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Joint Surface Preparation Standard
NACE No. 5/SSPC-SP 12

Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating

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Foreword

Since publication of NACE Standard RP0172, "Surface Preparation of Steel and Other Hard Materials by Water Blasting Prior to Coating or Recoating," surface preparation using water jetting equipment has found acceptance as a viable method. The coatings industry, under the influence of government regulations, is working to find environmentally sensitive and user-friendly methods of surface preparation. The use of a high-energy water stream to strip existing coatings and for surface cleaning has advantages over dry abrasive blasting with respect to worker respiratory exposure and work area air quality. Respiratory requirements for water jetting may be less stringent than for other methods of surface preparation.

Abrasive blasting, one of the most common surface preparation techniques, is sometimes not feasible or desirable because the resultant flying abrasive particles and drifting dust may damage highly sensitive rotary equipment and filters, cause contamination of nearby mechanical equipment and structures, or cause contamination of the environment. Abrasive blasting may also trap contaminants within the topography. This standard describes the surface preparation technique known as water jetting, which provides an alternative method of removing coating systems, including lead-based paint systems. Water jetting is effective in removing (1) deleterious amounts of water-soluble surface contaminants that may not otherwise be removed by dry abrasive blasting alone, specifically in the bottom of pits and craters of severely corroded metallic substrates; (2) surface grease and oil; (3) rust; (4) shot-creting spatter; and (5) existing coatings and linings. Cold working of the topography of the surface does not occur in water jetting. Because water jetting does not provide the primary anchor pattern known to the coatings industry, this standard recommends its use primarily for recoating or relining projects where there is an adequate preexisting profile.

This standard addresses degrees of cleanliness, types of equipment, operating procedures, and safety factors associated with water jetting. Although this standard discusses jetting pressures up to 250 MPa[(1)] (36,000 psi), higher pressures may be used as technology and equipment evolve. High-pressure water jetting has application in a broad spectrum of industry; however, its use as described in this standard is particularly suited to the process industry, power plants, and other industrial plants where the use of high-performance coatings requires extensive surface preparation and/or surface decontamination.

This standard was prepared by NACE/SSPC Joint Task Group D on Surface Preparation by High-Pressure Water Jetting and is issued by NACE International under the auspices of NACE Group Committee T-6 on Protective Coatings and Linings and by the Steel Structures Painting Council. This standard replaces NACE Standard RP0172, "Surface Preparation of Steel and Other Hard Materials by Water Blasting Prior to Coating or Recoating," and addresses current technology and equipment for high-pressure water cleaning, including water jetting.

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(1) 1 MPa = 10 bar

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Contents

Section 1: General

1.1 This standard provides requirements for the use of high- and ultrahigh-pressure water jetting to achieve various degrees of surface cleanliness. This standard is limited in scope to the use of water only without the addition of solid particles in the stream.

1.2 Information on water jetting equipment, production rates, procedures, and principles is available in the appendices. Appendices A, B, C, D, E, F, and G do not provide requirements but give additional information on water jetting that will be useful to the owner, user, or contractor.

Section 2: Definitions

2.1 This section provides basic water jetting definitions. Additional definitions relevant to water jetting are contained in "Recommended Practices for the Use of Manually Operated High-Pressure Water Jetting Equipment."[2]

2.1.1 **Water Jetting (WJ)**: Water jetting is the use of standard jetting water at high or ultrahigh pressure to prepare a surface for recoating using pressures above 70 MPa (10,000 psi). Water jetting will not produce an etch or profile of the magnitude currently recognized by the surface preparation industry; rather, it exposes the original abrasive-blasted surface profile.

2.1.2 **Standard Jetting Water**: Standard jetting water is water of sufficient purity and quality that it does not impose additional contaminants on the surface being cleaned and, of critical importance to water jetting operations, does not contain sediments or other impurities that are destructive to the proper functioning of the water jetting equipment being used.

2.1.3 **Low-Pressure Water Cleaning (LP WC)**: LP WC is cleaning performed at pressures less than 34 MPa (5,000 psi).

