Joint Surface Preparation Standard

SSPC-SP 12/NACE No. 5
Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating

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Foreword

This joint standard describes the surface preparation technique known as waterjetting. This technique provides an alternative method of removing coating systems or other materials from metal surfaces, including lead-based paint systems, prior to the application of a protective coating or lining system. This standard is intended for use by coating or lining specifiers, applicators, inspectors, or others whose responsibility it may be to define a standard degree of surface cleanliness. Since publication of NACE Standard RP0172,[1] surface preparation using waterjetting equipment has found acceptance as a viable method.

Waterjetting can be effective in removing water-soluble surface contaminants that may not be removed by dry abrasive blasting alone, specifically, those contaminants found at the bottom of pits of severely corroded metallic substrates. Waterjetting also helps to remove surface grease and oil, rust, shot-creting spatter, and existing coatings and linings. Waterjetting is also used in areas where abrasive blasting is not a feasible method of surface preparation.

The use of a high-pressure water stream to strip existing coatings and clean the surface has advantages over open dry abrasive blasting with respect to worker respiratory exposure and work area air quality. Respiratory requirements for waterjetting may be less stringent than for other methods of surface preparation.

Waterjetting does not provide the primary anchor pattern on steel known to the coatings industry as “profile.” The coatings industry uses waterjetting primarily for recoating or relining projects in which there is an adequate preexisting profile. Waterjetting has application in a broad spectrum of industries. It is used when high-performance coatings require extensive surface preparation and/or surface decontamination.

This standard was originally prepared by SSPC/NACE Joint Task Group TGD. It was technically revised in 2002 by Task Group 001 on Surface Preparation by High-Pressure Waterjetting. This Task Group is administered by Specific Technology Group (STG) 04 on Protective Coatings and Linings—Surface Preparation, and is sponsored by STG 02 on Protective Coatings and Linings—Atmospheric, and STG 03 on Protective Coatings and Linings—Immersion/Buried. This standard is issued by SSPC Group Committee C.2 on Surface Preparation, and by NACE International under the auspices of STG 04.

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Section 1: General

1.1 This standard describes the use of waterjetting to achieve a defined degree of cleaning of surfaces prior to the application of a protective coating or lining system. These requirements include the end condition of the surface plus materials and procedures necessary to verify the end condition. This standard is limited in scope to the use of water only.

1.2 This standard is written primarily for applications in which the substrate is carbon steel. However, waterjetting can be used on nonferrous substrates such as bronze, aluminum, and other metals such as stainless steel. This standard does not address the cleaning of concrete. Cleaning of concrete is discussed in SSPC SP-13/NACE No. 6.[2]

1.3 Appendices A, B, and C give additional information on waterjetting equipment, production rates, procedures, and principles.

1.4 Visual Reference Photographs: SSPC-VIS 4/NACE VIS 7, "Guide and Reference Photographs for Steel Surfaces Prepared by Waterjetting,"[3] provides color photographs for the various grades of surface preparation as a function of the initial condition of the steel. The latest issue of the reference photographs should be used.

Section 2: Definitions

2.1 This section provides basic waterjetting definitions. Additional definitions relevant to waterjetting are contained in the WaterJet Technology Association's[(1)] "Recommended Practices for the Use of Manually Operated High-Pressure Waterjetting Equipment."[4]

2.1.1 **Waterjetting (WJ):** Use of standard jetting water discharged from a nozzle at pressures of 70 MPa (10,000 psig) or greater to prepare a surface for coating or inspection. Waterjetting uses a pressurized stream of water with a velocity that is greater than 340 m/s (1,100 ft/s) when exiting the orifice. Waterjetting does not produce an etch or profile of the magnitude currently recognized by the coatings industry. Rather, it exposes the original abrasive-blasted surface profile if one exists.

2.1.2 **Water Cleaning (WC):** Use of pressurized water discharged from a nozzle to remove unwanted matter from a surface.

2.1.3 **Standard Jetting Water:** Water of sufficient purity and quality that it does not impose additional contaminants on the surface being cleaned and does not contain sediments or other impurities that are destructive to the proper functioning of waterjetting equipment.

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

2.1.5 **High-Pressure Water Cleaning (HP WC):** Water cleaning performed at pressures from 34 to 70 MPa (5,000 to 10,000 psig).

2.1.6 **High-Pressure Waterjetting (HP WJ):** Waterjetting performed at pressures from 70 to 210 MPa (10,000 to 30,000 psig).

