remove the water from the surface immediately, thereby preventing flash rust. After filtration the water is then recycled. If effluent jetting water is captured for reuse in the jetting method, caution should be used to avoid introducing any contaminants of concern back to the cleaned substrate. Dust emissions are low because the particulates are wetted and do not disperse in the atmosphere. The environmental risk is low as long as the water is properly contained or collected. The rate of coating removal can approach or exceed that of dry abrasive blasting depending on the coating system and the complexity of the structure and project.

8.1.5 Flash Rust: Levels of flash rusting are defined in SSPC-VIS 4/NACE VIS 7, "Guide and Consensus reference Photographs for Steel Surfaces Prepared by Waterjetting." Flash rust and rust bloom are evaluated separately from visual cleanliness prior to recoating. If the surface is cleaned by waterjetting, the uniform rust bloom may not be a problem provided the desired nonvisible cleanliness is achieved and verified by testing. Section 8.3 is a more thorough discussion of flash rusting.

8.2 WET ABRASIVE BLAST CLEANING: The methods, equipment, and other features of wet abrasive blast cleaning are described in SSPC-TR 2/NACE 6G198, "Wet Abrasive Blast Cleaning." Two systems for wet abrasive blast cleaning are described: pressurized water/abrasive blasting, which uses water to propel the abrasive, and air/water/abrasive blasting, which uses compressed air to propel the abrasive. The system processes range from mostly abrasive with a small amount of water to mostly water with a small amount of abrasive.

Wet abrasive blasting is a process that can produce surface cleanliness and anchor patterns (surface roughness) similar to those obtained with dry abrasive blasting. The level of surface preparation specified is the same as if dry abrasive blasting was the process being used, that is SSPC-SP 5, SP 10, SP 6, SP 14, and SP 7. However, because the visual appearance of wet abrasive blasted surfaces is not necessarily the same as the visual appearance of dry abrasive blasted surfaces, inspectors should exercise care and judgment. SSPC-VIS 5/NACE VIS 9, "Guide and Consensus reference Photographs for Steel Surfaces Prepared by Wet Abrasive Blast Cleaning" is a separate visual guide for wet abrasive blasting. Acceptable variations in appearance that do not affect surface

cleanliness include variations caused by type of steel, original surface condition, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat affected zones, blasting abrasives, and differences due to blasting technique.

Surfaces cleaned by wet abrasive blasting typically appear darker and duller in appearance than surfaces cleaned with the same abrasive in dry abrasive blasting. Wide variations in appearance can be observed among abrasives within a given generic class. See SSPC-VIS 1 for illustrative photographs for dry blasting.

When the surface is still damp or wet, it will appear darker, and defects and variations in shading are magnified. As the surface dries, streaks will form which are not necessarily depicted in small unit size photographs, but which can be clearly seen on larger areas.

Wetted abrasive should be removed from the substrate after blasting. This is frequently accomplished with a low pressure water cleaning. Sometimes a soluble salt remover is added to the water. If rust back is of concern, an inhibitor can be added to the water. The coating manufacturer should confirm that the use of additives to the water will not effect coating performance.

8.2.1 Air/Water/Abrasive Blasting: Air/water/abrasive blasting is a cleaning method in which water is injected into the air/abrasive stream generated by conventional air-pressurized abrasive blasting equipment, or in which the premixed abrasive/water combination is forced into the blast air stream generated by a conventional air compressor. Other generic terms to describe specific air/water/abrasive blast cleaning methods are water shroud blasting, wet-head blasting, wet blasting, low volume water abrasive blasting, water induction nozzle (WIN), and slurry blasting.

Water helps to remove contaminants from the substrate, to wet the abrasive, and to substantially reduce dispersion of fine particulates (dust). Particulates are often caused by the breakup of the abrasives, surface corrosion products, and paint if the surface has been previously painted. Dust suppression is achieved by thoroughly wetting the abrasive and other particles to encapsulate them with a thin film of moisture. The objective is to suppress the dusting effect caused by the impact of the abrasive on the substrate, while retaining the blasting characteristics of dry abrasive, including creation of an anchor profile. The amount of water varies; removal of salts is a secondary objective.

The equipment used for wet abrasive blasting generally consists of conventional dry abrasive blasting equipment supplemented with modules to inject water into the abrasive stream, or specialized equipment that creates an abrasive/water slurry that is forced into the compressed blast air stream. Several methods exist for introducing water into the air stream. With radial water injectors (water rings), water induced nozzles, and coaxial water injectors, water is injected near the blast nozzle.