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

2.1.5 **High-Pressure Water Jetting (HP WJ)**: HP WJ is cleaning performed at pressures from 70 to 170 MPa (10,000 to 25,000 psi).

2.1.6 **Ultrahigh-Pressure Water Jetting (UHP WJ)**: UHP WJ is cleaning performed at pressures above 170 MPa (25,000 psi).

2.1.7 **Surface Cleanliness (SC)**: Surface cleanliness is the condition of the substrate after water jetting has removed partial or total residues of chloride, soluble ferrous salts, and sulfate contaminants.

Section 3: Surface Cleanliness Conditions

3.1 Table 1 lists four conditions of surface cleanliness in terms of **visible** contaminants. A surface shall be prepared to one of these four visual conditions prior to recoating. As part of the surface preparation, deposits of oil, grease, and foreign matter must be removed by ultrahigh-pressure water jetting, by steam cleaning with detergent, by methods in accordance with SSPC-SP 1[3] or by another method agreed upon by all parties to the contract. NOTE: Direct correlation to existing dry media blasting standards is inaccurate or inappropriate when describing the capabilities of water jetting and the results achieved by water jetting.

3.2 Table 2 lists three surface preparation conditions in terms of **nonvisible** chemical contaminants. In addition to the requirement given in Paragraph 3.1, a surface shall be prepared to one of these three nonvisual conditions prior to recoating, when deemed necessary.

[2] U.S. Water Jet Technology Association, "Recommended Practices for the Use of Manually Operated High-Pressure Water Jetting Equipment" (St. Louis, MO: U.S. Water Jet Technology Association, 1987).
[3] SSPC-SP 1 (latest revision), "Solvent Cleaning" (Pittsburgh, PA: SSPC).

3.3 The specifier shall use one of the visual surface preparation definitions (WJ-1 to WJ-4) and one of the nonvisual surface preparation definitions (SC-1 to SC-3) to specify the degree of visible and nonvisible surface matter to be removed, when deemed necessary. An example of a specification statement would be, "All surfaces to be recoated shall be cleaned in accordance with NACE/SSPC WJ-2/SC-1; the method of HP WJ or UHP WJ ultimately selected by the contractor will be based on his confidence in the capabilities of the equipment and its components." The specifier and contractor shall agree on the test method to be used for determining the amount of nonvisible contaminants.

3.4 The specifier shall consult with the coating manufacturer to ascertain the tolerance of the candidate coating(s) to surface conditions existing after water jetting, commensurate with the in-service application.

TABLE 1
Visual Surface Preparation Definitions

Condition	**Description of surface** (when viewed without magnification)
WJ-1	A WJ-1 surface shall be free of all previously existing visible rust, coatings, mill scale, and foreign matter and have a matte metal finish.[A,B,C]
WJ-2	A WJ-2 surface shall be cleaned to a matte finish with at least 95% of the surface area free of all previously existing visible residues and the remaining 5% containing only randomly dispersed stains of rust, coatings, and foreign matter.[A,B,C]
WJ-3	A WJ-3 surface shall be cleaned to a matte finish with at least two-thirds of the surface free of all visible residues (except mill scale), and the remaining one-third containing only randomly dispersed stains of previously existing rust, coatings, and foreign matter.[A,C]
WJ-4	A WJ-4 surface shall have all loose rust, loose mill scale, and loose coatings uniformly removed.[C]

[A] NOTE: HP WJ and UHP WJ surfaces do not exhibit the hue of a dry abrasive-blasted steel surface. The matte finish color of clean steel immediately after WJ will turn to a golden hue unless an inhibitor is used or environmental controls are employed. On older steel surfaces that have areas of paint or are paint-free, the matte finish color will vary even though all visible surface material has been removed.
[B] UHP WJ at pressures in excess of 240 MPa (35,000 psi) are capable of removing mill scale, but production rates may or may not be cost effective in the effort to remove mill scale.
[C] The experience of the contractor and, in many cases, the preparation of a sample area, determine the success of a specific level of HP WJ or UHP WJ in removing an existing coating or sheet lining material, rust scale, rust nodules or tubercles, mill scale, or other tightly adhered matter from a substrate.

