

# Conventional, Advanced and Disruptive Surface Preparation Technologies: Summary, Comparison and Implications

Author: WirxGroup LLC

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## ***Other contributors:***

Loren Hatle (*WirxGroup*)  
Jerry Fenley (*CleanerBlast*)  
Kevin Daum (*Save the Oceans*)  
Robin Wright (*WirxGroup*)

**ABSTRACT:** The diversity and complexity of applications employing metal surface preparation treatments and temporary protectant sector technologies relevant to energy and pipeline industries makes it difficult to find reference materials relating and comparing methods and products to their respective roles corrosion control processes. The work presented here is meant to bridge that gap. The first part refers corrosion control, the nature of corrosion in steel, and factors that affect performance of corrosion protective coatings. The second part details the roles and compares the efficacy of various surface preparation treatments, with an emphasis on recently introduced technologies separately, and used conjointly to enhance or replace traditional surface preparation treatment methods.

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**BACKGROUND:** Every year towers, tanks, gates, turbines, and pipelines are taken out of operation and replaced due to adhesion-related coating failures. While coatings capabilities continue to advance, coating performance remains inextricably dependent on adhesion. Although preventable, corrosion continues to occur because conventionally prepared metal surfaces do not provide an optimally receptive surface for coating adhesion. The bottom line: coatings cannot adhere to contaminated surfaces. Surface contamination and site circumstances directly correlate to adhesion failures.

Several NACE studies have determined that surface preparation failure is a major cause of corrosion problems. This becomes even more evident in the field. Even layers of coating that should theoretically be impermeable to water are vulnerable. For any metal coating to perform well, optimal adhesion to the substrate and the absence interference materials is critical. Ineffective surface preparation cuts coating performance and longevity in half, which can leave metal assets vulnerable to premature and unexpected corrosion occurrences. Economic consequences of failure are a strong motivation for metal asset owners, coatings contractors, and corrosion engineers to address this issue in an advanced, and comprehensive, manner.

*“The most important single factor influencing the life of a paint is the proper preparation of the metal surface.” (Uhlig and Revie. Corrosion & Corrosion Control.)*

## **OBSTACLES TO ACHIEVING IDEAL SURFACE PREPARATION EFFECTIVENESS**

To achieve optimal impermeability, coatings must perfectly and permanently match the surface and pores of the surface. The distance between the surface of the substrate and the coating should be as small as possible, with no microcontamination between substrate and coating to prevent perfect adhesion. Reliable, fail-safe surface decontamination in the field is therefore critical to creating an optimally receptive surface for coating.

However, obtaining good adhesion in practical situations requires consideration of situational variations (meteorological, geographical, seasonal, etc.) that confound attempts perfect or near-perfect surface preparation. New coatings applied over-the-ditch is highly vulnerable to adhesion failures that lead to serious consequences for coatings, substrates, and pipeline integrity. Coating systems, whether applied in the field or metal shop, require a perfectly prepared surface on the substrate in order to achieve excellent adhesion.

*“... a poor paint system on a properly prepared metal surface usually outperforms a better paint system on a poorly prepared surface.” (Uhlig and Revie. Corrosion & Corrosion Control.)*

Strongly bonded microcontaminants and salts embedded in blasted surfaces lead to disbondment and blisters that allow water or water vapor to permeate to the substrate. If there is the slightest permeability to water or water vapor exists, a corrosion reaction will occur rapidly in the presence of those

microcontaminants and salts. Even in controlled metal fabrication, eradication of microcontaminants cannot be achieved beyond visual levels using conventional methods.

The increasing importance of eliminating soluble salts and other microcontaminants plays an ever-increasing role in surface preparation as the aggregate contaminant load on steel surfaces have increased with every generation of recycled steel, up to the present third and fourth generations of recycled steel. These aggregate contaminants are typically FeS (iron sulfide) and ionically bonded FeCl<sub>2</sub> (iron salt). Independently these contaminants are very difficult to identify in the field and thus go ignored or unidentified, creating a ‘ticking time bomb’ that inevitably disbonds and eventually breaches protective coatings, rendering surfaces vulnerable to further corrosion.

