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Paper

WHAT'S HAPPENING IN SURFACE PREPARATION STANDARDS FOR PAINT

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ABSTRACT

The first association standards for the use of waterjetting cleaning in surface preparation were released in 1994 by Society for Protective Coatings (SSPC, Pittsburgh PA) and NACE Int. (Houston, TX). Since that time, the standards have been revised within the US; and ISO has published standards. The latest release for SSPC and NACE is due to come out in 2011. This paper will highlight the changes- what was; what is to come, and what prompted the changes.

1. INTRODUCTION

This paper is divided into three topics found in waterjet cleaning surface preparation documents: Visual, Flash Rust, and Non-Visible (Salts).

There have been remarkable few failures reported to the author starting in the early 1990's on coatings placed over waterjet cleaned surfaces. However, there have been many subtle attempts to malign waterjet cleaning or to make it so complicated in containment as to force an economic hardship.

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" is the standard document for the American continents and for NACE or SSPC Certified Inspectors who work globally. (REF 1) NACE NO. 5 was first published in 1995 and was revised in 2002. There has been a continual revision with a ballot for final drafts due in June 2011. (REF 2, 3, 4)

SSPC (Pittsburgh PA) and NACE International (Houston, TX) uses words as primary source. NACE and SSPC recognize that no set of pictures will illustrate all conditions.

ISO (Geneva Switzerland) uses a combination of words and pictures. (REF 6) ISO took its standard for blast cleanliness from the Swedish Standard Institution "Pictorial Surface Preparation Standard for Painting Steel Surfaces" as a set of photographs, with very little text. This emphasis on photographs is continuing to lead to confusion between practices based on ISO 8501-1 or 8501-4 and the SSPC- NACE Versions.

2. VISUAL LEVELS OF CLEANLINESS

2.1. NACE, SSPC Definitions

In NACE, SSPC and ISO there are traditionally four levels of surface cleanliness in terms of visible contaminants. The NACE- SSPC waterjet cleaning documents maintain those four levels of visual cleanliness.

The original 1995 version contained all four of the conditions in one table and one document:

The follow is an excerpt of Table 1 of the 1995 Version (1). These are the defined surfaces, when viewed without magnification.

Table 1 Visual Consideration Table
(REF 1)

WJ-1	surface shall be free of all previously existing visible rust, coatings, mill scale, and foreign matter and have a matte metal
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.
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.
WJ-4	surface shall have all loose rust, loose mill scale, and loose coatings uniformly removed

There was difficulty interpreting if only stains of coatings were allowed or if coating pieces could be left on the surface. Both interpretations could result from this language. Inspectors trained on dry blast were only leaving stains.

The 2011 Draft(s) have separated the four levels into 4 documents. (REF 2, 3, 4)

The template language that has been approved is TG 276, Final Template PROPOSED NACE/SSPC JOINT SURFACE PREPARATION STANDARD *"Waterjet Cleaning of Metals—Very Thorough Cleaning (WJ-2)"* (REF 2):

It begins in the introduction with a descriptive table. The four degrees of surface cleanliness achieved by waterjet cleaning, which are addressed in separate standards, are as follows:

Table 2 Overview of Degrees of
Visual Surface Cleanliness (REF 2)

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

Current each of the four proposed standard documents has its focused definition.

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. (REF 3)

Very Thorough Cleaning (WJ-2): A metal surface after Very Thorough Cleaning, 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 except for randomly dispersed stains of rust and other corrosion products, tightly adherent thin coatings, and other tightly adherent foreign matter. The staining or tightly adherent matter shall be limited to no more than 5 percent of each unit area of surface and may consist of randomly dispersed stains of rust and other corrosion products or previously applied coating, tightly adherent thin coatings, and other tightly adherent foreign matter. (REF 2)

Thorough Cleaning (WJ-3): A metal surface after Thorough Cleaning, 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 except for randomly dispersed stains of rust and other corrosion products, tightly adherent thin coatings, and other tightly adherent foreign matter. The staining or tightly adherent matter shall be limited to no more than 33 percent of each unit area of surface and may consist of randomly dispersed stains of rust and other corrosion products or previously applied coating, tightly adherent thin coatings, and other tightly adherent foreign matter. (REF 4)