TABLE 2
Nonvisual Surface Preparation Definitions[4]

Condition	Description of Surface
SC-1	An SC-1 surface shall be free of all detectable levels of contaminants as determined using available field test equipment with sensitivity approximating laboratory test equipment. For purposes of this standard, contaminants are water-soluble chlorides, iron-soluble salts, and sulfates.
SC-2	An SC-2 surface shall have less than 7 µg/cm^2 chloride contaminants, less than 10 µg/cm^2 of soluble ferrous ion levels, and less than 17 µg/cm^2 of sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test equipment.
SC-3	An SC-3 surface shall have less than 50 µg/cm^2 chloride and sulfate contaminants as verified by field or laboratory analysis using reliable, reproducible test equipment.

[4] Additional information on suitable procedures for extracting and analyzing soluble salts is available in Appendix B.

Section 4: Safety

4.1 At the prejob conference, all personnel directly and indirectly involved in the water jetting, washing, and cleaning operation shall obtain, thoroughly study, and observe all safety precautions and procedures of the latest issue of "Recommended Practices for the Use of Manually Operated High-Pressure Water Jetting Equipment."

4.2 Safety procedures shall be observed which prevent injury to the operator and other personnel who are in close proximity to the work area.

4.2.1 A pressure control valve or other suitable design shall be used to protect the operator and anyone else within close proximity of the work site. When the operator releases the trigger, the system must immediately interrupt the high- or ultrahigh-pressure water flow. Automatic safety devices must be incorporated into the design of the pump unit.

4.2.2 Safety considerations require the use of well-trained, experienced operators for the safe execution of any high- or ultrahigh-pressure water jetting operation.

4.2.3 Operators shall wear ear plugs, a face shield, a rain suit, and gloves and must have firm footing when using the water jet. The platform shall be stabilized when using swinging scaffolds, bosun chairs, and similar riggings. Other safety devices shall always be considered to prevent possible accidents in special applications.

4.2.4 While the water jet unit is in operation, an attendant shall be present to monitor functional and safety conditions.

4.3 Injuries caused by water cleaning or water jetting equipment can be life threatening. Every operator shall be given a medical alert card and must present this card to medical personnel prior to treatment. The card shall have the following information on it:

"This person has been water jetting at pressures up to 345 MPa (50,000 psi) and/or a water jet velocity up to 870 m/s (2,850 ft/s). People injured by direct contact with high- or ultrahigh-pressure water typically experience unusual infections with microaerophilic organisms. These may be gram-negative pathogens, such as those found in sewage. Before administering treatment, the attending physician shall immediately contact a local poison control center for appropriate treatment information."

Section 5: Cautionary Notes

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

5.2 Water used in water jetting 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. For example, for 240-MPa (35,000-psi) water jetting equipment, drinking-quality water is filtered through 5-μm (or smaller) filters. The cleaner the water, the longer is the service life of the water jetting equipment.

5.3 Any detergents or other types of cleaners used in conjunction with water jetting shall be removed from surfaces prior to applying a coating. Compatibility of the detergents with the special seals and high-alloy metals of the water jetting equipment must be carefully investigated to ensure that UHP WJ machines are not damaged. The manufacturer of the water jetting equipment shall be consulted to ensure compatibility of inhibitors with the equipment if inhibitors will be used with the standard jetting water. The manufacturer of the coatings shall be consulted to ensure compatibility of inhibitors with the coatings.

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Appendix A—Commentary on Production Rates

A1.1 Water jetting production rates are affected by operator skill and the condition of the steel surface.[5,6] Regardless of the surface conditions, production rates are usually improved when:

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

(b) Mechanized, automated water jetting equipment is used.

A1.1.1 New metal with tightly adhering mill scale requires the highest level of operator skill and concentration to produce a clean surface by water jetting; older, more corroded or previously coated surfaces require an average level of skill and concentration for desired results. This is the opposite of abrasive blasting, where poor surface conditions require the highest levels of operator skill and concentration.

A1.2 As a general rule, production and ease of removal increase as the water jetting pressure increases.

