SSPC: The Society for Protective Coatings/NACE International

Joint Surface Preparation Standard

Waterjet Cleaning of Metals
SSPC-SP WJ-1/NACE WJ-1 – Clean To Bare Substrate

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Foreword

This SSPC/NACE joint standard defines the Clean to Bare Substrate (WJ-1) degree of surface cleanliness of coated or uncoated metallic substrates achieved by the use of waterjet cleaning prior to the application of a protective coating or lining. Waterjet cleaning is the use of pressurized surface preparation water for removing coatings and other materials, including hazardous materials, from a substrate to achieve a defined degree of surface cleanliness. Waterjet cleaning includes various methods such as low-pressure water cleaning (LP WC), high-pressure water cleaning (HP WC), high-pressure waterjetting (HP WJ), and ultrahigh-pressure waterjetting (UHP WJ).

The four degrees of surface cleanliness achieved by waterjet cleaning, which are addressed in separate standards, are as follows:

Degree of Surface Cleanliness	Designation
Clean to Bare Substrate	WJ-1
Very Thorough Cleaning	WJ-2
Thorough Cleaning	WJ-3
Light Cleaning	WJ-4

Clean to Bare Substrate (WJ-1) provides a greater degree of surface cleanliness than Very Thorough Cleaning (WJ-2).

Waterjet cleaning to achieve the Clean to Bare Substrate (WJ-1) degree of surface cleanliness is used when the objective is to remove every trace of rust and other corrosion products, coating, and mill scale. Discoloration of the surface may be present.

Waterjet cleaning does not provide the primary anchor pattern on the metallic substrate known as "surface profile." The coatings industry uses waterjet cleaning primarily for recoating or relining projects in which there is an adequate pre-existing surface profile. The degrees of surface cleanliness cited above to be achieved by waterjet cleaning methods are not intended to require that a surface profile be present or defined prior to coating application.

Waterjet cleaning reduces and may completely remove water-soluble surface contaminants, notably those contaminants found at the bottom of pits on the surface of corroded metallic substrates. Waterjet cleaning also helps remove oil, grease, rust and other corrosion products, and other foreign matter (for example, shotcrete spatter) from the surface, and is used when it is a more feasible method of surface preparation than, for example, abrasive blast cleaning, power or hand tool cleaning, or chemical stripping. Waterjet cleaning may be used when the application of high-performance coatings requires extensive surface preparation, surface decontamination, or both.

This standard is intended for use by coating or lining specifiers, applicators, inspectors, or others who have responsibility to define a standard degree of surface cleanliness to be achieved by waterjet cleaning methods.

This standard was prepared by SSPC/NACE Joint Task Group (TG) 275, "Surface Preparation of Metals to WJ-1 (Clean to Bare Substrate) by High-Pressure Waterjetting." TG 275 is administered by Specific Technology Group (STG) 04, "Coatings and Linings, Protective—Surface Preparation," and is sponsored by STG 02, "Coatings and Linings, Protective—Atmospheric," and STG 03, "Coatings and Linings, Protective—Immersion and Buried Service." This standard is issued by SSPC Group Committee C.2 on Surface Preparation, and by NACE under the auspices of STG 04. This standard is one of a set of four standards on degrees of surface cleanliness to be achieved by waterjet cleaning that are intended to replace SSPC-SP 12/NACE No. 5,[1] which includes all four degrees of surface cleanliness.

In SSPC/NACE standards, the terms *shall, must, should*, and *may* are used in accordance with Paragraph 2.2.1.8 of the Agreement between SSPC: The Society for Protective Coatings and NACE International. The terms *shall* and *must* are used to state mandatory requirements. The term *should* is used to state something considered good and is recommended, but is not mandatory. The term *may* is used to state something considered optional.

Section 1: General

1.1 This standard defines the Clean to Bare Substrate (WJ-1) degree of surface cleanliness of uncoated or coated metallic substrates by use of waterjet cleaning. The defined degree of cleanliness shall be achieved prior to the application of a specified protective coating or lining system. These requirements include the end condition of the surface and materials and procedures necessary to achieve and verify the end condition, as determined by visual inspection. This standard also may be used in situations in which the degree of cleanliness is required, but protective coatings or linings are not immediately applied. (Paragraphs A1 and A2 of Appendix A provide additional information.) Waterjet cleaning does not establish but may reveal an existing surface profile on a metallic substrate. If the existing surface profile is not acceptable for subsequent coating application, alternative surface preparation methods to create the required surface profile must be considered. (Paragraph A3 of Appendix A provides additional information.)