A hybrid process sometimes called AIWB, abrasive injected water blasting, was introduced after SSPC-TR 2/NACE 6G198

was published. This AIWB process mixes a conventional abrasive air stream with water jets up to 240 MPa (35,000 psi) at the nozzle. The volume of abrasive can be varied. It mixes a conventional abrasive air stream using 0.2 to 1.1 kg/min (0.5 to 2.5 pounds/min) with the water jet stream up to 240 MPa (35,000 psi) at the nozzle. It uses both a conventional fluid pump and a compressed air stream and produces a diffuse spread pattern.

With slurry blasters, the water is injected into the air/abrasive stream at some point substantially upstream from the blast nozzle or at the abrasive hopper, rather than at the nozzle. In the low volume, low pressure water abrasive blasting system (LV LP WB), four parts of abrasive are wetted with one part of water in a hopper. This slightly wetted abrasive slurry is carried in a conventional compressed air stream and produces results very similar to dry abrasive blasting. There is minimal water run-off.

8.2.2 Water/Abrasive Blast Cleaning: The methods, equipment, and other features of water/abrasive blast cleaning are described in SSPC-TR 2/NACE 6G198, "Wet Abrasive Blast Cleaning." Water/abrasive blast cleaning is a cleaning method in which abrasive is injected into the water stream generated by conventional fluid pumps. Other generic terms to describe specific water/abrasive blast cleaning methods are slurry blasting, abrasive water jet (AWJ), or abrasive injected waterjetting/blasting (AIWJ), abrasive injected ultra-high pressure (UHP AB), high pressure abrasive blast (HP AB); low pressure abrasive blast (LP AB).

The typical devices used for this method of cleaning consist of a fluid pump with a venturi nozzle of some type in which the water flow draws the abrasive into the water stream or the abrasive media is injected into the water stream under pressure. The addition of expendable abrasives to high pressure water jets improves the productivity of the technique, enables the removal of intact materials, and facilitates the creation of a surface profile.

Because the fluid stream is well defined, these devices usually cut a narrow blast pattern. The hybrid system described in 8.2.1, a rotating injection nozzle designed for pressure washers, and the UHP AB systems produce diffuse spread patterns.

8.3 FLASH RUST AND RUST BLOOM: 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. In 1991, G.C. Soltz reported that steel will not rust in 100% relative humidity if all of the salts are removed. [G.C. Soltz, "The Effects of Substrate Contaminants on the Life of Epoxy Coatings Submerged in Sea Water," National Shipbuilding Research Program, March 1991.] This is true, but when water condenses on the surface, the steel rusts. In practical terms, tap water, rainwater, pond water, and the

water that is typically found in nature or used for cleaning will contain soluble materials and dissolved oxygen. Soluble salt removers and/or inhibitors can be added to the water during the cleaning process to reduce the potential of flash rusting (see Section 8.4). The use of low conductivity water with the removal of all salts (as measured by field tests) will significantly reduce the amount of flash rust. The amount of flash rust also can be significantly reduced with the addition of forced air drying or use of a vacuum shroud which does not allow the water to remain on the surface as it is drying.

Flash rust and rust bloom are often used interchangeably. However, all rust bloom is not flash rust. Rust bloom is usually thought to be 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. The distinguishing feature of flash rust is that it occurs within minutes or hours of cleaning. Flash rusting can form quickly to change the initial appearance. It is not the rust itself, but the source of the re-rusting that is of concern to the coating manufacturers, as inert iron oxides (rust) are used as pigments. Very dark, splotchy rust spots which appear to be isolated in localized areas usually indicate that spots of salt contaminant are left in pits, under metal lips, or in crevices. These non-visible contaminants are found to be detrimental to coating performance. 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 rust bloom that can be tolerated in a given environment must be determined for each coating system by the coating manufacturer.

Flash rusting is not addressed in the dry abrasive blast cleaning standards except in the 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 contaminants have been left on the steel, which is generally not acceptable to the coatings manufacturers. G.C. Soltz has found that, for abrasive blasting, coating the surface before it has re-rusted is no assurance that the coating performance will not be compromised. [G.C. Soltz, "Understanding How Substrate Contaminants Affect the Performance of Epoxy Coatings & How To minimize Contamination," SSPC 1998 Proceedings, "Increasing the Value of Coatings", p 208-219.] The Journal of Protective Coatings and Linings (JPCL) has other articles published on this subject.