A1.3 Cleanup time to remove waste material should be considered as part of the overall production rate.

A1.4 Appendix G provides reported case histories relative to production rates.

Appendix B—Procedures for Extracting and Analyzing Soluble Salts

B1.1 The specifier and contractor shall agree on the test method or procedure to be used for determining the level of nonvisible contaminants. Section 3 contains additional information on surface cleanliness conditions.

B1.2 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[1]

(b) ISO[7] Swabbing Method[1]

(c) ISO/DIS 8502-5, Section 5.1, "Washing of the Test Area"[2]

(d) Any suitable controlled washing procedures available may be used if desired. During the washing procedure, clean plastic or rubber gloves should be worn to ensure that the wash water is not accidentally contaminated.

B1.3 Procedure for Extracting Soluble Salts by Surface Cells

(a) Limpet Cell Method[1]

(b) Surface Conductivity Cell Method[1]

(c) Nonrigid Extraction Cell Method[1]

(d) Cell Retrieval Procedure[1]

B1.4 Procedure for Field Analysis of Chloride Ions

The extract retrieved under Procedures B1.2 or B1.3 may be analyzed by one of the following methods:

(a) Chloride Chemical Test Strips[1]

(b) Chloride Chemical Titration Kit[1]

(c) Ion Detection Tube Method[2]

The following laboratory method is available as a referee method:

(a) Specific Chloride Ion Electrode[1]

B1.5 Procedure for Field Analysis of Sulfate Ions

The extract retrieved under Procedures B1.2 or B1.3 may be analyzed by one of the following methods:

(a) Turbidity Field Comparator Methods[1]

(b) Turbidity Method[1]

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(5) J.J. Howlett Jr., R. Dupuy, "Ultrahigh-Pressure Water Jetting (UHP WJ): A Useful Tool for Deposit Removal and Surface Preparation," CORROSION/92, paper no. 253 (Houston, TX: NACE International, 1992).
(6) L.M. Frenzel, R. DeAngelis, J. Bates, "Evaluation of 20,000-psi Water Jetting for Surface Preparation of Steel Prior to Coating or Recoating" (1983). Reprints available from Butterworth Jetting, Houston, TX. Also available in L.M. Frenzel, The Cleaner (Three Lakes, WI: Cole Publishing Inc., 1992).
(7) International Organization for Standardization (ISO), 1 rue de Varembe, Case Postale 56, CH-1121 Geneve 20, Switzerland.

(c) Field Comparator Method[1]

B1.6 Procedure for Field Analysis of Soluble Iron Salts

The extract retrieved under Procedures B1.2 or B1.3 may be analyzed by one of the following methods:

(a) Ferrous Chemical Test Strips[1]

(b) Field Test for Soluble Ion Corrosion Products[2]

(c) Semiquantitative Test for Ferrous Ions[3]

B1.7 References

1. FHWA-RD-91-011, "Effect of Surface Contaminants on Coating Life" (McLean, VA: U.S. Department of Transportation, Federal Highway Administration, 1991). Also available as SSPC Publication 91-07 (Pittsburgh, PA: SSPC, 1991).

2. ISO/DIS 8502-5, "Preparation of Steel Substrates Before Application of Paint and Related Products - Test for Assessment of Surface Cleanliness - Part 5: Measurement of Chloride on Steel Surfaces Prepared for Painting (Ion Detection Tube Method)" (Geneva, Switzerland: International Organization for Standardization, 1993).

3. NACE Publication 6G186 (latest revision), "Surface Preparation of Contaminated Steel Surfaces" (Houston, TX: NACE International).

Appendix C—Water Jetting Equipment

C1.1 The commercial water jet unit can be skid, trailer, or truck mounted; 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.

C1.2 The units operate at pressures up to 240 MPa (35,000 psi) or higher, using a hydraulic hose with a bursting strength two and one-half times the capability of its maximum-rated operating strength.

C1.3 A water flow rate of 4 to 53 L/min (1 to 14 gal/min) is typical.

C1.4 Pressure loss is a function of the flow rate of the water through the hose and the inside diameter of the hose. Consult the manufacturer for specific information on potential pressure loss for each type of equipment.