1.1.1 Clean to Bare Substrate (WJ-1) is the waterjet cleaning equivalent to the International Organization for Standardization (ISO)[(1)] 8501-1[2] degree of cleanliness Sa 3, cleaning to bare metal. ISO 8501-4[3] notes the use of various common terms for methods of waterjet cleaning: water jetting, water blast cleaning, hydrojetting, aquajetting, hydroblasting, aquablasting, and "cleaning by directing a jet of pressurized water onto the surface to be cleaned."

1.2 Although carbon steel is the metallic substrate most frequently cleaned in the field using waterjetting technology, waterjet cleaning may be used on metallic substrates other than carbon steel, including other ferrous substrates such as alloy steels, stainless steels, ductile iron and cast irons, nonferrous substrates such as aluminum, and copper alloys such as bronze. For convenience, the written definitions of the degrees of surface cleanliness of the metallic substrate use the general term "rust and other corrosion products." The term "rust" is intended to apply to carbon steel substrates and the term "other corrosion products" (such as surface oxides) is intended to apply to metallic substrates other than carbon steel that are being waterjet cleaned. "Flash rust" is an oxidation product that forms as a wetted carbon steel substrate dries. The visual guides and comparators referenced for cleanliness and flash rust only illustrate carbon steel substrates.

1.3 This standard does not address surface preparation of concrete. Information on surface preparation of concrete can be found in SSPC-SP 13/ NACE No. 6.[4]

1.4 This standard is limited to requirements for visible surface contaminants. Information on nonvisible contamination can be found in Paragraph A8 of Appendix A.

Section 2: Definitions

2.1 Clean to Bare Substrate (WJ-1): A metal surface after Clean to Bare Substrate, when viewed without magnification, shall have a matte (dull, mottled) finish and shall be free of all visible oil, grease, dirt, rust and other corrosion products, previous coatings, mill scale, and foreign matter.

2.1.1 Thin films of mill scale, rust and other corrosion products, and coating are not allowed. (Paragraphs A4 and A5 provide additional information).

(1) International Organization for Standardization (ISO), 1 ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland.

2.1.2 The gray to brown-black discoloration remaining on corroded and pitted carbon steel that cannot be removed by further waterjet cleaning is allowed.

2.1.3 SSPC-VIS 4/NACE VIS 7[5] or other visual guide or comparator may be specified to supplement the written definition. In any dispute, the written standard shall take precedence over the visual guide or comparator. (Paragraph A6 of Appendix A provides additional information.)

Section 3: Additional Technical Considerations

3.1 Flash Rust

Flash rust is an additional consideration when a carbon steel substrate is subjected to waterjet cleaning. Gray or brown-black discoloration remaining in the pits of waterjet cleaned carbon steel is not the same as flash rust. Metals other than carbon steel can manifest discoloration as well. Degrees of flash rust may be qualitatively described as follows:

3.1.1 No flash rust: A carbon steel surface that, when viewed without magnification, exhibits no visible flash rust.

3.1.2 Light (L) flash rusted surface: A carbon steel surface that, when viewed without magnification, exhibits small quantities of a rust layer through which the carbon steel substrate may be observed. The rust or discoloration may be evenly distributed or present in patches, but it is tightly adherent and not easily removed by lightly wiping with a cloth.

3.1.3 Moderate (M) flash rusted surface: A carbon steel surface that, when viewed without magnification, exhibits a layer of rust that obscures the original carbon steel surface. The rust layer may be evenly distributed or present in patches, but it is reasonably well adherent and leaves light marks on a cloth that is lightly wiped over the surface.

3.1.4 Heavy (H) flash rusted surface: A carbon steel surface that, when viewed without magnification, exhibits a layer of heavy rust that hides original carbon steel surface completely. The rust may be evenly distributed or present in patches, but it is loosely adherent, easily comes off, and leaves significant marks on a cloth that is lightly wiped over the surface.

(Paragraphs A6, A9, and A10 of Appendix A provide additional information. Appendix B provides additional information on methods of assessing the degree of flash rust.)