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," (92-08), found that coatings can perform quite well over a blasted surface that has a uniform rust bloom.

8.4 INHIBITORS AND SALT REMOVERS: To some extent, the surface preparation industry does not always distinguish clearly between rust inhibitors and salt removers. If salts are removed, the corrosion rate is reduced because the strength of the electrolyte in the corrosion cell is decreased. An inhibitor generally retards the reaction of oxygen or oxidizing agents with iron. Inhibitors and/or soluble salt removers can be added to the pressurized cleaning water or to a rinse water to temporarily prevent rust formation.

Environmental and health concerns in recent years have prompted changes in the chemistry of rust inhibitors. The chemical components of rust inhibitors includes polyphosphates, volatile amines, benzoates, nitrites, surface tension reducers, organic acids, chelating agents, and other proprietary compounds. These can also be included in the formulation of water-borne paints to reduce rust bloom. Additives containing soluble salts or film formers, while providing short-term protection, can adversely affect the long-term performance of the coating system.

Chemical rinse aids range from very acidic to neutral to basic. The product literature normally focuses on the perceived benefits of the materials, and not on the chemistry. The material safety data sheet will generally list the pH.

If an additive is used in the water, it is imperative that the coating manufacturer be queried about the compatibility of the coating with the water additive such as an inhibitor or soluble salt remover. Some coatings manufacturers will accept the compatibility process in ASTM D 5367, "Practice for Evaluating Coatings Applied over Surfaces Treated with Inhibitors Used to Prevent Flash Rusting of Steel When Water or Water/Abrasive Blasted." Other coatings manufacturers prefer their own in-house test methods. At the present time many coatings manufacturers prefer placing their coatings over a clean, light flash rust whose origin is not in question rather than adding the uncertainty of an inhibitor, chemical rinse aid, or soluble salt remover.

9. Other Cleaning Methods

9.1 CHEMICAL STRIPPING: Paint strippers are frequently used to remove paint from industrial structures. Alkaline strippers are more effective in removing oil-based paints, and solvent type strippers are more effective in removing latex paints. It may be necessary to use both types to strip alternating layers of oil and latex coatings from a surface. Strippers usually contain a thickener to provide more contact time for solvent or chemical attack on the paint. Some are covered with a sheet of plastic to increase the contact time. Chemical stripping is one method of removing old, lead-containing paint.

An alkaline (caustic) based or solvent based chemical stripper is applied to the surface using trowels, brushes, rollers, or spray application. After the specified dwell time, the stripper is removed using traditional scrapers, although water cleaning or ice blasting can be used. Mill scale and rust are not removed, and a profile is not generated, but an existing profile can be restored.

A relatively new class of chemical strippers are selective adhesion release agents (SARA) based on alcohol hydroxy-carboxylic acid peroxide (AHP). These are slow acting but are environmentally friendly. A permeable cloth can be placed on the ground at the base of the structure to collect the paint debris, while the stripper can be absorbed into the ground. SARA strippers do not work well on highly cross-linked novolac epoxies, rigid urethanes, and vinyl esters, but they are useful in removing alkyds, latexes, polyurethanes, epoxy esters, and amine and polyamide epoxies.

The specific type of stripper must be selected based upon the generic type of the existing coating system as well as health, safety, and environmental concerns. Some of the strippers require a minimum four hours set time while others may require two full days. In addition, many of the solvent strippers involve chemical reactions which generate heat. This heat must be contained in order for the chemical reaction to continue, which may require covers if ambient temperatures are too low. Many paint strippers are available for the complete immersion of painted surfaces, but these are generally specialty items.

Once the strippers have performed the desired softening of the existing coating system, they are frequently removed by a scraper. Water cleaning or ice blasting methods increase the volume of waste due to the addition of the water. Even for the removal of non-lead containing coatings, the resulting waste stream may be classified as hazardous due to either the caustic or the solvent component. Information on chemical stripping can be found in the technology update SSPC-TU 6, "Chemical Stripping of Organic Coatings from Steel Structures" and in Volume 1 of the SSPC Painting Manual.