C1.5 Water jets are produced by orifices, or tips, which can have different forms. The higher the pressure, the more limited is the choice of forms. At 240 MPa (35,000 psi), the round jet can be produced reliably. Other orifices, such as fan jets, are available, but service may be limited. Tips can be designed to produce multiple jets of water that are normally rotated to achieve higher material removal rates. In general, round jets are "cutters" while fan jets are "scrapers" and/or "pushers." Interchangeable nozzle tips should be used to produce the desired streams. Consult the manufacturer for specific recommendations.

Appendix D—Operating Procedures

D1.1 Although a water jetting machine will produce a concentrated stream of water through a hose and nozzle at pressures of 70 to 345 MPa (10,000 to 50,000 psi), with current technology the most practical pressures for surface preparation cleaning are between 70 to 240 MPa (10,000 to 35,000 psi). Under certain conditions, lower water pressures may be used. The use of ultrahigh pressure with reduced water volume produces less thrust with less operator fatigue. The results obtained by HP WJ and UHP WJ are not necessarily similar. For example, surface grease and oil may not be removed by HP WJ at 70 MPa (10,000 psi); surface oil and grease are removed during the water jet process with UHP WJ at 207 MPa (30,000 psi).

D1.2 Typically, the water jet nozzle should be held 5 to 25 cm (2 to 10 in.) from the surface that is being cleaned; in some cases a distance of 0.6 m to 1 m (2 to 3 ft) may achieve the desired cleaning. When ultrahigh-pressure water jetting, the nozzle will be held 6 to 13 mm (0.25 to 0.5 in.) from the substrate in some instances. Consult the manufacturer for specific recommendations.

D1.3 To remove heavy rust scale, the water jet nozzle should be held 5 cm (2 in.) from the surface being cleaned. This distance provides great impact, so the work is performed quickly. Ultrahigh-pressure equipment should be held 6 to 13 mm (0.25 to 0.5 in.) from the surface.

D1.4 The angle of the nozzle and distance from the surface should be determined by the type of matter to be removed and the type of equipment (e.g., HP WJ or UHP WJ) being used.

D1.4.1 To remove brittle substances such as aged paint or rust scale, the nozzle should be held virtually perpendicular to the surface.

D1.4.2 To remove heavy mastics, the nozzle should be held at angles up to 45° to peel the mastic away from the surface.

D1.5 Rust inhibitors, if specified to prevent oxidation of bare steel, may be injected at the nozzle or at the water supply. Coating manufacturers should be consulted to determine the compatibility of the coating to be applied with the type of inhibitor used.

Appendix E—Efficiency of Water Jetting at Various Pressure Ratings

E1.1 Current published data on the levels of high-pressure water jetting required to remove rust, paint, mill scale, and other contaminants are incomplete due to the recent introduction of pressures of 250 MPa (36,000 psi). However, descriptions of the results of the 1983 study, "Evaluation of 20,000-psi Water Jetting for Surface Preparation of Steel Prior to Coating or Recoating," are given in Paragraphs E1.1.1, E1.1.2, and E1.1.3.[6] Further research is being to validate preliminary data. As additional data become available, this information will be inserted in the appendices to update the information contained within this standard.

E1.1.1 At pressures less than 70 MPa (10,000 psi), loose rust, debris, and material in depressions and pits will be removed, but black oxide (magnetite) remains. A uniform matte finish cannot be achieved.

E1.1.2 At pressures of 70 MPa (10,000 psi), a uniform matte finish is obtained that quickly turns to a golden hue unless inhibitors or environmental controls are employed. Black oxide products (magnetite) will be slowly removed, but not fast enough to be a practical industry application.

E1.1.3 At pressures of 140 MPa (20,000 psi), a uniform matte finish is obtained that quickly turns to a golden hue unless inhibitors or environmental controls are employed. Black oxide products (magnetite), paint, elastomeric coatings, enamel, red oxide, and polypropylene sheet lining are removed. Generally, chemical contaminants will be removed with varying degrees of effectiveness.