Light Cleaning (WJ-4): A metal surface after Light Cleaning, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, loose mill scale, loose rust and other corrosion products, and loose coating. Any residual material shall be tightly adhered to the metal substrate and may consist of randomly dispersed stains of rust and other corrosion products or previously applied coating, tightly adherent thin coatings, and other tightly adherent foreign matter. (REF 5)

This latest language makes it clear that adherent material will be present, except on WJ-1 (Clean to Bare Substrate) and that the discoloration of corroded metal will still be present. "The gray to brown-black discoloration remaining on corroded and pitted carbon steel that cannot be removed by further waterjet cleaning is not considered part of the percentage staining."

2.2. ISO Definitions

The ISO standards for dry blast cleaning (8501-1) originated as photographs with descriptive material. The photos were primary; the descriptive material was secondary.

NACE and SSPC require that the written language be primary while the photos are secondary reference material. "In any dispute, the written standard shall take precedence over the visual guide or comparator." (REF 2)

The ISO High-Pressure Water Jetting document is, in this author's opinion, negligently silent on the highest level of cleanliness- ISO Level 3.(REF 6) By adopting, with little to no change, the language from ISO 8501-1 which deals with dry blast cleaning, the author of the document left no room for a further cleaning level. This language does not recognize that waterjet cleaning can leave material at the top of the substrate, and clean the bottom of the pits and crevices, while dry blast cleaning removes material at the top of the peaks and leaves material in the pits or crevices.

Table 3 Description of Surface Appearance After Cleaning (REF 6)

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 adherent coatings, firmly adherent foreign matter and stains of previously existent rust.
Wa 2½	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.

NOTE: This part of ISO 8501 does not imply that cleanliness is limited to Wa 2½, but achieving a greater degree of cleanliness could involve a disproportionate increase in time. (ISO 8501-4, 2006) (REF 6)

2.3. Commentary:

The 2002 SSPC- NACE version included words to ensure that the "entire" surface was to be cleaned as unscrupulous contractors were using the percentages to not clean, for example, 30% of the entire surface.

It has taken from 2002 to 2011 to separate and coordinate the four levels of cleanliness into four documents with similar language that parallels the general surface preparation documents which also deal with dry blast cleaning and other manual cleaning techniques.

Because NACE- SSPC use their numbered hierarchy system differently from ISO, NACE and SSPC have moved to descriptors within the title to avoid confusion.

3. FLASH RUST

Flash Rust was not included in the 1995 Standard version. (REF 1) Flash Rust was defined in 1994 photographs of International Paint. All of the Societies (SSPC, NACE, ISO) have adopted the International Paint photos as global visual reference sources. The

2002 NACE-SSPC Standard Practice includes “flash rust.” Originally “Flash Rust” was used for the rust that formed as water-borne coatings dried on steel surfaces. By 1985, flash rust was used also for water- abrasive cleaning systems. Thus Flash Rust has historically been associated with water and the drying of wet steel.

There are two recent publications for Flash Rust inspection. The National Shipbuilding Research Program (NSRP) Surface Prep Coatings Panel (SPC) funded The Manual on How to Inspect for Flash Rust (REF 14) and Recommended Guidelines for Evaluating Flash Rust. (REF 15)

When people learned that they could paint over “Flash Rust”, the definition of flash rust started to encompass almost all fast re-rusting. There are three Basic “terms” of rust are found in standards and used throughout the paint industry: rust bloom, rust back, and flash rust. The occurrence started to murkily merge.

The questions are: “What is flash rust?” How is flash rust different from rust back or rust bloom? These three terms associated with the rusting of prepared steel have often used interchangeably. Unfortunately, the terms are not interchangeable, but their use in this manner is understandable because precise definitions and chemical characterization that clearly differentiate among them do not exist. The distinction is very simple.