9.2 SODIUM BICARBONATE (BAKING SODA) BLAST

CLEANING: A relatively new, low-dusting method of blast cleaning uses a slurry of water and sodium bicarbonate, a water soluble non-reactive salt, to remove paint from a surface. The portable unit can be wheeled from one location to another. Once in place, the system requires a source of compressed air (typically 600-700 kPa [85-100 psi] at the nozzle), clean water, and drainage. In most cases, special ventilation or dust collection is unnecessary. The operator can vary the angle of attack, standoff, and dwell time to strip layer by layer or all at once.

This blast medium is a formulation of sodium bicarbonate and is free from silica dusts and toxic fumes. The medium is claimed to be effective in:

- removing surface rust from screws and other metal parts without imbedding itself into the material being stripped
- removing coatings down to the metal or one layer at a time
- controlling layer removal, allowing for an extra measure of safety when used on galvanized or other specialty protected metals
- removing grease, oil, paint, and dirt from flat or contoured surfaces, cooling towers, motor parts, and hard-to-reach equipment parts.

This system was developed for removal of aircraft coatings and similar materials from surfaces which do not require "profiling". It also reduces dusting.

For blasting alone, productivity depends on the coating being removed and the degree of cleaning. Removal rates can be as high as 11 m²/h (120 ft²/h) for removal of thin deteriorated films. Removal of deteriorated thicker films may be much slower, on the order of 2 to 5 m²/h (20 to 50 ft²/h). Intact films may not be dislodged using sodium bicarbonate blasting. Sodium bicarbonate blasting is discussed in Volume 1 of the SSPC Painting Manual.

9.3 PLIANT MEDIA BLASTING (SPONGE JETTING):

Another low dusting method of cleaning, sponge jetting, involves the use of specialized blasting equipment that propels a manufactured urethane sponge against the surface to be cleaned. The sponge particles are approximately 3 to 6 mm (1/8 to 1/4 inch) in diameter and are available in a mild grade for degreasing and aggressive grades for paint or mill scale removal. The aggressive grades have the sponge formed around an abrasive. Abrasives include staurolite, garnet, and steel grit.

The productivity is lower than traditional abrasive blast cleaning (30-50% of the productivity), but typically will be higher than power tool cleaning to bare metal and vacuum blast cleaning. White metal quality of preparation is possible and a surface profile of approximately 50 micrometers (2 mils) can be achieved. The dust generated is low because the cells of the sponge help to suppress the dust, and the paint tends to be dislodged in larger chips rather than being pulverized, as is the case with traditional abrasive blast cleaning.

9.4 CARBON DIOXIDE (DRY ICE) BLASTING: In this dust free method, liquid carbon dioxide is formed into pellets of dry ice using specialized equipment. The CO₂ pellets are approximately the size of rice. The pellets are conveyed through a blast hose using compressed air in a manner similar to open abrasive blast cleaning. The pellets exit through a specialized nozzle assembly.

An advantage of CO₂ blasting is a reduction in the volume of debris created as the abrasive sublimates upon use. As a result, the waste involves only the paint being removed. Carbon dioxide is also non-conductive and will not create a spark, and therefore can be considered for use in areas where any sparking is unacceptable.

Disadvantages are that the abrasive does not appear to be hard enough to productively remove heavy coatings, rust, or mill scale. More than just stains of old primer will remain on the surface. Tight coatings are difficult to remove without frosting the surface. The equipment is also expensive. Carbon dioxide blast cleaning is discussed in more detail in Volume 1 of the SSPC Painting Manual.

9.5 ELECTROCHEMICAL STRIPPING: A very recent method of paint removal is electrochemical stripping. By applying cathodic current to a painted metal substrate, disbonding

of the coating is achieved. The benign electrolyte is contained in a liquid-absorbent material to which a counter electrode is attached. This combination, often combined with a liner, is applied to the painted metal surface, with magnets in the case of steel. If the paint is intact it must be scored to initiate current flow. After electrochemical treatment for 0.5 to 2 hours at 8 to 10 volts, the pads are removed and paint fragments are recovered. No particles become airborne making this method attractive for lead paint removal.

Banks of conducting pads may cover an area up to 14 m² (150 ft²) and can be run simultaneously. This method was developed particularly for application on highway structures to remove lead based alkyd-type coatings, but it may be employed for paint removal on other objects. Electrochemical stripping is discussed in more detail in Volume 1 of the SSPC Painting Manual.