E1.1.4 At pressures of 235 to 250 MPa (34,000 to 36,000 psi), a uniform matte finish is obtained that quickly turns to a golden hue unless inhibitors or environmental controls are employed. Surface material, including most mill scale, is removed from the base material. Extremely well-bonded mill scale may require additional time spent in localized jetting. Nonvisible chemical contaminants (i.e., chlorides, sulfates, etc.) will be removed along with most radioactive materials. Removal of base material may occur with prolonged application at these pressures.

E1.2 Test results from Howlett and Dupuy[5] clearly demonstrate that UHP WJ is superior to dry abrasive blasting in removing chlorides to safe levels. Their work consisted of determining the amount of chlorides, sulfate, phosphates, and nitrates after employing various methods of surface preparation, including dry abrasive blasting and inhibited and uninhibited ultrahigh-pressure water jetting.

Appendix F—Principles of Water Jetting

F1.1 *Water jetting* is the term used when energy is utilized in the removal of existing coatings and/or surface preparation for the subsequent application of a coating. To understand how much energy is in the stream of water, the following dimensionless mathematical expression defines the relationship between power, pressure, and flow rate:

$$Power = \frac{Pressure\ (P)\ x\ Flow\ Rate\ (Q)}{K} \qquad (1)$$

K is a constant whose value is determined by the units of measure being used (i.e., metric [MPa, L/min, kW] or English [psi, gal/min, hp]).

For example:

$$Power = \frac{(P)(Q)}{60} \qquad (2)$$

with P in MPa,[8] Q in L/min, and power in "hydraulic" kW; or:

[8] For P in bar, K = 600.

$$Power = \frac{(P)(Q)}{1714} \qquad (3)$$

with P in psi, Q in gal/min, and power in "hydraulic" hp.

F1.1.1 The above formulas cannot be used without exercising application judgment. For example:

240 MPa (35,000 psi) x 19 L/min (5 gal/min) ÷ 60 (1714) = 76 kW (102 hp)

35 MPa (5,000 psi) x 132 L/min (35 gal/min) ÷ 60 (1714) = 76 kW (102 hp)

Putting 76 kW (102 hp) to work in the form of 19 L/min (5 gal/min) at 240 MPa (35,000 psi) and successfully removing a tough coating does NOT mean 132 L/min (35 gal/min) at 35 MPa (5,000 psi) will produce the same results.

F1.1.2 Application judgment is employed by operators or users who make the decisions concerning which type of energized water to use:

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

(b) HP WJ (pressure and flow rate play an equal role); or

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

The threshold pressure[9] of a coating must also be determined. In general, the tougher or harder the coating (i.e., the more resistant to the pocketknife test), the higher the threshold pressure will be; the softer and more jelly-like the coating, the lower the threshold pressure will be.

F1.1.2.1 Once the threshold pressure is achieved or exceeded, the production rate increases dramatically. Therefore, water jetting production rates are affected by two conditions:

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

(b) Water jet cutting plus erosion at pressures greater than the threshold pressure.

F1.1.3 Another way to look at energized water is to determine its energy density, or the amount of hydraulic energy per unit area (the amount of kW [hp] per orifice area). With regard to the examples in Paragraph F1.1.1, consider the following:

UHP WJ: 19 L/min (5 gal/min) at 240 MPa (35,000 psi) requires a 0.9-mm (0.036-in.) diameter orifice that has an area of 0.65 mm^2 (0.0010 $in.^2$).

76 kW/0.65 mm^2 = 117 kW/mm^2
102 hp/0.0010 $in.^2$ = 102,000 hp/$in.^2$

HP WC: 132 L/min (35 gal/min) at 35 MPa (5,000 psi) requires a 3.8-mm (0.15-in.) diameter orifice that has an area of 11.6 mm^2 (0.018 $in.^2$)

76 kW/12 mm^2 = 6.55 kW/mm^2
102 hp/0.018 $in.^2$ = 5,700 hp/$in.^2$

Compare the energy density of UHP WJ and HP WC. UHP jets have 18 times the energy density of HP WC jets.