“Rust Bloom” is somewhat uniform rust spread evenly over a large section of the surface. Rust Bloom is a generic term for “**new rust**.” The observer doesn’t know if “rust bloom” originates from flash rust or rust-back.

“**Flash Rust**” is used in waterjet cleaning (WJ) and wet abrasive blast cleaning (WAB) standards. Flash Rust is the corrosion or rusting process that occurs **AS WATER IS DRYING.** Flash rust often looks like rust bloom because it is NEW RUST.

“Flash rust” is an oxidation product that forms when a wetted carbon steel substrate dries. “Flash Rust” is the rust that occurs from the time the waterjetting (WJ) process starts to the time the water used for the waterjetting process dries.

Although carbon steel is the metallic substrate most frequently cleaned in the field using waterjetting technology, waterjet cleaning can be used on metallic substrates other than carbon steel, including ferrous substrates such as alloy steels, stainless steels, 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.

“Rust-Back” is used in dry abrasive blast standards. Rust-Back occurs on surfaces that appear to be dry. Rust Back is the rust that occurs when **DRY,** bare steel is exposed to conditions of high humidity, moisture, or a corrosive atmosphere.

Rust-Back: Rust-back (re-rusting) occurs when freshly cleaned steel is exposed to moisture, contamination, or a corrosive atmosphere. The time interval between blast cleaning and rust-back varies greatly from one environment to another. Under mild ambient conditions, if water-soluble salts are present, it is best to blast clean and coat a surface on the same day. Severe conditions may require a more expeditious coating application to avoid contamination from fallout. Chemical contamination should be removed prior to coating.

Typically, NO "rust-back" is allowed in dry blast cleaning prior to painting, but it is acceptable to paint over "Flash Rust" in waterjetting. Long term corrosion is not flash rust. Often a surface is cleaned by waterjet and then left for days. This results in a combination of flash rust and rust back.

How much "Flash Rust" is formed is directly related to time of wetness. For a given set of panels, during waterjetting cleaning, the **time of wetness** is the predominate factor in the amount of flash rust. A contractor can control the amount of flash rust by controlling the dry time. In other words, if the water is removed by vacuum or air blast, the flash rust is minimal. Enclose the same panel in a box with open top so that the drying time is lengthened to produce light to moderate flash rust. Enclose the panel in a box with the top closed or covered with cloth to product moderate to heavy flash rust. Any salt on the surface is considered to be removed during the cleaning process or at a low level.

However, by the same comparison, during dry blast cleaning, the amount of non-visible salts on the surface will be the predominate factor in the kinetics controlling the amount RUST BACK and how fast it appears. Painting over "salt" is treacherous.

In other words, assuming that the relative humidity is the same for the panels, the kinetics of rust back is affected by the level of salts. See **Figures 1 and 2**. These are doped panels left in the controlled laboratory environment that were blasted at two hours; and photographed after 5 hours, 24 hours, and 11 days. The observer cannot see the salts, but even in an air-conditioned laboratory environment, the effect of the salt on rust back is evident. Rust Back after blasting was observed within 3 hours, even though there was no high humidity or condensation. The rust back is directly related to the amount of doped sodium chloride. The doped levels are: A- 125 $\mu g/cm^2$; B- 31 $\mu g/cm^2$; C- 8 $\mu g/cm^2$; D- 1 $\mu g/cm^2$. See also the discussion on non-visible salts.

3.1. Characterization Studies

There are many chemical forms of rust. **Flash Rust** has taken on a life of its own with respect to characterization and quantification studies.

Dr. Charles S Tricou researched "rust back" and "flash rust" and discussed the difficulty in characterizing rust that formed from natural weathering and environmental chambers. (REF 7)

Calve, Meunier, and Lacam have published multiple papers on "flash rust" characterization and performance but produced their flash rust by atmosphere exposure,

after waterjet cleaning, of the panels from November 2000 to May 2001 or they placed panels into high humidity chambers. (REF 8, 9, 10, 11) In this author's opinion, this rust is certainly not "flash rust" formed as the steel is drying during a waterjet cleaning operation. It is a combination of flash rust and rust back.

