Wet surface preparation

Water jetting & wet-abrasive blasting

Introduction

Wet surface preparation methods may be preferred in various repair and refurbishment scenarios due to HSE and operational advantages. The continued proliferation of water jetting and wet abrasive blasting, is related to legislation pressure to protect people and the environment. Many abrasive materials require safe disposal, and the dust created in relation to dry abrasive blasting methods represent a hazard for the operators. Furthermore many sites do not allow abrasive blasting without complete or partial closing down of the facility during blasting. In many repair and maintenance situations it is therefore preferred to use alternative surface preparation such as wet surface preparation.

Safety

Use adequate personal safety equipment and follow sound procedures. Observe all safety instructions from water jetting and wet-abrasive blasting equipment manufacturers including proper electrical grounding of all relevant equipment.

Scope

This document provides an overview of the basics of water jetting and wet-abrasive blasting as well as recommendations for good practice. The text is related to use on metallic substrates all though water jetting is also highly suitable to prepare concrete. The guidance provided here is relevant to most protective coating systems in Hempel's assortment.

Water jetting

Water jetting is surface preparation by means of high pressure water only. When propelled at a surface at sufficiently high velocity, water removes rust and old paint from the substrate, which is thereby made ready for painting. Also it effectively removes soluble salts. However, water jetting does not create a roughness profile in a metallic substrate. Indications are that it contributes to a slight rounding of an existing profile. As such water jetting is only a suitable surface preparation method for metal in case an existing profile has already been created in the substrate by other means. For this reason water jetting is mainly used for maintenance work on areas with intact coating. The method can effectively remove the existing coating to expose the blast profile created by the original sandblasting during new construction. On degrade areas with corrosion the original blast profile will have corroded away.

Table 1: *Definition of Cleaning / Blasting Types*

Method	Water pressure	Area of use
Low Pressure Water Cleaning (LPWC)	Below 34 MPa (5000 psi)	For industrial and domestic use
High Pressure Water Cleaning (HPWC)	34-70 MPa (5000 – 10000 psi)	Removal of marine growth
High Pressure Water Jetting (HPWJ)	70-210 MPa (10000-30000 psi)	Removal of coatings, partly rust
Ultra High Pressure Water Jetting (UHPWJ)	Above 210 MPa (30000 psi)	Removal of coatings and rust

In practical use it has been found that complete removal of coatings and rust is only attained at pressures beyond 210 MPa (=2100 bar), and that roughening of the paint surface by means of sweep hydro-blasting is attained at a pressure of around 160 MPa (=1600 bar). Note that whereas water flow rates are important for power and output for HPWJ, water pressurization becomes the dominant parameter in determining power and output for UHPWJ.

Standards
Water jetting standards govern water pressure, steel cleanliness and degree of flash rusting.
Water pressurization: Industry consensus is that the use of water pressurized at 70 MPa (=700 bar) or above constitutes water jetting. Below this pressure the operation is defined as water cleaning. The joint SSPC SP 5 / NACE 12 Surface Preparation and Cleaning of Metals by Water Jetting-standard provides the most comprehensive definition of what constitute water cleaning and water jetting:

ISO 8501-4: 2020 operates with 5 initial substrate conditions, 3 preparation or cleanliness grades and 3 grades of flash rust. These are illustrated by means of 23 pictures: 5 illustrating initial conditions of the steel substrate, 15 illustrating the three preparation grades attainable from the five initial substrate conditions, and 3 pictures illustrating the attainable flash rust degrees Low, Medium and Heavy.

ISO 8501-4:2020 descriptions of initial substrate conditions are as follows:

Table 2: *Initial Substrate Condition Descriptions in ISO 8501-4:2020*

DC A	A surface where the paint coating system has degraded to an extent similar to that illustrated by ISO 4628-3, grade Ri 3.
DC B	A surface where the paint coating system has degraded to an extent similar to that illustrated by ISO 4628-3, grade Ri 4.
DC C	A surface which might have been painted that has degraded to a major extent as illustrated by ISO 4628-3, grade Ri 5, or when completely degraded as illustrated by ISO 8501-1, rust grade C.
DP I	An iron oxide epoxy prefabrication (shop) primer surface that has degraded.
DP Z	A zinc silicate prefabrication (shop) primer surface that has degraded.