3.2 Appearance Variations

3.2.1 Acceptable variations in appearance that do not affect the degree of surface cleanliness defined in Paragraph 2.1 include variations caused by composition of the metallic substrate, original surface condition, thickness of the metal, weld metal, mill or fabrication marks, heat treating, heat-affected zones, and differences resulting from the initial abrasive blast cleaning abrasives or the abrasive blast pattern if previously blast cleaned, or waterjet cleaning pattern.

3.2.1.1 Carbon steel surfaces cleaned by waterjet cleaning initially exhibit a matte finish with a color that can range from light gray to dark brown-black but immediately acquires a golden hue unless a corrosion inhibitor or environmental controls are used. The matte finish on older carbon steel surfaces that have areas from which coating was removed and areas that were coating-free at the time of cleaning varies even when all visible surface material has been removed.

3.2.2 Metallic substrates show variations in texture, shade, color, tone, pitting, flaking, and mill scale that should be considered during the waterjet cleaning process. (Paragraph A6 of Appendix A provides additional information.)

3.2.3 Direct correlation to existing dry abrasive blasting standards and visual comparators is inaccurate or inappropriate.

Section 4: Associated Documents

4.1 Documents associated with this standard and cited in its mandatory sections include:

Document	Title
SSPC-SP 5/NACE No. 1[6]	“White Metal Blast Cleaning”
SSPC-SP 13/NACE No. 6	“Surface Preparation of Concrete”
SSPC-VIS 4/NACE VIS 7	“Guide and Visual Reference Photographs for Steel Cleaned by Waterjetting”
SSPC-SP 1[7]	“Solvent Cleaning”

4.2 If there is a conflict between the requirements of any of the documents listed in Paragraph 4.1 and this standard, the requirements of this standard shall govern.

Section 5: Procedures Before Waterjet Cleaning

5.1 Precleaning: Visible deposits of oil, grease, foreign matter, and other contaminants shall be removed by waterjet cleaning, by methods in accordance with SSPC-SP 1, or as specified. (Paragraphs A4, A5, and A10 of Appendix A and Paragraph C2.6 of Appendix C provide additional information.)

5.2 Prior to beginning waterjet cleaning, surface imperfections such as sharp fins, sharp edges, weld spatter, or burning slag shall be addressed to the extent required by the procurement documents (project specifications). (Paragraph A12 of Appendix A provides additional information.)

5.3 CAUTION: Waterjet cleaning can be destructive to nonmetallic surfaces. Wood, rubber, insulation, electric installations, instrumentation, etc., must be protected from direct and indirect impingement of water streams.

5.4 If a visual guide or comparator is specified to supplement the written standard, the condition of the substrate prior to waterjet cleaning should be determined before the waterjet cleaning commences. (Paragraph A6 of Appendix A provides additional information.)

Section 6: Waterjet Cleaning Methods

6.1 Any of the following waterjet cleaning methods may be used to achieve the Clean to Bare Substrate (WJ-1) degree of surface cleanliness. These waterjet cleaning methods all require the use of surface preparation water (hereinafter referred to as "SP water") in accordance with Paragraph 6.2. The presence of toxic metals in a coating being removed can place restrictions on the methods of cleaning permitted. The chosen method shall comply with applicable regulations. (Paragraph A13 of Appendix A and Paragraph C2.3 of Appendix C provide additional information.)

6.1.1 Water cleaning (WC): Use of pressurized SP water discharged from a nozzle to remove unwanted matter from a surface.

6.1.1.1 Low-pressure water cleaning (LP WC): Water cleaning performed at pressures less than 34 MPa (5,000 psig). This is also called "power washing" or "pressure washing."

6.1.1.2 High-pressure water cleaning (HP WC): Water cleaning performed at pressures from 34 to 70 MPa (5,000 to 10,000 psig).

6.1.2 Waterjetting (WJ): Use of SP water discharged from a nozzle at pressures of 70 MPa (10,000 psig) or greater to prepare a surface for coating or inspection. The velocity of the SP water exiting the orifice is greater than 340 m/s (1,100 ft/s).

6.1.2.1 High-pressure waterjetting (HP WJ): Waterjetting performed at pressures from 70 to 210 MPa (10,000 to 30,000 psig).

6.1.2.2 Ultrahigh-pressure waterjetting (UHP WJ): Waterjetting performed at pressures greater than 210 MPa (30,000 psig).