In the field, coating over contaminated surfaces may seem unavoidable because the limitations of conventional metal surface preparation processes in dealing with microcontamination. Coating life can be reduced by 30 percent, 50 percent, and 75 percent in such cases. Coatings cannot fill the gap in effective surface preparation; even improvements in coatings technologies claiming to be “surface-tolerant” do not extend to applications over steel with chloride or sulfate corrosion cells embedded in the steel.

Areas of special consideration for the pipeline industry include marine and energy sector atmospheres subject to strong contaminants and corrosion ions, recycled, and repaired (previously corroded) steel and weldments.

- **Marine conditions** dictate that anything short of optimal surface preparation is an exercise in futility. Even with multiple white blast efforts, marine surfaces contaminated with chloride and sulfate ions incur almost immediate surface reaction problems. The harsher the conditions, the more extreme the need for surface preparation measures to go beyond merely visual surface hygiene. Factors such as the remote location of offshore platforms, the prevalence of highly corrosive salt fog in coastal regions, and the high risk of coating failure serious enough to compromise the safety of structures make it easy to understand the important role effective surface decontamination plays in successful industrial and infrastructure operations. Energy sector atmospheres that include strong contaminants and corrosive ions also require the best surface preparation to prevent coating failure.
- **Previously corroded and recycled steel** presents surface difficulties greater than that of new, clean steel. Where rust has occurred and coatings are subsequently applied, even though the surface is blasted clean, coatings will fail more rapidly than over the virgin metal due to contamination. Because of the inability of recycling processes to filter out microcontaminants, such contamination becomes more concentrated with each generation of recycling.
- **Where welding repairs or junctions are needed**, eradication of visual and microscopic contamination must occur to effectively prepare surfaces to prevent puddling issues, promote surface acceptance of the repair, and ensure strong coating adhesion over the subsequent profile.

Because conventional surface preparation systems cannot adequately relieve microcontamination, organizations have settled for undesirable compromise between economical and physical feasibility that exclude the possibility of achieving the ideal objectives of surface preparation. However, the ideal is achievable:

*“The ultimate objective of surface preparation is to create proper adhesion of a coating over an underlying substrate. Adhesion is the key to coating effectiveness. It determines whether the coating is merely a thin film lying on the surface or if it becomes an actual part of the substrate. Adhesion is even more critical for coatings subjected to corrosive or immersion environments. Proper surface preparation is vital to the service life and overall effectiveness of a coating for protection*

*of the substrate. Cleanliness is essential for adhesion of the coating to the substrate. Coatings applied over rust, dirt, or oil bond poorly to the substrate. Early coating failure usually will result unless the substrate is free from these contaminants.” (US Army. Corps of Engineers, Engineering and Design: Painting, New Construction, and Maintenance.)*

Coatings succeed or fail in direct proportion to their level of adhesion. Optimizing surface preparation ensures that maximum adhesion and bond strength may develop at the interface between the substrate and the coating.

## **THE ROLE OF MICROCONTAMINATION IN ADHESION FAILURE**

### **Osmosis**

Water is small in molecular size and has a high electronegative attraction to polar molecules. Water and water vapor easily penetrate microscopic pores, holidays, cracks, and defects inherent in coating systems. Water will fill any “free” space left by solvents or microcontaminants, and many chemicals, such as sulfuric, salts and chlorides, hydroxides and solvents, are hydroscopic (attract and react with water).

Contaminants remaining on a surface prevent bonding of the paint and set up osmotic driving forces. Moisture collects in areas of poor adhesion or crosslinking, water causing a swelling in coating film and subsequent additional water penetration. Water-soluble salts and non-soluble sulfates are notorious for causing osmotic blistering of coatings in immersion service and accelerate corrosion in atmospheric service if allowed to remain on a substrate before coating.

Water molecules separate polar bonds holding resin particles together and become attracted to and swell molecules at sites of covalent bonds. The swelling further expands the space between bonds. The volume of the coating begins to expand due to the increased presence of water intrusion, up to 20 - 50% or more until the bond necessary to film adhesion/cohesion are negated.

Moisture ultimately comes into contact with the underlying substrate. The iron in steel dissolves into positively charged ferrous ions, liberating two negatively charged electrons. Corrosion reactions continue as a depolarizer reduces electrons from the solution at the cathode (usually oxygen). Oxygen in the air and the water reacts with liberated electrons to form hydroxyl ions. Hydroxyl ions formed at the cathode react with sodium, potassium, and other positively charged cations to form a strong alkaline solution.