ISO 8501-4: 2020 definitions of cleanliness degrees are as follows:

Table 3*: Definitions of Cleanliness Degrees according to ISO 8501-4:2020*

Wa 1	**Light High Pressure water Jetting:** When viewed without magnification, the surface shall be free from visible oil and grease, loose or defective paint, loose rust and other foreign matter. Any residual contamination shall be randomly dispersed and firmly adherent.
Wa 2	**Thorough High Pressure water Jetting:** When viewed without magnification, the surface shall be free from visible oil, grease and dirt and most of the rust, previous paint coatings and other foreign matter. Any residual contamination shall be randomly dispersed and can consist of firmly adhering coatings, firmly adherent foreign matter and stains of previously existent rust.
Wa 2½	**Very thorough High Pressure water Jetting:** When viewed without magnification, the surface shall be free from all visible rust, oil, grease, dirt, previous paint coatings and, except for slight traces, all other foreign matter. Discoloration of the surface can be present where the original coating was not intact. The grey or brown/black discoloration observed on pitted and corroded steel cannot be removed by further water jetting.

Equipment

The waterjet unit can be mounted on various platforms, and powered either electrically or by a diesel engine. It usually consists of a pump, hoses, lance, nozzles and various equipment. The units operate at pressures up to 300 MPa (=3000 bar) with water flow rates typically between 4-53 L/min. Pressure loss is an important consideration. To avoid undue pressure loss ensure that hoses are as broad and short as possible. Hose bursting strength should be minimum 2.5 times the capability of the maximum operating strength of the unit. Nozzle configuration is important for unit output. As a rule, tips providing multiple jets of water that are rotated provide a better work rate. Always consult equipment manufacturer for specific recommendations related to operation and safety.

Wet abrasive blasting

Wet-abrasive blasting is surface preparation by means of water, compressed air and abrasive, with the water being either a propellant for the abrasive material or used for dust suppression. This type of surface preparation provides both cleanliness and profile in one go. As such it can be used for both new-building and maintenance projects. The extent of salt removal depends on set up. In case water is used only for dust suppression it may be insufficient to remove salts. In all events a potable water wash-down after wet-abrasive blasting is recommended to ensure removal of abrasive, dust, dirt and salts.

Standards

Currently the only evaluation standard for wet-abrasive blasting is the joint NACE / SSPC visual standard SSPC-VIS 5 / NACE VIS 9. This standard operates with 2 original conditions (ISO 8501-1 C and D), 2 cleanliness degrees WAB-6 and WAB 10 (similar to ISO 8501-1 Sa 2 and Sa 2½), and 3 degrees of flash rust very similar to ISO 8501-4: 2020.

Abrasives

Only non-metallic abrasives like slag and garnet must be used for wet-abrasive blasting. Metal abrasives will rust, agglomerate into lumps and pollute the substrate. Harder and more insoluble abrasives like garnet will provide for less blasting hose clogging and a better profile. Size distribution must be able to provide specified roughness while keeping in mind that small abrasives are more difficult to wash off in corners and areas of difficult access. Reusing abrasives is not recommended for wet-abrasive blasting. Apart from providing a poorer profile, and containing a higher level of contaminants, spent material will more easily clog the blasting hoses.

Equipment
Basically there are three types of wet-abrasive blasting equipment:

- A water injector type set-up introducing water at the nozzle of what is basically a dry-abrasive blasting set-up. Water is added for dust suppression purposes only.
- Water blasting with abrasive injection is basically a water jetting set-up with abrasives introduced internally at the nozzle. This is done to enable the creation of a profile on the substrate.
- A slurry blasting set up, mixes water and abrasive in the blasting pot, with a water pump and a compressor providing water and thrust. This is the most clogging prone set-up as water and abrasive are mixed from the outset and travel jointly through blasting hoses.

Blasting hoses should be hard and firm, without holes and with external couplings. To minimize the risk of clogging during slurry blasting operations and to avoid pressure loss, hoses should be as short and broad as possible, and the abrasive should be as large and hard as possible. Also, water should be prevented from running back into the abrasive hose. As always in operations involving electricity and water the equipment should have proper grounding. Always consult the manufacturer for full details of safety and operation of equipment.