10. Film Thickness

It is essential that ample coating be applied after blast cleaning to adequately cover and protect the peaks of the surface profile. The method of measuring dry film thickness (DFT) described in SSPC-PA 2, "Measurement of Dry Coating Thickness with Magnetic Gages," takes into account the effect of surface profile so that the measured DFT is approximately the thickness of the coating over the peaks. Thus, the depth of the surface profile should be considered in determining the amount of coating to be applied. For example, if a 50 micrometer (2 mil) DFT is desired, it will require a larger volume of paint to fill the valleys in a 75 micrometer (3 mil) profile than to fill the valleys in a 25 micrometer (1 mil) profile and still have 50 micrometers (2 mils) over the peaks. Because of the existence of rogue peaks, a greater coating thickness may need to be specified when coating deeper profiles.

11. Consensus Reference Photographs

Note that consensus reference photographs, when used in conjunction with SSPC surface preparation standards, give only an approximation of the final surface condition, because the consensus reference photographs are based on one specific set of steel conditions and cleaning operations. These conditions will not be identical to the conditions faced on other projects. It is cautioned, therefore, that any consensus reference photographs should be considered a supplement to, and not a substitute for, surface preparation standards. The use of consensus reference photographs in conjunction with SSPC standards is required only when they are specified in the procurement document covering the work. It is suggested, however, that consensus reference photographs be specified in the procurement document. Although they will not precisely match the appearance of the steel on every project, they 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 grades.

Even when consensus reference photographs are included in the procurement document, however, it must be recognized that the written standards prevail.

SSPC has consensus reference photographs for degrees of blast cleaning (SSPC-VIS 1), for the amount of rust on a painted 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 (SSPC-VIS 4 and VIS 5) or ASTM (SSPC-VIS 2). Other associations, such as ISO, as well as individual companies, have visual standards. The following sections summarize the SSPC consensus reference photographs.

11.1 SSPC-VIS 1, "GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY DRY ABRASIVE BLAST CLEANING": SSPC-VIS 1 provides standard consensus reference photographs for seven rust conditions (pre-blast conditions) and five degrees of blast cleaning thoroughness. End conditions corresponding to SSPC-SP 5, 6, 7, 10 and 14 are depicted over four initial unpainted conditions and three painted conditions. SSPC-VIS 1, which contains the actual photographs, is a separate publication (SSPC #02-12); however, a written "Guide to SSPC-VIS 1" is included in this volume. The appendix of SSPC-VIS 1 includes supplementary photographs depicting the appearance of white metal surfaces prepared from alternative non-metallic and metallic abrasives. Additional photographs show the effect of profile height, viewing angle, and diffusion of light.

11.2 SSPC-VIS 2, "STANDARD METHOD OF EVALUATING DEGREE OF RUSTING ON PAINTED STEEL SURFACES": This standard defines a rust grade scale which goes from 10 (no rust) to 0 (totally rusted). SSPC-VIS 2 defines three rust distributions:

- General Rust – consisting of various size rust spots randomly scattered over the surface
- Spot Rust – where the rusting is concentrated in a few large spots
- Pinpoint Rust – where each rust spot is very small and scattered across the surface.

SSPC-VIS 2 consists of 27 color photographs depicting rust grades 1 to 9 for each rust distribution. The photographs were subjected to computer analysis to ensure they illustrate the percentage of rust defined in the written standard. For each color photograph, there is a corresponding black and white image showing only the rusted area. The written description and the black and white images are contained in this volume, and are identical in technical content (though not format) to ASTM D 610. In addition to the text and the black and white images reproduced in this volume, the separate publication SSPC-VIS 2 includes a full color set of 27 photographs that show rust staining and represent a more realistic picture of the painted surface

11.3 SSPC-VIS 3, "GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY HAND AND POWER TOOL CLEANING": SSPC-VIS 3 provides consensus reference photographs for four grades of hand and power tool cleaning (SSPC-SP 2, 3, 11, and 15) of seven initial conditions of steel (four unpainted and three painted surfaces). The tools used to clean these surfaces include hand and power wire brushes, sanding discs, and non-woven abrasive discs. Needle guns and/or rotary flap peen assemblies were used to create the profile in the surfaces cleaned to SSPC-SP 11 and SP 15.

While a guide to the VIS 3 standard is included in this volume, the color photographs are only available as a separate supplement. Written standards are the primary means to determine conformance with cleaning requirements; photographs should not be used as a substitute for the written standards.