The very high alkalinity disbonds coating at the cathodic metal interface, while additional accumulated hydroxyl groups (OH<sup>-</sup>) attract more water due to hydrogen bonding, resulting in cathodic blistering at corrosion sites.

Positively charged ferrous ions migrate to the cathode, attracted by negative hydroxide ions, and react to form oxidized ferrous hydroxide rust. Ferrous ions going into solution at the anode cause metal loss that forms pits in steel. Subsequent oxidation and hydrolysis result in a decrease of the pH and formation of more hydrated iron oxides.

### **Alkalis**

Many industries, from food industries to refineries and chemical companies, use alkalis in their processing. Surfaces exposed to caustics or other alkalis are difficult to prepare for optimal coating adhesion. Often coatings react with trace alkalis remaining on the surface. Even vinyl resins, considered among the most alkali resistant of synthetic resins, are affected by alkali dust or solution that has contaminated a steel surface, even though cleaned by normal procedures such as abrasive blasting.

## MIC

Microbiologically influenced corrosion (MIC) is responsible for many corrosion problems. During the metabolic process, sulfate is reduced to sulfide, which reacts with hydrogen produced by metabolic activities or by cathodic reaction of corrosion processes to form hydrogen sulfide. Hydrogen sulfide is very corrosive to ferrous metals and further reacts with dissolved iron to form an iron sulfide film over the metal substrate. Galvanic coupling between iron sulfide film and nearby metal substrates cause corrosion to accelerate. Microbials are considered microcontaminants.

## Sulfides

Sulfides react directly with iron without the need for water to form heavy iron sulfide scale, which oxidizes rapidly to form iron oxide. Iron sulfide is cathodic to steel, and can also accelerate existing corrosion reactions where sulfide contamination exists. Sulfides are non-water soluble contaminants with strong ionic bonds to surfaces that are extremely difficult to break.

## Soluble Salts

Soluble salts play an important role in a corrosion mechanism, for example:

$\text{NaCl} \rightarrow \text{Na}^+ \text{ (sodium ion)} + \text{Cl}^- \text{ (chloride ion)}$

$\text{Fe}^{+++} \text{ (iron ion)} + 3 \text{Cl}^- \text{ (chloride ion)} \rightarrow \text{FeCl}_3 \text{ (iron chloride)}$

$\text{FeCl}_3 \text{ and H}_2\text{O (water)} \rightarrow \text{Fe (OH)}_3 \text{ (iron hydroxide) and HCl (chloride acid)}$

This chloride acid accelerates the process in which iron electrons are lost:

$\text{Na}^+ \text{ and e}^- \rightarrow \text{Na}$

$\text{Na} + \text{H}_2\text{O} \rightarrow \text{NaOH and H}_2 \text{ (hydrogen)}$   $\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$

- Chlorides and sulfates react chemically with steel to form corrosion cells in pits.
- Chloride and sulfate levels of mere micrograms are sufficient to induce blistering.
- Atmospheric chlorides, sulfates, and similar particulates are easily deposited on exposed steel.
- Uniform surface distribution of soluble salts promotes osmotic blistering and undercutting.

Salt particles present in most site situations are difficult to remove. Rinsing a clean blasted area with clean water will not remove the salt particles and contamination in the voids of the blasted pipe. Remaining salts attract water and pose a continued risk because in actual practice, no coatings are 100% water vapor and water impermeable. Salts drive osmosis.

The presence of soluble salts (particularly sulfates and chlorides) at the metal/paint interface is a long-standing problem for the protective coatings industry. International Standards Organization (ISO) is continually working to improve standards and guidance for dealing with water-soluble salt contamination. That these standards currently are forced to make allowances for a limited presence of remaining soluble salts serves to underline both the inability of conventional methods to eradicate these contaminants and the dire need to eliminate them altogether from surfaces in order to achieve the objectives of corrosion control.