2.1.7 **Ultrahigh-Pressure Waterjetting (UHP WJ):** Waterjetting performed at pressures above 210 MPa (30,000 psig).

2.1.8 **Nonvisible Contamination (NV):** Nonvisible contamination is the presence of organic matter, such as very thin films of oil and grease, and/or soluble ionic materials such as chlorides, ferrous salts, and sulfates that remain on the substrate after cleaning.

2.1.9 **Visible Surface Cleanliness (VC):** Visible surface cleanliness is the visible condition of the substrate, when viewed without magnification, after cleaning.

Section 3: Surface Cleanliness Requirements

3.1 Table 1 lists four definitions of surface cleanliness in terms of visible contaminants. A surface shall be prepared to one of these four visual conditions prior to recoating.

3.1.1 As part of the surface preparation, deposits of oil, grease, and foreign matter must be removed by waterjetting, by water cleaning, by steam cleaning, by methods in accordance with SSPC-SP 1,[5] or by

[(1)] WaterJet Technology Association, 917 Locust Street, Suite 1100, St. Louis, MO 63101-1419.

another method agreed upon by the contracting parties.

3.1.2 NOTE: Direct correlation to existing dry media blasting standards is inaccurate or inappropriate when describing the capabilities of water cleaning and the visible results achieved by water cleaning.

3.1.3 The entire surface to be prepared for coating shall be subjected to the cleaning method.

3.1.4 For WJ-4 (see Table 1) any remaining mill scale, rust, coating, or foreign materials shall be tightly adherent. All of the underlying metal need not be exposed.

3.1.5 Photographs may be specified to supplement the written definition. In any dispute, the written standards shall take precedence over visual reference photographs or visual standards such as SSPC-VIS 4/NACE VIS 7.[3]

3.2 Table 2 lists definitions of flash rusted surfaces (See Section 4). When deemed necessary, a surface should be prepared to one of these flash rusted surface conditions prior to recoating.

3.3 The specifier shall use one of the visual surface preparation definitions (WJ-1 to WJ-4 in Table 1) and, when deemed necessary, one of the flash rust definitions.

3.3.1 The following is an example of a specification statement:

"All surfaces to be recoated shall be cleaned to SSPC-SP 12/NACE No. 5, WJ-2/L, Very Thorough or Substantial Cleaning, Light Flash Rusting."

3.4 Appendix A contains information on nonvisible surface contaminants. In addition to the requirements given in Paragraph 3.1, the specifier should consider whether a surface should be prepared not to exceed the maximum level of nonvisible surface contamination prior to recoating. A suggested specification statement for nonvisible contaminants is given in Appendix A.

Table 1: Visual Surface Preparation Definitions

Term	Description of Surface
WJ-1	**Clean to Bare Substrate:** A WJ-1 surface shall be cleaned to a finish which, when viewed without magnification, is free of all visible rust, dirt, previous coatings, mill scale, and foreign matter. Discoloration of the surface may be present.[(A, B, C)]
WJ-2	**Very Thorough or Substantial Cleaning:** A WJ-2 surface shall be cleaned to a matte (dull, mottled) finish which, when viewed without magnification, is free of all visible oil, grease, dirt, and rust except for randomly dispersed stains of rust, tightly adherent thin coatings, and other tightly adherent foreign matter. The staining or tightly adherent matter is limited to a maximum of 5% of the surface.[(A, B, C)]
WJ-3	**Thorough Cleaning:** A WJ-3 surface shall be cleaned to a matte (dull, mottled) finish which, when viewed without magnification, is free of all visible oil, grease, dirt, and rust except for randomly dispersed stains of rust, tightly adherent thin coatings, and other tightly adherent foreign matter. The staining or tightly adherent matter is limited to a maximum of 33% of the surface.[(A, B, C)]
WJ-4	**Light Cleaning:** A WJ-4 surface shall be cleaned to a finish which, when viewed without magnification, is free of all visible oil, grease, dirt, dust, loose mill scale, loose rust, and loose coating. Any residual material shall be tightly adherent.[(C)]

[(A)] Surfaces cleaned by LP WC, HP WC, HP WJ, or UHP WJ do not exhibit the hue of a dry abrasive blasted steel surface. After waterjetting, the matte finish color of clean steel surface immediately turns to a golden hue unless an inhibitor is used or environmental controls are employed.[6] On older steel surfaces that have areas of coating and areas that are coating-free, the matte finish color varies even though all visible surface material has been removed. Color variations in steel can range from light gray to dark brown/black.