11.4 SSPC-VIS 4/NACE VIS 7, "GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY WATERJETTING": SSPC-VIS 4 provides consensus reference photographs for six rust conditions (pre-blast conditions) and four degrees of cleaning by waterjetting. End conditions corresponding to SSPC-SP 12: WJ-1, WJ-2, WJ-3, and WJ-4 are depicted over two initial unpainted conditions and four painted conditions. Three levels of flash rusting after cleaning are depicted for two initial rust conditions cleaned to two degrees of waterjetting cleanliness (WJ-2 and WJ-3). SSPC-VIS 4, which contains the color photographs, is a separate publication (SSPC #01-05); however, a written "Guide to SSPC-VIS 4" is included in this volume.

11.5 SSPC-VIS 5/NACE VIS 9, "GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY WET ABRASIVE BLAST CLEANING": SSPC-VIS 5 provides consensus reference photographs for two rust conditions (C and D) and two degrees of wet abrasive blast cleaning (SSPC-SP 6 and SP 10). Three levels of flash rusting after cleaning are depicted for the two initial rust conditions. SSPC-VIS 5, which contains the color photographs, is a separate publication (SSPC #01-06); however, a written "Guide to SSPC-VIS 5" is included in this volume.

11.6 ISO PICTORIAL STANDARDS: The International Organization for Standardization (ISO) in conjunction with Swedish Standards Institution (SIS) has issued a booklet of reference photographs (ISO 8501-1:1988/SIS SS 05 59 00) depicting the appearance of surfaces prepared by hand and power tool cleaning, abrasive blast cleaning (four degrees) and flame cleaning. The methods of cleaning are depicted over various rust grades of unpainted steel. ISO 8501-2 depicts a similar set of surfaces where the substrate was previously painted steel.

11.7 OTHER PHOTOGRAPHIC STANDARDS: The Production Technical Society (Japan) has printed color illustrations of wash primed and zinc-rich primed steel before

and after weathering and re-cleaning. The photographs of the Shipbuilding Association of Japan illustrate the appearance of painted, unpainted, welded, and flame-cut steel before and after various degrees of damage or weathering.

British standard BS 7079 Part A1 is equivalent to ISO 8501-1 (unpainted steel) and BS 7079 Part A2 is equivalent to ISO 8501-2 (previously painted steel).

11.8 PROJECT PREPARED STANDARDS: Prepared steel will often appear different from the photographic standards due to variations in initial surface conditions, abrasives being used, and so forth. Because of difficulties in comparisons, it is sometimes recommended that the contractor prepare blast cleaned samples representative of the steel to be blasted which, by mutual agreement of the owner and the contractor, are representative of the required surface cleanliness and appearance. Suggested dimensions of the reference steel panels are approximately 15 x 15 x 0.5 cm (6 x 6 x 3/16 inch) minimum. The blast cleaned panels should be completely protected from corrosion and contamination, and maintained as reference standards for the duration of the project. As an alternative to test panels, portions of the structure being prepared can be used.

12. Other SSPC Surface Preparation Documents in This Volume

12.1 SSPC-TR 1/NACE 6G194, "JOINT TECHNOLOGY REPORT ON THERMAL PRECLEANING": Thermal pre-cleaning is used in conjunction with other surface preparation methods, such as abrasive blast cleaning, to remove soluble salts from the pits of heavily corroded steel. The oil and gas industry as well as the rail car industry use thermal pre-cleaning extensively. This report describes the parameters used for dry heat and wet heat. It also lists methods for verifying the surface cleanliness.

12.2 SSPC-TR 2/NACE 6G198, "JOINT TECHNICAL REPORT ON WET ABRASIVE BLAST CLEANING": This document covers procedures, equipment, and materials involved in a variety of air/water/abrasive, water/abrasive, and water-pressurized abrasive blast cleaning systems. Various types of wet blast systems are described and compared. SSPC-TR 2 discusses selection of abrasives, water delivery systems, inhibitors, and equipment operation and maintenance. (See Section 8.2.)

12.3 SSPC-TU 2/NACE 6G197, "INFORMATIONAL REPORT AND TECHNOLOGY UPDATE: DESIGN, INSTALLATION, AND MAINTENANCE OF COATING SYSTEMS FOR CONCRETE USED IN SECONDARY CONTAINMENT": This report covers the design, installation, and maintenance of polymeric coating systems that are applied and directly bonded to concrete in secondary containment applications. This report is intended to inform manufacturers, specifiers, applicators, and

facility owners who are required to contain chemicals and/or protect concrete in these applications.