**Table 1**

Source	Immersion	Atmospheric
Suppliers	2-10 units/cm <sup>2</sup>	5-20 units/cm <sup>2</sup>
US Navy	3 units/cm <sup>2</sup>	5 units/cm <sup>2</sup>
DNV	2 units/cm <sup>2</sup>	2 units/cm <sup>2</sup>
Criteria for Soluble Salts (Cl <sup>-</sup> ) / Surface Preparation		

Chlorine contamination is an especially pervasive problem in heavy industrial and marine/coastal environments. Coatings applied over chloride-contamination evidence poor adhesion because of the hygroscopic nature of sodium chloride. Soluble salts, particularly chlorides and sulfates, not only initiate and accelerate corrosion of steel, but also become deeply embedded within corrosion products.

### **Effect of Salts on Corrosion and Coatings**

Studies demonstrate that the presence of both chlorides and sulfates cause loss of steel mass proportional to the amount of chloride or sulfate present. “Rust-back” of freshly blasted surfaces in moderate to high humidity is universally observed, with up to 50 percent decrease in effective life of lining systems, “attributed primarily to surface contamination by soluble salts not removed by blast cleaning” (Appleman). Obviously in high chloride, marine and coastal environments, this is a serious problem. The effects produced by a combination of chlorides and sulfates occurs every day in industrial zones near the coast, as the incorporation of a second contaminant has an additive effect in under film corrosion processes.

### **Types of Adhesion Failures Due to Soluble Salts**

Losses of adhesion, disbondment, (blistering, peeling, undercutting) and scribe creep are consequences of soluble salt contamination. While the surface of steel is wet and a blister filled with a watery liquid, steel appears bright and un-corroded because water will pass through the coating at a greater and faster degree than oxygen. This makes corrosion reaction sites caused by soluble salts difficult to detect. Oxygen gradually diffuses through coatings and finds its way to the blister or other contaminated areas that have interfered with proper adhesion, where it forms local corrosion cells that begin undetected corrosion reactions.

The size of a blister depends upon the degree of adhesion of the coating to the surface at that point and the internal pressure of the blister. Pressure at the interface between the coating and surface may become sufficient to lift the coating away from the substrate and separate coating from substrate, causing break-through blisters that breach the coating altogether and expose the substrate to external (environmental) corrosion factors.

Underfilm corrosion is similarly caused by the action of rust under coating. If coating has been applied over a previously corroded surface or one that may be contaminated with strongly bonded microscopic chlorides or sulfides, corrosion reactions are initiated beneath the coating. Corrosion initiated in the substrate, beneath coating, acts as a wedge, pushing coating away from the surface and building up corrosion products between the surface and the underside of the coating. It is worth noting that organic coatings are known to degrade quickly in aggressive environments specifically because of underfilm corrosion.

As  $\text{FeSO}_4$  corrosion products layer promote accelerated rust formation, the coating is destroyed. Microscopic contaminant concentrations have been enough to promote significant under film corrosion of steel in mere hours of testing. Once enough corrosion cells form, ionic conduction is overtaken by corrosion caused by diffusion of oxygen through the film.

## **OVERVIEW OF SURFACE PREPARATION TECHNOLOGIES FOR CORROSION CONTROL**

The main obstacles to ideal surface preparation results: identifying and implementing effective, efficient, and cost-effective eradication of detrimental non-soluble microcontaminants and soluble salts that lead to under film corrosion. The means to achieving the ideal (surface preparation driven) corrosion prevention strategy involves selecting processes or technologies that work together to optimize results.