Steel surfaces show variations in texture, shade, color, tone, pitting, flaking, and mill scale that should be considered during the cleaning process. Acceptable variations in appearance that do not affect surface cleanliness include variations caused by type of steel or other metals, original surface condition, thickness of the steel, weld metal, mill fabrication marks, heat treating, heat-affected zones, and differences in the initial abrasive blast cleaning or in the waterjet cleaning pattern.

The gray or brown-to-black discoloration seen on corroded and pitted steel after waterjetting cannot be removed by further waterjetting. A brown-black discoloration of ferric oxide may remain as a tightly adherent thin film on corroded and pitted steel and is not considered part of the percentage staining.

[(B)] Waterjetting at pressures in excess of 240 MPa (35,000 psig) is capable of removing tightly adherent mill scale, but production rates are not always cost effective.

[(C)] Mill scale, rust, and coating are considered tightly adherent if they cannot be removed by lifting with a dull putty knife. (See SSPC-SP 7/NACE No. 4,[7]).

Section 4: Flash Rusted Surface Requirements

4.1 Table 2 lists four definitions of flash rusted surface requirements. *Flash rust* or *water bloom* is a light oxidation of the steel that occurs as waterjetted carbon steel dries. With the exception of stainless steel surfaces, any steel surface may show flash rust within 0.5 to 2 hours, or longer depending on environmental conditions, after cleaning by water. Flash rust quickly changes the appearance. Flash rust may be reduced or eliminated by physical or chemical methods. The color of the flash rust may vary depending on the age and composition of the steel and the time-of-wetness of the substrate prior to drying. With time, the flash rust changes from a yellow-brown, well adherent, light rust to a red-brown, loosely adherent, heavy rust.

4.2 It is a common practice to remove heavy flash rust by low-pressure water cleaning. The visual appearance of steel that has heavily flash rusted after initial cleaning and is then recleaned by low-pressure water cleaning (up to 34 MPa [5,000 psig]) has a different appearance than the original light flash rusted steel depicted in SSPC-VIS 4/NACE VIS 7.

4.3 The coating manufacturer should be consulted to ascertain the tolerance of the candidate coatings to visual cleanliness, nonvisible contaminants, and the amount of flash rust commensurate with the in-service application. These conditions should be present at the time of recoating.

4.4 The following is an example of a specification statement concerning flash rust:

"At the time of the recoating, the amount of flash rust shall be no greater than moderate (M) as defined in SSPC-SP 12/NACE No. 5."

Table 2: Flash Rusted Surface Definitions

Term	Description of Surface
No Flash Rust	A steel surface which, when viewed without magnification, exhibits no visible flash rust.
Light (L)	A surface which, when viewed without magnification, exhibits small quantities of a yellow-brown rust layer through which the steel substrate may be observed. The rust or discoloration may be evenly distributed or present in patches, but it is tightly adherent and not easily removed by lightly wiping with a cloth.
Moderate (M)	A surface which, when viewed without magnification, exhibits a layer of yellow-brown rust that obscures the original steel surface. The rust layer may be evenly distributed or present in patches, but it is reasonably well adherent and leaves light marks on a cloth that is lightly wiped over the surface.
Heavy (H)	A surface which, when viewed without magnification, exhibits a layer of heavy red-brown rust that hides the initial surface condition completely. The rust may be evenly distributed or present in patches, but the rust is loosely adherent, easily comes off, and leaves significant marks on a cloth that is lightly wiped over the surface.

Section 5: Occupational and Environmental Requirements

5.1 Because waterjet cleaning is a hazardous operation, all work shall be conducted in compliance with all applicable occupational health and safety rules and environmental regulations.

Section 6: Cautionary Notes

6.1 Waterjetting can be destructive to nonmetallic surfaces. Soft wood, insulation, electric installations, and instrumentation must be protected from direct and indirect water streams.

6.2 Water used in waterjetting units must be clean and free of erosive silts or other contaminants that damage pump valves and/or leave deposits on the surface being cleaned. The cleaner the water, the longer the service life of the waterjetting equipment.

6.3 Any detergents or other types of cleaners used in conjunction with waterjetting shall be removed from surfaces prior to applying a coating.

6.4 Compatibility of the detergents with the special seals and high-alloy metals of the waterjetting equipment must be carefully investigated to ensure that WJ machines are not damaged.

6.5 If inhibitors are to be used with the standard jetting water, the manufacturer of the waterjetting equipment shall be consulted to ensure compatibility of inhibitors with the equipment.