A chemical resistant coating is often applied to concrete to extend the service life of the secondary containment structure and properly contain the chemicals. This report focuses on those aspects of the design, materials, and procedures that are specific to coating for concrete in secondary containment applications, making reference to other publications when appropriate. While there are numerous successful commercial products and designs for containment of chemicals, this report focuses on concrete structures that are coated with thermoset polymer coating systems. Other potentially effective containment systems, such as acid-resistant brick and thermoplastic liners, are not described in this report.

12.4 SSPC-TU 4, "FIELD METHODS FOR RETRIEVAL AND ANALYSIS OF SOLUBLE SALTS ON SUBSTRATES":

This technology update describes methods for estimating the amount of soluble salt on a surface. Two types of retrieval methods, the cell method and the swabbing or washing method, are applicable to field retrieval. The "total" extraction method involves immersion of the surface in boiling water and, hence, is useful only in a laboratory.

SSPC-TU 4 gives detailed procedures for obtaining a liquid sample and for analyzing it to determine the level of soluble salt. Test kits are available to simplify the extraction and analysis. The SSPC standard on waterjetting, SSPC-SP 12, defines three levels of soluble salt contamination or non-visible surface cleanliness.

12.5 SSPC-TU 6, "CHEMICAL STRIPPING OF ORGANIC COATINGS FROM STEEL STRUCTURES":

This document defines chemical strippers and discusses their use for removing conventional organic coatings from steel structures. Chemical stripping involves application of a chemical to existing paint, allowing it to dwell for a period of time to attack the organic binder, removing bulk paint/stripper residues, and properly cleaning the steel substrate prior to repainting. This technology update describes methods used to identify the type of stripper that will work most effectively, and typical application and removal options. It also presents containment and disposal options for stripper wastes. Chemical stripping is also discussed in Volume 1 of the SSPC Painting Manual.

13. Non-SSPC Cleaning Standards

The recommendations, standards, and guides of a number of other associations reference the SSPC surface preparation standards, including: American Association of State Highway and Transportation Officials (AASHTO); American Institute of Steel Construction (AISC); American Iron and Steel Institute (AISI); American Petroleum Institute (API); American Railway Bridge and Building Association (ARBBA); American Water Works Association (AWWA); Canadian Institute of Steel Construction (CISC); Painting and Decorating Contractors of America (PDCA); Steel Plate Fabricators Association (SPFA);

and the Texas Structural Steel Institute (TSSI). They are also used by many state highway departments and other federal, state, and local agencies.

Governmental agencies have been active in preparing good surface preparation specifications, but most of these deal with thin metal and do not particularly apply to structures. The US Army Corps of Engineers Civil Works Division has issued CW-09940, "Guide Specifications for Painting Hydraulic Structures and Appurtenant Works." This specification covers the cleaning and treating of structural steel as well as the application of paint and the paints to be used. It makes use of the SSPC surface preparation standards.

Federal Specification TT-C-490, "Chemical Conversion Coatings and Pretreatments for Ferrous Surfaces (Base for Organic Coatings)," covers various types of surface preparation and pretreatments.

For internal use, the U.S. Department of the Navy, Naval Sea Systems Command, has prepared Chapter 631, "Preservation of Ships in Service (Surface Preparation and Painting) NAVSEA-S9086-VD-STM-OOOC/H-631," which includes surface preparation standards in addition to painting specifications and paint systems. Detailed specifications for pickling are included.

The International Organization for Standardization (ISO) has included written definitions and photographs depicting the appearance of uncoated steel surfaces cleaned by flame cleaning (ISO 8501-1:1988). This book also includes photographs for uncoated steel surfaces cleaned by hand and power tools and by abrasive blasting. A parallel standard ISO 8501-2 depicts degrees of cleaning over previously painted surfaces.

The British Standards Institution standard BS 7079:Parts A1 and A2, "Preparation of Steel Substrates Before Application of Paints and Related Products" is essentially equivalent to ISO 8501-1 and ISO 8501-2.