6.2 Surface preparation water (SP water): Water of sufficient purity and quality that it does not prevent the surface being cleaned from achieving the WJ-1 degree of surface cleanliness or nonvisible contamination criteria when contained in the procurement documents. SP water should not contain sediments or other impurities that are destructive to the proper functioning of the cleaning equipment. (Paragraph A7 of Appendix A provides additional information.)

Section 7: Procedures Following Waterjet Cleaning and Immediately Prior to Coating

7.1 Visible deposits of oil, grease, foreign matter, and other contaminants shall be removed by waterjet cleaning, by methods in accordance with SSPC-SP 1, or as specified. (Paragraphs A4, A5, A10, and A11 of Appendix A and Paragraph C2.6 of Appendix C provide additional information.)

7.2 The existing surface profile shall be assessed to determine conformance with the requirements of the procurement documents. (Paragraphs A3 and A14 of Appendix A provide additional information.)

7.3 Immediately prior to coating application, the entire surface shall comply with the degree of surface cleanliness specified herein, and to the extent established, the procurement document (project specification) requirements, and degree of flash rust.

7.4 Flash rust shall be mitigated in accordance with the requirements of the procurement documents. An example of a specification statement is provided in Paragraph A10 of Appendix A. It is common practice to remove heavy flash rust by LP WC, HP WC, or dry abrasive sweep blasting.

7.5 Dust and loose residues shall be removed from cleaned surfaces by brushing; blowing off with clean, dry air; vacuum cleaning; or other specified methods. Moisture separators, oil separators, traps, or other equipment may be necessary to achieve clean, dry air. (Paragraph A13 of Appendix A provides additional information.)

References

1. SSPC-SP 12/NACE No. 5 (latest revision), "Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating" (Pittsburgh, PA: SSPC, and Houston, TX: NACE).

2. ISO 8501-1 (latest revision), "Preparation of steel substrates before application of paints and related products—Visual assessment of surface cleanliness—Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings" (Geneva, Switzerland: ISO).

3. ISO 8501-4 (latest revision), "Preparation of steel substrates before application of paints and related products—Visual assessment of surface cleanliness—Part 4: "Initial surface conditions, preparation grades and flash rust grades in connection with high-pressure water jetting" (Geneva, Switzerland: ISO).

4. SSPC-SP 13/NACE No. 6 (latest revision), "Surface Preparation of Concrete" (Pittsburgh, PA: SSPC, and Houston, TX: NACE).

5. SSPC-VIS 4/NACE VIS 7 (latest revision), “Guide and Visual Reference Photographs for Steel Cleaned by Waterjetting” (Pittsburgh, PA: SSPC, and Houston, TX: NACE).

6. SSPC-SP 5/NACE No. 1 (latest revision), “White Metal Blast Cleaning” (Pittsburgh, PA: SSPC, and Houston, TX: NACE).

7. SSPC-SP 1 (latest revision), “Solvent Cleaning” (Pittsburgh, PA: SSPC).

8. SSPC-PA Guide 4 (latest revision), “Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems” (Pittsburgh, PA: SSPC).

9. SSPC-Guide 15 (latest revision), “Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates” (Pittsburgh, PA: SSPC).

10. SSPC-SP COM (latest revision), “Surface Preparation Commentary for Steel and Concrete Substrates” (Pittsburgh, PA: SSPC).

11. NACE SP0178 (formerly RP0178) (latest revision), “Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service” (Houston, TX: NACE).

12. SSPC-PA 2 (latest revision), “Measurement of Dry Coating Thickness with Magnetic Gages” (Pittsburgh, PA: SSPC).

13. “Recommended Guidelines for Evaluating Flash Rust” (Charleston, SC: National Shipbuilding Research Program [NSRP],[2] 2009). (Available from SSPC and NACE.)

14. ISO 8502-3 (latest revision), “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)” (Geneva, Switzerland: ISO).

15. ASTM[3] D 3359 (latest revision), “Standard Test Methods for Measuring Adhesion by Tape Test” (West Conshohocken, PA: ASTM).

16. “Recommended Practices for the Use of Manually Operated High-Pressure Waterjetting Equipment” (latest revision) (St. Louis, MO: WaterJet Technology Association [WJTA]).[4]

17. D.A. Summers, WaterJetting Technology (London, UK: Chapman and Hall, 1995).

18. SSPC-Guide 6 (latest revision), “Guide for Containing Debris Generated During Paint Removal Operations” (Pittsburgh, PA: SSPC).