As water passes through the orifice, the orifice converts potential energy (pressure) to kinetic energy (1/2 mv^2). The energy increases linearly with the mass flow, but increases with the square of the velocity.

$$Kinetic\ Energy = \frac{1}{2}mv^2 \qquad (4)$$

where m = mass and v = velocity. (Velocity is derived from pressure; mass is derived from water volume.)

Appendix G—Reported Case Histories on Production Rates

NOTE: This appendix consists of case histories that have not been verified by independent NACE/SSPC studies.

G1.1 In the 1983 case of removal of heavy rust from new steel with some intact mill scale, dry abrasive blasting was approximately twice as fast as 140-MPa (20,000-psi) water jetting. In the case of heavy rust 6 to 10 mm (0.25 to 0.38 in.) thick on old steel with no mill scale or paint, water jetting was three to four times faster than the dry blast. In the case of blasted steel that was rusted by salt water and chemical contaminants, dry abrasive blasting was simply not able to clean the corrosion cells. Water jetting not only removed the rust in the second and third cases, but it also cleaned the corrosion cells.[6]

[9] Threshold pressure is defined as the applied water jetting pressure at which the coating to be removed begins to lose its adhesion.

G1.2 When 140-MPa (20,000 psi) water jetting was used in 1983 to clean a coal scrubber plate coated with elastomeric polyurethane, the production rate to commercial finish was approximately six times that of dry abrasive blasting. Water jetting also removed the sulfur contaminants that had migrated to the metal wall. The adhesion of polyurethane to the steel was above 5 MPa (700 psi) when measured with an adhesion tester. The surface profile on this steel, which had initially been sand blasted to 130 µm (5 mils), remained the same. The contour looked like a sand-blasted pattern except that loose material in the valleys had been removed. The same phenomenon was observed when steel panels (UNS[10] G10200) that had been rusted in salt chambers were cleaned with 140-MPa (20,000-psi) water jetting. The anchor pattern was unchanged from the original sand-blast pattern; the top view looked like a sand-blast pattern except loose material was absent.[6]

G1.3 The 1983 cleaning rate for water jetting at 140 MPa (20,000 psi) for the removal of 1,000-µm (40-mil) urethane coatings on flue gas scrubbers is 0.7 m^2/h (7.5 ft^2/h).[6]

G1.4 The 1983 cleaning rate for water jetting at 140 MPa (20,000 psi) for the removal of nonskid urethane coatings is 2.9 m^2/h (31 ft^2/h).[6]

G1.5 The 1983 cleaning rate for water jetting at 140 MPa (20,000 psi) for the removal of thick rust and 50% paint coverage on pitted barge steel to a near-white condition is 5.6 m^2/h (60 ft^2/h).[6]

G1.6 Table G-1 provides 1991 cleaning rates for water jetting at 240 MPa (35,000 psi). At 240 MPa (35,000 psi) water jetting is two to three times faster than at 70 MPa (10,000 psi) in achieving the same degree of cleanliness.

G1.7 Table G-2 provides 1994 cleaning rates for water jetting at 207 MPa (30,000 psi).

TABLE G-1[11]
UHP Water Jetting Cleaning Rates at 240 MPa (35,000 psi)
21 L/min (5.6 gal/min) Water Usage

Original Condition	Cleaning Rates m^2/h (ft^2/h)
1000-µm (40-mil) urethane coating on flue gas scrubbers	1.4 to 1.9 (15 to 20)
Nonskid urethane coatings	2.8 (30)
Thick, rust-pitted steel on barge; flat surface; 50% paint coverage; water jet to WJ-2	5.6 (60)

TABLE G-2[12]
UHP Water Jetting Cleaning Rates at 207 MPa (30,000 psi)
10 L/min (2.8 gal/min) Water Usage

Original Condition	Cleaning Rates m^2/h (ft^2/h)
Multiple-layer ship hull coatings	7.0 to 9.5 (75 to 100)
Nonskid urethane coatings	19 (200)

[10] Metals and Alloys in the Unified Numbering System (latest revision), a joint publication of the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096.
[11] 1991 data.
[12] 1994 data.