**Table 2** denotes technologies currently used for the surface preparation phases of corrosion control.

## Surface Preparation/Pre-Coating Technologies Overview

Surface Preparation Process/Technology	Surface Preparation Phase	Pros	Cons
Dry Abrasive Blasting	Initial Surface Preparation Phase	Dry blasting mechanically produces commercial, near white, or white metal surfaces and breaks up layers of rust, mill scale, and coatings while creating a suitable surface profile.	Ineffective in removal of non-soluble sulfides and water-soluble salts. Can drive contaminants down into surfaces if abrasives become contaminated with oil, grease, and chloride and sulfate salts. Not designed to remove small microcrystalline salt particles deposited on steel. Contamination remaining in the steel after blast cleaning quickly darkens, and within a short period, start to re-rust. Repeated and continual dry blasting may erode the steel to the point where corrosion products are temporarily removed from the pits, but can add appreciably to the cost of cleaning a surface and may degrade strength of metal. Environmental, worker safety and cost issues.
Hydroblasting	Initial Surface Preparation Phase	Ultra-high pressure water jets (20,000-40,000 psi) produces commercial, near white, or white metal surfaces similar to dry blasting, and breaks up layers of rust, mill scale, and coatings while creating a suitable surface profile, with some effect on removing soluble salts.	Pressurized water does not remove tight rust and mill scale, thus the salts embedded in under layers of the corrosion and within pits are left untouched. Does not remove strongly bonded salts and non-soluble sulfides, especially at the microscopic level. Worker safety issues.
Wet Abrasive Vapor Blasting	Initial Surface Preparation Phase	Low pressure water / very low abrasive use produces commercial, near white, or white metal surfaces similar to dry blasting, mechanically breaks up layers of rust, mill scale, and coatings while creating a suitable surface profile. Best blasting option for low cost, high environmental and worker safety. Can be used on delicate to heavy materials.	Removes some soluble salts, does not drive water or abrasives into surface. Not designed to remove small microcrystalline salt particles deposited on steel. Contamination remaining in the steel after blast cleaning quickly darkens, and within a short period, start to re-rust.
Solvent Cleaning	Secondary Surface Preparation Phase	Solvent cleaning can remove water-soluble salts to some degree, however. To dissolve the salt, the water or steam must penetrate and wet the surface containing the salts.	Does not remove non water-soluble contaminants. The procedure works well to remove soluble salts from the rust layer, but exposes remaining strongly bonded salts and micro contaminants embedded in the surface to moisture needed to develop active corrosion cells.
Inhibitors/Metal Conditioners	Secondary Surface Preparation Phase	Temporarily mask or retard flash rusting through the dilution of some, and insulation of all, surface contaminants. Film forming agents can interfere with coating adhesion.	Corrosion inhibitors do not remove contaminants of any kind, but temporarily mask or retard flash rusting through the dilution of some, and the insulation of all, surface contaminants. False positive temporarily masks the failure mechanisms that eventually cause underfilm corrosion.
Acid/Alkaline Etch	Secondary Surface Preparation Phase	Acid etching and primer remove oxidation.	Alkaline etch leaves behind alkaline salts that form corrosion sites. These products are neither designed or claim to decontaminate surfaces, but may remove flash rust. Add etch is rinsed with water to neutralize the surface, exposing surface to water, which activate corrosion cells in combination with remaining contamination. Since they are not removed, non-soluble sulfides, and a large portion of soluble salts, remain to create active corrosion reaction sites known to cause rust and pitting beneath acid primer. Add etch primer causes phosphoric coatings to lose adhesion.
Dehumidification	Secondary Surface Preparation Phase	Dehumidification can maintain visual white-clean standards just long enough to pass visual pre-coating surface inspections.	Dehumidification processes are expensive and difficult to control. Dehumidification makes no attempt to remove water-soluble chlorides or non-soluble sulfides.
Mechanical Pickling/Power Tool Cleaning	Secondary Surface Preparation Phase	Power tool cleaning/mechanical pickling provides mechanical (not chemical) metal hygiene.	Not effective in removing soluble salts or non-soluble sulfides.
Metal Decontamination	Secondary Surface Preparation Phase	Cleans at microscopic level to exceed highest SSPC/NACE metal hygiene standards. Goes deep into pores and crevices to solubilize, react and permanently disperse strongly bonded soluble salts, non-soluble sulfides and microcontaminants to produce extremely clean surfaces with zero ionic contaminants detected, which improves the condition of metal substrates to optimize reception and adhesion of coatings. Safe for environment and worker health. Low cost. Not film or residue forming.	Only one product currently on the market, thus the technology may be unfamiliar to potential users.
Hard Film Temporary Protectant	Optional Post-Hygiene Phase	Protects cleaned bare metal surfaces or finished metal parts temporarily from external corrosion until brought into use, during interstage protection prior to further assembly or processing, or during shipping or storage. Suitable for outdoor storage. Removable.	Difficult to remove. May leave residue which interferes with coating. May cause harm to environment, due to solvent base or solvent-based removal method. External corrosion protection only; does not address underfilm corrosion. Adhesion and resistance to delamination in aggressive environments varies widely between products.
Waxy or Oily Film Temporary Protectant	Optional Post-Hygiene Phase	Used to protect cleaned bare metal or finished metal parts temporarily from external corrosion, particularly in the case of wire ropes, cables, and chains where flex is needed to prevent breakage of the protective film; for these applications the protective also serves as a lubricant. Generally safe for environment and workers. Removable. Low cost.	Difficult to remove. May attract dust and dirt. May leave residue which interferes with coating. External corrosion protection only; does not address underfilm corrosion. Solvent based removal methods may cause health risk for environment and/or workers.
Eco-Friendly Removable Paint	Optional Post-Hygiene Phase	Protects cleaned bare metal surfaces or finished metal parts temporarily from external corrosion until brought into use, during interstage protection prior to further assembly or processing, or during shipping or storage. Suitable for outdoor storage and in harsh conditions. Removable. Low environmental impact.	Adhesion and resistance to delamination in aggressive environments varies widely between products. External corrosion protection only; does not address underfilm corrosion.