Appendix A: Explanatory Notes (Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the the provisions herein.

A1 Function: Clean to Bare Substrate (WJ-1) provides a greater degree of surface cleanliness than Very Thorough Cleaning (WJ-2). The hierarchy of waterjet cleaning standards is as follows: WJ-1, WJ-2, WJ-3, and WJ-4. Clean to Bare Substrate (WJ-1) should be used when the highest degree of cleaning is required. The primary functions of waterjet cleaning before coating are:

(a) To remove material from the surface that can cause early failure of the coating system;
(b) To enhance the adhesion of the new coating system;
(c) To expose the surface profile of the substrate that is underneath the existing coating or rust and other corrosion products. (Paragraph A3 provides additional information.); and
(d) To reduce or remove nonvisible contamination.

Clean to Bare Substrate (WJ-1) is used when the objective is to remove every trace of the coating, mill scale, and rust and other corrosion products, and when the extra effort required to remove all of these materials is determined to be warranted. Discoloration of the metal substrate surface may be present. Waterjet cleaning reduces and may completely remove water-soluble surface contaminants, notably those contaminants found at the bottom of pits on the surface of corroded metallic substrates.

A2 Maintenance Coating Work: When this standard is used in maintenance coating work, specific instructions should be provided on the extent of surface to be waterjet cleaned or spot-waterjet cleaned to this degree of surface cleanliness. In these cases, the surface cleanliness should be achieved across the entire area specified. For example, if all weld seams are to be cleaned in a maintenance operation, the degree of surface cleanliness applies to 100 percent of all weld seams. If the entire structure is to be cleaned, this degree of surface cleanliness applies to 100 percent of the entire structure. SSPC-PA Guide 4[8] provides a description of accepted practices for retaining old sound coating, removing unsound coating, feathering, and spot cleaning.

A3 Surface Profile: Waterjet cleaning reveals the surface profile (roughness) of the substrate that exists under the original coatings or rust and other corrosion products. When a coating is specified, another surface preparation method may

[2] National Shipbuilding Research Program (NSRP), Advanced Technology International (ATI), 5300 International Blvd., Charleston, SC 29418-6937.
[3] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.
[4] WaterJet Technology Association (WJTA), 906 Olive St., Suite 1200, St. Louis, MO 63101-1448.

be needed in addition to the waterjet cleaning to achieve the surface profile suitable for the specified coating system.

A4 Rust Scale: If rust scale is present, it must be removed. Rust scale is not a suitable substrate over which to apply coatings, and, if not removed, may also prevent removal of water-soluble salts that may accelerate corrosion. Methods other than waterjet cleaning may be used.

A5 Mill Scale: Mill scale is not allowed in this degree of surface cleanliness. Mill scale is that dark blue-black layer of iron oxide on the surface of hot-rolled steel. Over time, the adherence of the mill scale can change. Older mill scale might be removed easily in the field with waterjetting at 100 MPa (15,000 psi) and above. Waterjetting at pressures greater than 240 MPa (35,000 psig) is capable of removing tightly adherent mill scale, but production rates are not always cost effective. When the mill scale comes off, the steel surface under the mill scale has whatever surface profile is under the mill scale.

A6 Reference Photographs: Photographs may be specified to supplement the written definition. SSPC VIS 4/NACE VIS 7 depicts various precleaning conditions and the appearance of a carbon steel surface that is consistent with the Clean to Bare Substrate (WJ-1) degree of surface cleanliness defined in this standard. In any dispute, the written standard shall take precedence over the visual guide. The visual appearance of carbon steel that has heavily flash rusted after initial waterjet cleaning and is then recleaned by LP WC has a different appearance from the original light flash-rusted steel depicted in SSPC VIS 4/NACE VIS 7.

A7 Quality of Water: SP water used by waterjet cleaning equipment should be clean and free of erosive silts or other contaminants that damage pump valves and/or prevent the surface from achieving the specified degree of surface cleanliness. A general rule is that the cleaner the water, the longer the service life of the waterjet cleaning equipment. The use of deionized water may be detrimental to some water pumps and care should be taken to ensure compatibility.

A8 Nonvisible Contamination (NV)

A8.1 Nonvisible contamination (NV): Nonvisible contamination is the presence of organic matter, such as thin films of oil and grease, and inorganic and/or soluble ionic materials such as chlorides, ferrous salts, nitrates, and sulfates that may be present on the substrate. (Paragraphs A6, A7, and A8 provide additional information.)