Calve again starts with several months of exposure as their flash rust production. "After UHP waterjetting, the three types of sample plates were exposed outside (corrosivity class C5M according to ISO 12944) from April 2001 to June 2001 at Lorient." (REF 9)

Calve does not use the long weathering cycle to produce "flash rust." In Calve the waterjet cleaned surface had coatings performance comparable to the blast cleaned surface. "For the abrasive blasted Sa 2.5 preparation, four paint systems (S1, S4, S6 and S12) performed satisfactorily. For the UHP water-jetted preparation, the following four systems performed satisfactorily: S1, S4, S8, and S12. …The systems S4 and S12 performed best, however." (REF 10)

3.2 Examples of Rust Bloom, Rust Back, and Flash Rust

Figures 3, 4 and 5 show rust bloom. You cannot tell the origin of rust bloom just from observation.

Figure 3 "**rust bloom**" originated during **waterjet** cleaning, so it is **FLASH RUST**. It is the prerogative of the coatings manufacturer to say whether or not a level of flash rust can be painted over. In a typical instance with atmosphere exposure, many of the industrial coatings manufacturers would find this to be an acceptable surface for painting.

Figure 4 "**rust bloom"** originated during **dry abrasive** blast cleaning under controlled humidity and temperature. The fast re-rusting arose from salt on the abrasive that ricocheted from the top of the tank car to the side. This is **RUST BACK** and must be removed before painting. It is the presence of salt that made this re-rust happen fast.

Figure 5 "**rust bloom**" is a **combination** of flash rust during waterjet cleaning, and because it was maintained for days before painting, rust back. When a surface has been waterjet cleaned, and it is not painted, the steel surface may continued to corrode. There is frequently a combination of flash rust and rust back. This is what people mean when they say- the surface is turning. The contract documents and the coatings manufacturer should give guidance whether this re-rust should be removed or may be painted over.

4. NON- VISIBLE (SOLUBLE SALTS)

Non-visible contaminants, i.e. salt, had its own table of requirements in the 1995 version as a mandatory item to be specified. (REF 1) By 2002, Soluble Salt had become a "Hot" topic, and everyone had their own, mostly political, idea where the levels should be. Frenzel issued a comprehensive report in 2010 on levels of salts as proposed originally by the coatings manufacturers. (REF 12)

Most paint companies and new construction shipyards or contractors are following the International Maritime Organization. The International Maritime Organization (IMO) (London), an agency of the United Nations, issued the Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-Side Skin Spaces of Bulk Carriers (PSPC), passed as Resolution MSC.215(82), which stipulates a maximum value of **50 mg/m^2** (5µg/cm^2) as weight equivalent **sodium chloride**.

From 1995 to present, in the NACE- SSPC waterjet cleaning documents, the Non-visual table was moved from the mandatory section to the "non-mandatory" or "informational" or "Commentary" section. The experts on the committees feel that there is no consensus on "safe" levels for coatings performance.

This is the original NACE- SSPC Table 2 for Salts. (REF 1) The idea was to have a "go, no go" medium value as SC-2. In the 50-10 µg/cm^2 chloride range, some coatings were fine and other failed. Typically, coatings on surfaces of SC-3 failed rapidly.

Table 4
Nonvisual Surface Preparation definitions (REF 1)

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.

Even as this table was published, there were critics who thought the levels were too low; other critics thought they were too high. This recognition that Soluble Salts was so important that it should be part of Surface Preparation mandatory requirements led to many committee meetings.

Frenzel (REF 12) includes the ISO Technical Report date is a compilation of the Coating Manufacturer's recommendations.

By comparison, this is a Table in recent DRAFT of NACE Task Group 418. (REF 13)
The objective is to define set values for total salt contamination. However, TG 418 gives no guidance; it divides the original 1995 values into nine values.

Table 5
Table 1 from NACE TG 418 2011
Risk Category of Total Equivalent Weight of NaCl
THIS IS A DRAFT which has not been balloted nor published.