Comparison of cleanliness for wet and dry surface preparation methods

Wet surface preparation methods are governed by specialized standards. However cleanliness standards of dry and wet-abrasive blasting methods are pegged to each other. Water jetting cleanliness standards also are made in reference to traditional dry abrasive blasting standards. Below table provides a guide to rough levels of parity between dry and wet surface preparation cleanliness standards.

Table 4: *Comparison of Cleanliness Standards*

ISO 8501-1 Dry abrasive blasting	NACE Dry abrasive blasting	NACE Wet abrasive blasting	SSPC Dry abrasive blasting	SSPC Wet abrasive blasting	ISO 8501-4 Water jetting	NACE 5 / SSPC 12 Water jetting
Sa 3	1	WAB 1	SP-5	SP-5 WAB		WJ-1
Sa 2½	2	WAB 2	SP-10	SP-10 WAB	Wa 2½	WJ-2
Sa 2	3	WAB 3	SP-6	SP-6 WAB	Wa 2	WJ-3
	8	WAB 8	SP-14	SP-14 WAB		
Sa 1	4	WAB 4	SP-7	SP-7 WAB	Wa 1	WJ-4

Please note that standards for water-jetting cleanliness deviate from those of dry and wet abrasive blasting in terms of inclusion of the state of old coating material at initial condition of the substrate, and in terms of the extent to which remaining coatings forms a part of the final result. This is due to the fact that water jetting is mainly a method for maintenance project surface preparation and because full removal of old coatings by this method is not always considered worth the effort. Also, wet surface preparation methods in general presents a visually different and duller substrate after surface preparation than what is usually the case with dry abrasive blasting methods.

Flash rust

Flash rust occur on carbon steel in relation to both water jetting and wet abrasive blasting. The speed of flash rust development depends mainly on time-of-wetness and temperature of the substrate as well as relative humidity at the substrate. High pressure water jetting heats up the steel plates, causing the water to evaporate faster, thereby limiting time of wetness and flash rusting. In general flash rust development is a relatively speedy process, which may necessitate follow-up pressure washing to ensure a result which is within specification parameters. Unlike old untreated rust, flash rust is relatively free of chlorides and other pollutants making it less hygroscopic. Accordingly limited flash rust can be successfully coated, and the paint system continue to provide good long term performance.

In the standards flash rust is characterized according to 6 parameters including colour, dispersion, adhesion, opacity as well as ease of marking and amount of pressure during testing. Flash rust adhesion is the most important parameter and must always be tested for by means of brush-cloth test as specified below. Hempel recommends to use ISO 8501-4:2020 in the evaluation of flash rust.

Table 5*: Definition of Flash rust Degrees in ISO 8501-4:2020*

L	**Light flash rust:** A surface which when viewed without magnification exhibits small quantities of a yellow/brown rust layer through which the steel substrate can be seen. The rust (seen as a discoloration) can be evenly distributed or present in patches, but it will be tightly adherent and not easily removed by gentle wiping with a cloth.

M	**Medium flash rust:** A surface which when viewed without magnification exhibits a layer of yellow/brown rust that obscures the original steel surface. The rust layer can be evenly distributed or present in patches, but it will be reasonably well adherent and it will lightly mark a cloth that is gently wiped over the surface.
H	**Heavy flash rust:** A surface which when viewed without magnification exhibits a layer of red-yellow/brown rust that obscures the original steel surface and is loosely adherent. The rust layer evenly distributed or present in patches and it will readily mark a cloth that is gently wiped over the surface.

Evaluation of flash rust degrees is roughly similar throughout the industry, with SSPC / NACE standards being almost identical to the ISO standard.

In practice it may be difficult to achieve the required level of flash rust. This can be remedied by means of follow-up pressure washing (LPWC or HPWC) at 250 bar or above. Air-blowing of the water jetted substrate can be used to speed up drying and limit the flash rusting.

Flash rust inhibitors

Various companies have marketed additives to be added to the water used for wet surface preparation with the purpose of limiting the degree of flash rusting. These additives are typically an 15-30% (W/W) aqueous solution of triethanolamine (CAS no. 102-71-6) or similar. Hempel does not sell such inhibitors and cannot as such advice on details of their correct use. In general they are acceptable as long as all chemicals evaporate from the substrate and leaves a clean surface before application of Hempel's coating system.