A8.2 Steel contaminated with water-soluble salts (e.g., sodium chloride and potassium sulfate) rapidly develops rust-back. Rust-back can be minimized by removing these salts from the steel surface and eliminating sources of recontamination during and after cleaning. These contaminants, along with their concentrations, may be identified using laboratory and field tests as described in SSPC Guide 15.[9] Conductivity measurement is another method for testing for water-soluble salts.

A8.3 Other nonvisible contaminants (e.g., oil, acid, base, silicone, wax) may have an effect on coating performance. Coatings manufacturers should be consulted for recommendations of maximum surface contamination allowed. The specifier should determine what level of nonvisible contaminants may remain.

A8.4 The test method or procedure to be used for determining the level of remaining nonvisible contaminants should be addressed in the procurement documents (project specification).

A8.5 The level of nonvisible contaminants found in an extraction from the surface that may remain on the surface is usually expressed as mass per unit area; for example, $\mu g/cm^2$ or mg/m^2 ($1\ \mu g/cm^2 = 10\ mg/m^2$).

A8.6 The following is an example specification for salt contamination based on concentration measurements:

"Immediately prior to the application of the coating, the surface extract shall not contain more than xx $\mu g/cm^2$ of the specific contaminant (e.g., chloride) when tested with a specified method."

A8.7 The following is an example specification for salt contamination based on conductivity measurements:

"Immediately prior to the application of the coating, the conductivity of the surface extract shall not exceed xx $\mu S/cm$ when tested with a specified method."

A9 Use of Corrosion Inhibitors: It may be advantageous to add corrosion inhibitors to the SP water or apply them to the surface immediately after waterjet cleaning to temporarily prevent rust formation. Some corrosion inhibitor treatments may interfere with the performance of certain coatings systems. The coatings manufacturer should be consulted to ensure the compatibility of corrosion inhibitors with the coatings.

A10 Specification Statement:

A10.1 The specifier should use the degree of surface cleanliness and one of the degrees of flash rust to specify the required end condition. The following are examples of a specification statement:

"All surfaces to be recoated shall be waterjet cleaned to SSPC-SP WJ-1 L/NACE WJ-1/L, Clean to Bare Substrate, Light Flash Rust."

"At the time of the recoating, the degree of flash rust shall be no greater than moderate (M)."

A10.2 In addition, the specifier should consider whether a surface should be cleaned as required to achieve a particular, not to exceed maximum, level of nonvisible contamination (NV) prior to recoating. A suggested specification statement for nonvisible contamination (NV) is given in Paragraph A8.

A11 Flash Rust: An oxidation product that forms as a wetted carbon steel substrate dries. With the exception of stainless steel surfaces, any steel surface may show flash rust within 30 minutes or longer while the substrate is drying (water evaporation) after waterjet cleaning, depending on environmental conditions. Flash rust has the appearance of rust bloom. Flash rust quickly changes the appearance of the waterjet cleaned surface and may be reduced or eliminated by physical or chemical methods. The color of the flash rust may vary depending on the age and composition of the steel and the time-of-wetness of the substrate prior to drying. With time, the flash rust changes from a yellow-brown, well adherent, light rust to a red-brown, loosely adherent, heavy rust. Appendix B contains additional information on methods of assessing the degree of flash rust.

A12 Surface Imperfections:

A12.1 Surface imperfections that can cause premature failure are often present. Coatings tend to pull away from sharp edges and projections, leaving little or no coating to protect the underlying steel. Other features that are difficult to properly cover and protect include crevices, weld porosities, and laminations.

A12.2 Poorly adhering fabrication defects, such as weld slag residues, loose weld spatter, and surface laminations may be removed during the waterjet cleaning operation. Other surface defects, such as steel laminations, weld porosities, or deep corrosion pits may not be evident until the surface preparation has been completed. Therefore, proper planning for such surface repair work should be given prior consideration because the timing of the repairs may occur before, during, or after the waterjet cleaning operation. The SSPC-SP COM[10] and NACE SP0178[11] contain additional information on surface imperfections.

A12.3 The high cost of the methods to remedy surface imperfections (e.g., edge rounding and weld spatter removal) should be compared with the benefits of preventing premature coating failure. Therefore, those responsible for establishing the requirements and those responsible for performing the work should agree on the procedures to be used to repair surface imperfections to the extent required in the procurement documents (project specification).