6.6 The coatings manufacturer shall be consulted to ensure the compatibility of inhibitors with the coatings.

6.7 If effluent jetting water is captured for reuse in the jetting method, caution should be used to avoid introducing any removed contaminants back to the cleaned substrate. The effluent water should be treated to remove suspended particulate, hydrocarbons, chlorides, hazardous materials, or other by-products of the surface preparation procedures. The water should be placed in a clean water holding tank and tested to determine the content of possible contamination prior to reintroduction into the jetting stream. If detergents or degreasers are used prior to surface preparation, these waste streams should be segregated from the effluent jetting water to avoid contamination and possible equipment damage.

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3. SSPC-VIS 4/NACE VIS 7 (latest revision), "Guide and Reference Photographs for Steel Surfaces Prepared by Water-jetting" (Pittsburgh, PA: SSPC, and Houston, TX: NACE).

4. "Recommended Practices for the Use of Manually Operated High-Pressure Waterjetting Equipment," (St. Louis, MO: WaterJet Technology Association, 1987).

5. SSPC-SP 1 (latest revision), "Solvent Cleaning" (Pittsburgh, PA: SSPC).

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8. NACE Publication 6G186 (withdrawn), "Surface Preparation of Contaminated Steel Structures" (Houston, TX: NACE). (Available from NACE as an historical document only.)

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[(2)] International Organization for Standardization (ISO), 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.
[(3)] Federal Highway Administration (FHWA), 400 7th St. SW, Washington, DC 20590.
[(4)] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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NOTE: Appendices A, B, and C provide explanatory notes. They provide additional information on waterjetting.

Appendix A: Surface Cleanliness Conditions of Nonvisible Contaminants and Procedures for Extracting and Analyzing Soluble Salts

A1.1 For the purpose of this appendix, the list of non-visible contaminants is limited to water-soluble chlorides, iron-soluble salts, and sulfates. The contracting parties should be aware that other nonvisible contaminants may have an effect on the coating performance.[8] The specifier should determine whether, and to what condition, nonvisible chemical contaminants should be specified. Section 3 contains additional information on surface cleanliness conditions.

A1.2 The level of nonvisible contaminants that may remain on the surface is usually expressed as mass per unit area, for example, $\mu g/cm^2$ (grains/in.^{2}) or mg/m^2 (grains/yd^2) (1 $\mu g/cm^2$ = 10 mg/m^2 = 0.0001 grains/in.^{2} = 0.13 grains/yd^2).

A1.3 Coatings manufacturers should be consulted for recommendations of maximum surface contamination allowed. The specification should read as follows:

> "Immediately prior to the application of the coating, the surface shall not contain more than xx $\mu g/cm^2$ (grains/in.^{2}) of the specific contaminant (e.g., chloride) when tested with a specified method as agreed upon by contracting parties."

A1.4 The contracting parties shall agree on the test method or procedure to be used for determining the level of nonvisible contaminants.

Note: NACE and ISO committees are currently (2002) developing recommendations for the level of nonvisible contaminants that may be tolerated by different types of coatings in various services.

Table A1: Description of Nonvisible Surface Cleanliness Definitions[(A)] (NV)

Term	Description of Surface
NV-1	An NV-1 surface shall be free of detectable levels of soluble contaminants, as verified by field or laboratory analysis using reliable, reproducible test methods.
NV-2	An NV-2 surface shall have less than 7 $\mu g/cm^2$ (0.0007 grains/in.^{2}) of chloride contaminants, less than 10 $\mu g/cm^2$ (0.001 grains/in.^{2}) of soluble ferrous ion levels, or less than 17 $\mu g/cm^2$ (0.0017 grains/in.^{2}) of sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test methods.
NV-3	An NV-3 surface shall have less than 50 $\mu g/cm^2$ (0.005 grains/in.^{2}) of chloride or sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test methods.

[(A)] Additional information on suitable procedures for extracting and analyzing soluble salts is available in NACE Publication 6G186,[8] and SSPC-TU 4.[9]

A2.1 Procedure for Extracting Soluble Salts by Swabbing

The following procedures may be used to extract the soluble salts from the surface:

(a) SSPC Swabbing Method[9]
(b) Procedure described in ISO 8502-5, Section 5.1, "Washing of the Test Area"[10]
(c) Any suitable controlled washing procedures available and agreed to by the contracting parties. During the washing procedure, clean plastic or rubber gloves should be worn to ensure that the wash water is not accidentally contaminated.