Good practice

For best performance of the coating system it is essential to paint on a suitable surface. In real maintenance and refurbishment situations this may not always be possible. While Hempel acknowledge that compromises may be necessary, table 6 below is Hempel's recommendation for best possible performance. Lower cleanliness may or may not affect the durability depending on the condition of the existing coating and it's suitability for the intended service. E.g. Hempel expect no negative impact of small remains of an existing coating (up to Wa1) if the existing coating is an immersion grade epoxy and is not degraded chemically or mechanically. On the other hand if a zinc rich primer is to be applied the stell should be completely clean.

Table 6: *Recommended Cleanliness, Roughness and Flash Rust Grades for immersed and atmospheric service*

	Cleanliness SSPC VIS 5	**Cleanliness NACE VIS 9**	**Cleanliness ISO 8501-4**	**Roughness ISO 8503-1**	**Maximum Flash rust ISO 8501-4**
Atmospheric service	SP-10 WAB	NACE WAB 2	Wa 2½	Medium (G)	M
Immersion service	SP-10 WAB	NACE WAB 2	Wa 2½	Medium (G)	L

Removal of oil and grease: Water jetting or wet-abrasive blasting in itself may not remove all oil and grease from a substrate. Accordingly it is recommended to remove such pollutants prior to hydro-blasting by means of detergent washing.

Water jetting stand-off distance: Depending on pressure and equipment a 5-15 cm stand-off distance is recommended. The reason for the short stand-off distance is that the focused water jet-core in the spray zone, which is necessary for the removal of old coatings and rust, quickly dissipates into an unfocused mist of droplets as distance from the nozzle increases.

Square up all spot repair: In order to minimize damage to the existing paint system it is always recommended to amalgamate small repair areas adjacent to each other in a larger square area.

Feathering of edges: In relation to spot water jetting it is important to taper off all edges to ensure proper adhesion of the subsequent coating. This is done by water jetting the edges at an oblique angle with normal pressure, traverse rate and stand-off distance.

Roughening: In relation to spot-repair of aged coating surfaces it is sometimes recommended to do roughening of the remaining areas of coating by means of waterjet roughening. A profile can be made in the existing coating film by means of water jetting pressure around 1600 bar at normal stand-off distance and traverse rate. Roughening a surface by means of wet-abrasive blasting is similar to dry sweep blasting: Increase stand-off distance and traverse rate and blast at an angle.

Water quality

For all water jetting and wet-abrasive blasting operations silt-free, potable water should be used, preferably with a conductivity of maximum 250 µS/cm. Contaminated or silt-containing water will cause more flash rust and equipment wear and should therefore be avoided.

For wet-abrasive blasting it is furthermore not recommended to filter and re-use spent water as contaminant build up in the water is difficult to avoid, making the attainment of specified cleanliness and flash rust degrees more difficult.

Inspection

Inspection of water jetting and wet-abrasive blasting is a two-step process.

Cleanliness is inspected at a reference area immediately after treatment. Only by immediate inspection of a relatively small area is it possible to provide a precise evaluation of attained cleanliness degree prior to the onset of flash rust. However, the inspector must ensure that this standard is kept by continued observation of work on the remaining area.

Flash rust should be evaluated shortly before painting, and for the area as a whole, so as to have a full picture of the extent of flash rust at the time of paint application.

Cleanliness is inspected visually in daylight and at arms-length distance by comparing the cleaned surface with the visual standard.

Flash rust evaluation also involves two steps: First, visual inspection in daylight at arms-length distance by comparing the flash rust to the visual standard. Second, follow-up flash rust adhesion testing by means of the 'brush-cloth' test is also necessary.
Brush-cloth test is done as follows: A 4-inch nylon bristle brush is covered in white woven cotton cloth. The cloth is then swiped 15 cm across the surface in one motion. Finally, the cloth is compared to the description in ISO 8501-4:2020 or alternatively the reference pictures in Recommended Guidelines for Evaluating Flash Rust NSRP SP-3.

Inspection of wet-abrasive blasting is as specified for water jetting above, with the addition that inspection for remaining abrasive contaminants by eye and touch must be done prior to approval. This should always be done at the end of the inspection process at the same time as flash rust evaluation.