A13 Removal of Coatings with Hazardous Components—Hygiene: Waterjet cleaning is often used to remove coatings with hazardous components. Because the particles are wetted, respiratory protection requirements for waterjet cleaning may be less stringent than for other methods of surface preparation. However, the wetted particles tend to stay on the skin. Applicable industrial hygiene tests should be performed to determine the destination of the wetted particles. Good industrial hygiene should be followed.

A14 Film Thickness: It is essential that ample coating be applied after waterjet cleaning to adequately cover the peaks of the surface profile. The dry film thickness of the coating above the peaks of the surface profile should equal the thickness known to be needed for the desired protection. If the dry film thickness over the peaks is inadequate, premature rust-through or coating failure will occur. To ensure that coating thicknesses are properly measured, the procedures in SSPC-PA 2[12] for verification of accuracy of Type 1 and Type 2 gauges should be used.

Appendix B: Methods of Assessing the Degree of Flash Rust (Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the the provisions herein.

The degree of flash rust is related to the quantity of loose, clean rust dust that is present on the surface. One of the following alternative methods may be used to assess the degree of flash rust, or other methods may be used if specified.

B1 Wipe Test

The following procedure is suggested to standardize the amount of pressure used to perform a wipe test on a flash-rusted surface:

(a) Neatly wrap a white, lint-free, woven cloth around a standard 100 mm (4 in) nylon paint brush, and hold it in place in a manner that prevents the cloth from slipping.
(b) Swipe the cloth-wrapped paint brush across the flash-rusted surface in one motion, using pressure equivalent to that used to apply house paint to a door. The length of the swipe should be consistent (e.g., one pass covering 1,500 mm [6 in] in length).
(c) Remove the white cloth from the paint brush and evaluate the color and amount of rust on the cloth. “Recommended Guidelines for Evaluating Flash Rust,”[13] issued by the NSRP, provides guidance to perform this evaluation of flash rust.

If lint deposition is a concern, the project specification may require use of an alternate technique to determine the degree of flash rust.

B2 Tape Pull Test

The tape pull test is a modification of the pressure-sensitive tape method in ISO 8502-3.[14] The procedure is as follows:

(a) Select a test area on the flash-rusted surface to perform the test.
(b) Place a 50 mm (2 in) long piece of tape (as specified in ASTM D 3359[15]) on the selected test area and rub it thoroughly with a fingertip (not a fingernail) to ensure that the tape adheres firmly. Then peel the tape off

the surface and place it on a piece of white paper for reference.

(c) Repeat the procedure in (b) nine times (for a total of 10 times) using a fresh piece of tape applied to the same spot on the surface (selected test area) each time.

(d) Assess the appearance of the 10th tape and the appearance of the test area on the flash-rusted surface after the 10th tape is pulled off in accordance with Table B1.

Appendix C: Waterjet Cleaning Equipment and Operating Parameters (Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the the provisions herein.

C1 Waterjet Cleaning Equipment

Multiple configurations of pumps, heads, and containment systems are suitable for waterjet cleaning operations. The equipment systems may include manual lances, fixed lances on platforms, or robot-driven systems. Additional descriptions relevant to waterjet cleaning systems are in the WaterJet Technology Association's "Recommended Practices for the Use of Manually Operated High-Pressure Waterjetting Equipment,"[16] which also addresses concerns relevant to waterjet cleaning operations. The commercial waterjet cleaning unit can be mounted on a skid, trailer, or truck; can be equipped with various prime movers (diesel, electric motor, etc.); and usually consists of a pump, hoses, and various tools. The tools can be hand-held or mounted on a robot or controlled by a traversing mechanism. Water is propelled through a single jet, fan jet, pulse generator, or multiple rotating jets. Rotation of the nozzle head is provided by small electric, air, or hydraulic motors, or by slightly inclined orifices in a multiple-orifice nozzle.

C1.1 All waterjet cleaning units normally use a hydraulic hose with a minimum bursting strength of 2.5 times the capability of its maximum-rated operating strength.

C1.2 Waterjet streams are produced by orifices, or tips, that can have different forms–the higher the pressure, the more limited is the choice of forms. Round jets are most commonly used, but orifices of other shapes are available. Tips can be designed to produce multiple jets of water that are normally rotated to achieve higher material-removal rates. Interchangeable nozzle tips should be used to produce the desired streams. The manufacturer should be consulted for specific recommendations.