A2.2 Procedure for Extracting Soluble Salts by Surface Cells

(a) Limpet Cell Method[11]
(b) Surface Conductivity Cell Method[9,11]
(c) Nonrigid Extraction Cell Method[9,11,12]

A2.3 Procedure for Field Analysis of Chloride Ions

The extract retrieved using the procedures in Paragraphs A2.1 and A2.2 may be analyzed using one of the following methods:

(a) Chloride Chemical Test Strips[9]
(b) Chloride Chemical Titration Kit[9]
(c) Ion Detection Tube Method[9,10]

The following laboratory method is available as a referee method:

(a) Specific Chloride Ion Electrode[9,11,13]

A2.4 Procedure for Field Analysis of Sulfate Ions

The extract retrieved using the procedures in Paragraphs A2.1 and A2.2 may be analyzed using one of the following methods:

(a) Turbidity Field Comparator Methods[9, 11]
(b) Turbidity Method[9,11]
(c) Standard Test Method for Sulfate Ion in Water[14]

A2.5 Procedure for Field Analysis of Soluble Iron Salts

The extract retrieved using the procedures in Paragraph A2.1 or A2.2 may be analyzed using one of the following methods:

(a) Ferrous Chemical Test Strips[9,11]
(b) Semiquantitative Test for Ferrous Ions[8]
(c) Field Colorimetric Comparator Methods

A2.5.1 Papers treated with potassium ferricyanide may be used for the qualitative field detection of ferrous ions.[8,9]

Appendix B: Waterjetting Equipment

B1.1 The commercial waterjet unit can be mounted on a skid, trailer, or truck; can be equipped with various prime movers (diesel, electric motor, etc.); and usually consists of a pump, hoses, and various tools. The tools can be hand-held or mounted on a robot (or traversing mechanism). Water is propelled through a single jet, a fan jet, or multiple rotating jets. Rotation is provided by small electric, air, or hydraulic motors, or by slightly inclined orifices in a multiple-orifice nozzle.

B1.2 The units operate at pressures up to 240 to 290 MPa (35,000 to 42,000 psig), using a hydraulic hose with a minimum bursting strength of 2.5 times the capability of its maximum-rated operating strength.

B1.3 A water flow rate of 4 to 53 L/min (1 to 14 gal/min) is typical.

B1.4 Pressure loss is a function of the flow rate of the water through the hose and the inside diameter of the hose. The manufacturer should be consulted for specific information on potential pressure loss for each type of equipment.

B1.5 Waterjets are produced by orifices, or tips, that can have different forms. The higher the pressure, the more limited is the choice of forms. Round jets are most commonly used, but orifices of other shapes are available. Tips can be designed to produce multiple jets of water that are normally rotated to achieve higher material removal rates. Interchangeable nozzle tips should be used to produce the desired streams. The manufacturer shall be consulted for specific recommendations.

B1.6 The distance from the nozzle to the work piece substrate (standoff distance) is critical for effective cleaning with any of the water methods. Excessive standoff does not produce the desired cleaning.

Appendix C: Principles of Waterjetting

SSPC-SP 12/NACE No. 5 is a performance specification, not a process specification. Appendix C is not intended to be used as an equipment specification.

C1 Commentary on Production Rates

C1.1 Operator skill and the condition of the steel surface affect waterjetting production rates.[15,16,17] Regardless of the surface conditions, production rates usually improve when:

(a) The operator gains additional experience with high- and ultrahigh-pressure waterjetting; or

(b) Mechanized, automated waterjetting equipment is used.

C1.1.1 New metal with tightly adhering mill scale requires the highest level of operator skill and concentration to produce a clean surface by waterjetting. Older, more corroded, or previously coated surfaces require an average level of skill and concentration to achieve desired results. This is the opposite of abrasive blasting, when poor surface conditions require the highest levels of operator skill and concentration.

C1.2 As a general rule, production and ease of removal increase as the waterjetting pressure increases.

C1.3 Cleanup time to remove waste material should be considered when determining the overall production rate.

C2 Commentary on Waterjetting Parameters

C2.1 The specifier should describe the final condition of the substrate. Depending on the initial condition of the area and materials to be cleaned, the method to achieve Visible Conditions WJ-1, WJ-2, WJ-3, or WJ-4 may be LP WC, HP WC, HP WJ, or UHP WJ. The method of water cleaning or waterjetting ultimately is based on the capabilities of the equipment and its components. Dwell time, transverse rate, pressure, flow, stand-off distances, the number of nozzles, and rotation speed all interact in determining what material will remain and what will be removed.