NACE Salt Level	Level Name	Total NaCl Equivalent Salt Weight	
		mg/m²	µg/cm²
		Equal to or Less than	Equal to or Less than
NACE Salt Level 1	**SL-A**	10	1
NACE Salt Level 2	**SL-B**	20	2
NACE Salt Level 3	**SL-C**	30	3
NACE Salt Level 4	**SL-D**	50	5
NACE Salt Level 5	**SL-E**	70	7
NACE Salt Level 6	**SL-F**	100	10
NACE Salt Level 7	**SL-G**	200	20
NACE Salt Level 8	**SL-H**	300	30
NACE Salt Level 9	**SL-J**	400	40

There is still no consensus for "safe" levels. However, the trend is to go as low as economically feasible. Everyone agrees- the more salt on the surface under the paint, the more likely that there will be premature failures.

5. SUMMARY

Comparison of Dry Blast Cleaning and WaterJet Cleaning

Make no mistake. Cleaning with abrasives (dry or wet) and cleaning with water alone are two different processes. Both are being used.

Dry or Wet Abrasive	**WaterJet**
■ New and Repair	Repair
■ Makes new profile	Exposes profile under paint or corrosion
■ Erases from the Top	Shears at interface, lifts from bottom
■ Looks Uniform	Exposes all problems
■ Cleans top	Gets into crevices
■ Leaves crevices alone	Can leave detritus material at the top
■ **NO Rust-Back Allowed (Dry)**	**Flash Rust allowed**
■ Flash Rust Allowed (Wet Abrasive)	
■ Often leaves residue of salt	Removes water soluble salts

1. The new WJ standards cover four levels of visual cleanliness and will be issued in four documents.
2. Flash Rust has been defined as associated with the drying process.
3. Rust Back is associated with no water being present.
4. New visuals and "How to Inspect for Flash Rust" have been published.

5. There is still no consensus on allowable salt levels. Soluble Salts have separate standards.

6. ACKNOWLEDGEMENTS

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8. GRAPHICS

Figure 1- Panels Doped with Salt- Two Hours in Lab Environment

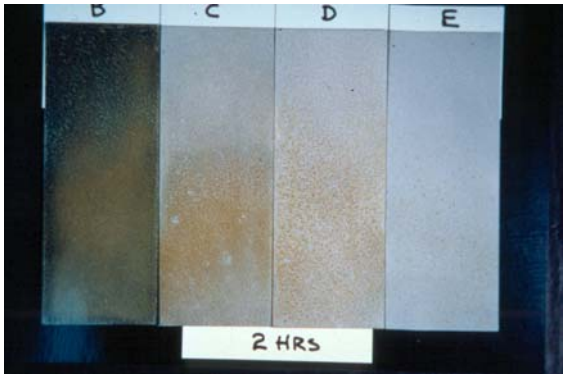

Figure 2 Panels Doped with Salt- Blasted at 2 hours;
Then 24 hours total Later in Lab Environment
Note: Rust Back on Panel B, C, and D

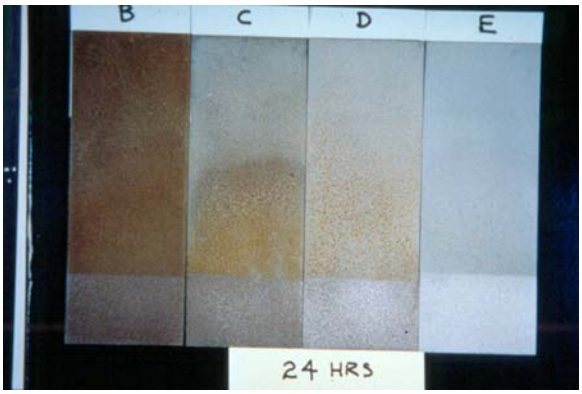

Figure 3 Rust Bloom USS Boxer
Notice: Difference in amount between
Vertical Sides and Sloping Girders

Figure 4 Rust Bloom

Rust Bloom is just at top not along the entire side.

Figure 5 Rust Bloom