C1.3 Effect of Corrosion Inhibitors and Detergents on Equipment: If corrosion inhibitors are to be used with the SP water, the manufacturer of the waterjet cleaning equipment should be consulted to ensure compatibility of corrosion inhibitors with the equipment. Compatibility of detergents with the special seals and high-alloy metals of the waterjet cleaning equipment should be carefully investigated to ensure that the cleaning equipment is not damaged.

C2 Operating Parameters

C2.1 Waterjet Cleaning Method Selection: The person performing the work should have sufficient experience to select the waterjet cleaning method and the specific combination of water pressure and flow (velocity and volume) to achieve the specified degree of surface cleanliness. A water flow rate of 4 to 53 L/min (1 to 14 gal/min) is typical.

(a) LP WC or HP WC (the flow rate of the water is the dominant energy characteristic);

(b HP WJ (pressure or water velocity and flow rate are equally important); or

(c) UHP WJ (pressure or water velocity is the dominant energy characteristic).

C2.2 Stand-off Distance: The distance from the nozzle to the work piece surface (stand-off distance) is critical for effective cleaning with any of the waterjet cleaning methods. Typical stand-off distances for HP WJ and UHP WJ range from 25 to 150 mm (1.0 to 6.0 in) for coatings removal. Typical stand-off distances range up to 600 mm (24 in) to remove foreign matter that is not tightly adherent. Excessive stand-off distance does not produce the desired cleaning.

TABLE B1
ASSESSMENT OF DEGREE OF FLASH RUST—TAPE PULL TEST

Degree of Flash Rust	Appearance of 10th Tape (after final pull from test area)	Appearance of Test Area (after 10th tape pull)
Light	No rust on tape	No change, or only slight change in test area appearance
Moderate	Slight, localized red-brown rust on tape	Significant change of test area appearance, showing localized areas of black rust
Heavy	Significant, uniform red-brown rust on tape, also showing grains of black rust	Significant change of test area appearance, showing localized areas of black rust

C2.3 Threshold Pressure: The threshold pressure of a coating can be determined. In general, the tougher, more resilient, or harder the coating (i.e., the more resistant to probing or cutting by a pocket knife), the higher the threshold pressure; the softer and more jelly-like the coating, the lower the threshold pressure. Threshold pressure is defined by Summers[17] as the minimum required pressure to penetrate the material. Once the threshold pressure is achieved or exceeded, the production rate increases dramatically. Therefore, waterjet cleaning production rates can be classified according to two conditions:

(a) Relatively Slow—Erosion at pressures lower than the threshold pressure; and
(b) Relatively Fast—Waterjet cutting and erosion at pressures greater than the threshold pressure.

Pressure loss is a function of the flow rate of the water through the hose and the inside diameter of the hose. The manufacturer should be consulted for specific information on potential pressure loss for each type of equipment.

C2.4 Depending on the initial condition of the area and the materials to be removed, the choice of waterjet cleaning method to achieve Clean to Bare Substrate (WJ-1) is ultimately based on the capabilities of the equipment and its components. Dwell time, traverse rate, pressure, flow, stand-off distances, the number of nozzles, and rotation speed all interact in determining materials that remain and those that are removed.

C2.5 Reuse of Effluent Water: If effluent water is captured for reuse by the waterjet cleaning equipment, caution should be used to avoid introducing any removed contaminants back onto the cleaned substrate. The effluent water may be placed in a clean holding tank and tested to determine the contaminant content prior to reintroduction into the water supply stream to the waterjet cleaning equipment. The effluent water should be monitored for suspended particulates, hydrocarbons, salts, hazardous materials, or other by-products of the surface preparation procedures.

C2.6 Additives: Any detergents, degreasers, or other types of cleaners used in conjunction with the waterjet cleaning method should be removed prior to applying a coating. If corrosion inhibitors are to be used with the SP water, the coating manufacturer should be consulted to ensure compatibility of corrosion inhibitors with the coating.

C2.7 Containment Systems: Containment systems may consist of water-impermeable membranes or vacuum collection heads or the systems described in SSPC-Guide 6.[18] The containment design should consider the pressures used and water volumes produced and if the process may be open or closed loop (with a single pass or multiple passes of the water through the system).