C2.2 There are two thoughts on increasing production rates during the removal of materials by pressurized water. First, determine the threshold pressure at which the material will just be removed. The user can then either increase the flow to achieve adequate production rates or increase the pressure by a factor no greater than three over the threshold pressure. These two methods do not necessarily yield the same result.[18]

C2.3 Details of the calculations in Table C1 are standard to the waterjetting industry and are beyond the scope of this standard.[19]

C2.4 Removal of degraded coating is coupled to thorough stressing of the remaining coating. The jet energy is the work done when the jet stream vertically impacts the coating surface. Energy is normally measured in kilojoules. The shear stress is developed against the vertical pit walls and larger fractures created on the eroded coating surface. This can, in gross terms, be thought of as a hydraulic load.

C2.5 Flexure stressing is induced by repetitive loading and unloading of the coatings systems by the jet streams as they pass over the surface. The rapid loading and unloading is vital to finding areas of low adherence and nonvisible adherence defects in the coating system.[19]

C2.6 Characteristics of typical pressurized water systems are included in Table C1.

Table C1: Typical Pressurized Water Systems

Pressure at Nozzle	70 MPa (10,000 psig)	140 MPa (20,000 psig)	280 MPa (40,000 psig)
Number of Tips	2	2	5
Diameter	1.0 mm (0.040 in.)	0.69 mm (0.027 in.)	0.28 mm (0.011 in.)
Flow	12.9 L/min (3.42 gpm)	8.3 L/min (2.2 gpm)	2.0 L/min (0.52 gpm)
Cross-Sectional Area	0.81 mm^2 (0.0013 $in.^2$)	0.37 mm^2 (0.00060 $in.^2$)	0.065 mm^2 (0.00010 $in.^2$)
Jet Velocity	360 m/s (1,180 ft/s)	520 m/s (1,700 ft/s)	730 m/s (2,400 ft/s)
Impact Force (per tip)	8.1 kg (18 lb)	7.7 kg (17 lb)	2.4 kg (5.3 lb)
Jet Energy	141 kJ (134 BTU)	189 kJ (179 BTU)	89 kJ (81 BTU)
Energy Intensity (energy/ cross-sectional area)	175 kJ/mm^2 (107,000 $BTU/in.^2$)	513 kJ/mm^2 (314,000 $BTU/in.^2$)	1,401 kJ/mm^2 (857,000 $BTU/in.^2$)

C2.7 In field terms, the 70-MPa (10,000-psig) jets may not significantly erode the coatings. Therefore, they are typically used for partial removal or for cleaning loose detrital material. The 140-MPa (20,000-psig) jets erode the coatings fairly rapidly and are typically used for partial removal. The 280-MPa (40,000-psig) jets erode and destroy coatings very fast and are typically used when most or all of the coating is to be removed (WJ-1 or WJ-2).

C2.8 Application judgment is employed by operators or users who make the decisions concerning which type of jetting water to use:

(a) HP WC (the water's flow rate is the predominant energy characteristic);

(b) HP WJ (pressure [i.e., the velocity of the water] and flow rate are equally important); or

(c) UHP WJ (the pressure [i.e., the velocity of the water] is the dominant energy characteristic).

C2.9 As water passes through the orifice, potential energy (pressure) is converted to kinetic energy. The energy increases linearly with the mass flow, but increases with the square of the velocity, as shown in Equation (C1).

$$Kinetic\ Energy = \frac{1}{2}mv^2 \qquad \text{(C1)}$$

where

m = mass (derived from water volume)
v = velocity (derived from pressure)

In order to calculate the kinetic energy from flow rates and velocity, a time period must be selected. A time period of 10 milliseconds is used for Equation (C1).

C2.10 The threshold pressure[5] of a coating must also be determined. In general, the tougher or harder the coating (i.e., the more resistant to testing by a pocket knife), the higher the threshold pressure; the softer and more jelly-like the coating, the lower the threshold pressure.

C2.10.1 Once the threshold pressure is achieved or exceeded, the production rate increases dramatically. Therefore, waterjetting production rates are affected by two conditions:

(a) Erosion at pressures lower than the threshold pressure, and

(b) Waterjet cutting and erosion at pressures greater than the threshold pressure.

[5] *Threshold pressure* is defined as the minimum pressure required to penetrate the material.[20]