14. Surface Preparation of Concrete for Coating

14.1 INDUSTRY STANDARDS: There are several relatively new SSPC publications for surface preparation and coating of concrete included in this volume:

- SSPC-SP 13/NACE NO. 6, "Surface Preparation of Concrete"
- SSPC-TU 2/NACE 6G197, "Informational Report and Technology Update: Design, Installation, and Maintenance of Coating Systems for Concrete Used in Secondary Containment"
- SSPC-TR 5, "Design, Installation, and Maintenance of Protective Polymer Flooring Systems for Concrete"
- SSPC-PA 7, "Applying Thin Film Coatings to Concrete"
- SSPC-TU 10, "Procedures for Applying Thick Film Coatings and Surfacing Over Concrete Floors"
- SSPC publication #04-03 "Surface Preparation and Coating of Concrete" is a compilation of SSPC documents taken from Volumes 1 and 2 of the SSPC

Painting Manual, The Inspection of Coatings and Linings, and SSPC 2003 technical presentations.

The International Concrete Repair Institute (ICRI) has defined nine concrete profiles, thirteen methods of achieving them, and five different coating thickness ranges. ICRI has also developed a set of rubber replica specimens for the nine different profiles. These rubber replicas and the accompanying document, ICRI Guideline No. 03732, "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays," are available from SSPC. NACE and ASTM have also issued standards on surface preparation, repair, coating, and inspection of concrete. These are referenced in the SSPC documents listed above.

14.2 METHODS OF CLEANING CONCRETE: Concrete may be cleaned by many of the same methods used to clean steel for painting. However, care must be exercised so as not to damage the concrete surface. Concrete may be cleaned with detergent/power washing, alkaline or steam cleaning, chemical cleaning, abrasive blasting, high-pressure water cleaning, or mechanical cleaning with pneumatic tools, scarifiers, grinders, and scabblers. Efflorescence must be removed from cementitious surfaces by dry wire brushing or other mechanical means before any washing occurs. Water will merely dissolve the efflorescence and force it into the concrete.

15. Surface Preparation of Other Metallic Surfaces

15.1 ALUMINUM: Because aluminum is soft and chemically reactive, special precautions must be exercised when preparing an aluminum surface for painting. Chipping hammers and scrapers tend to gouge the soft aluminum. Wire brushes work well on aluminum, but they must have stainless steel bristles, not carbon steel or copper. Abrasive mats, paper, and cloths can be used to remove corrosion products or to feather the edges of intact paint. However, these materials should not be used on any other type of surface to prevent cross contamination of the aluminum. Aluminum wool may also be used for cleaning.

Abrasive blast cleaning can be performed on aluminum if the abrasive and blasting pressure are chosen correctly. The most common situations are 80-grit aluminum oxide (alumina, corundum, or emery) or garnet at 410 - 480 kPa (60 - 70 psi). Ferrous abrasives should never be used. Alternative media for cleaning aluminum include pliant media (sponges), plastic pellets, agricultural abrasives (corn cobs, walnut shells, peach pits), glass beads, sodium bicarbonate (baking soda), and carbon dioxide (dry ice). Chemical stripping has been used on aluminum in situations where blasting is not feasible. Care must be exercised to use a stripper that does not attack the aluminum.

Waterjetting provides another option for cleaning aluminum. Usually, if a profile is desired and an existing profile does not

exist, abrasive is added to the water. Because aluminum is a soft metal, high-end ultra-high pressure waterjetting can impart a profile without an abrasive, although it will appear differently from a profile created using abrasives.

15.2 STAINLESS STEEL: As with aluminum, care must be taken to avoid contaminating the stainless steel with carbon steel or iron. Hence, common steel shot and grit are not used to blast stainless steel. A hard non-metallic abrasive such as aluminum oxide or garnet is commonly used. Because stainless steel is hard, reducing the blast pressure is not necessary.

The most common painting problem associated with stainless steel is lack of adhesion. Some contribute this to the

protective oxide film that forms on the surface. A blast profile increases the effective surface area to promote chemical bonding. An acid-etching vinyl butyral wash primer, SSPC-Paint 27, is sometimes used to promote adhesion.

15.3 COPPER ALLOYS: Most copper, bronze, or copper alloy substrates come in the form of pipes, valves, pumps, strainers, heat exchangers, and statues. As with all metallic surfaces, solvent cleaning is the first step in surface preparation. Usually, the only method specified for these alloys is hand or power tool sanding using abrasive cloths, belts, or pads.