## OVERVIEW OF ADVANCED SURFACE PREPARATION TECHNOLOGIES

During the last two decades, significant advances have been made in the development of surface preparation technologies. The sections below examine the efficacy of coupling mechanical (WAVB), chemical (surfactant decontamination) and physical (removable paint) methods for improving eventual coating system adhesion, durability, and stability.

### ***WET ABRASIVE VAPOR BLASTING (WAVB):***

#### **WAVB Background**

Health concerns surrounding incidence of silicosis led many developed countries to ban sandblasting as early as 1950. Respiratory health issues concerning other media in dry blasting soon followed suit, leading to the development of wet blasting technologies to remove coatings, contaminants, corrosion, and residues from hard surfaces. In addition to addressing respiratory issues, wet blasting technologies are much less sensitive to humidity than dry blasting and create fewer heat warping issues, due to the lubricating and cooling properties of water. WAVB and wet blasting function similarly in these areas.

However, WAVB is a vastly different technology. Wet blasting techniques secure a wet ring apparatus to the end of a blast nozzle to allow water to flow into a stream of ultra-high pressure air (25,000-40,000 PSI) and abrasive, with little control over water flow and air pressure. Wet blasting leaves surfaces drenched with water and wet abrasive that requires extensive cleaning. The same slurry can decrease operator vision as it builds up on helmet visors. Other health concerns included high risk of death and injury caused by hard to control high pressure blasting hoses and equipment, along with the increasing costs of abrasive media, led to the eventual development of Wet Abrasive Vapor Blasting (WAVB) in the 1990s.

Contractors and industry leaders such as have adopted WAVB technologies: ExxonMobil, British Petroleum, Chevron, Dow, BASF, Apache Corporation, Huntsman, Honeywell, PPG, Shell, Citgo, Ergon, Axiall, and Contract Resources. Advanced WAVB technologies were tested and specified for offshore platforms locations such as BP Thunderhorse and Louisiana LOOP (deep-water Gulf of Mexico) and Apache Oil (deep-water Indian Ocean) as well as the Exxon Refinery in Baton Rouge, LA. The focus of this overview is on subsequent second and third generation WAVB systems.

#### **WAVB Technology**

WAVB suppresses airborne dust by injecting an extruded mixture of water and media directly into a concurrent airstream under low pressure (20-175 PSI), resulting in a powerful, fine water mist. Moist abrasives propelled by this stream of compressed air allow abrasive particles to penetrate the substrate, dislodging coatings, rust, etc. and impart a profile (unless a profile is not desired, which can be avoided based on choice of non-abrasive media).

Abrasive media particles are encapsulated in water, without an excess of free water. Moistened media has more mass than dry media. As it strikes a surface, more force is delivered on impact, over a wider area to perform at production rates comparable to dry blasting. As particles pulverize on impact, fine dust remains sequestered in water and falls to the floor of the work area, preventing dust, slurry, and foreign material from sticking or impregnating surfaces, reducing the complexity of cleanup and containment needed for proper environmental and worker safety.

WAVB allows for lower and more controlled blasting pressures resulting in less damage to substrate and substantially less risk to worker safety than conventional blasting methods. In addition, WAVB is suitable for field repair and offshore maintenance operations as well as shop or fabrication applications due to its self-contained format, low media requirement lightweight, and small footprint.



WAVB uses only a fraction of the water and abrasive media conventional blasting processes require to complete surface preparation projects. Advantages to WAVB not addressed by conventional technologies include versatility across a wide range of substrates, suitability to organic and inorganic abrasive media, from very fine to very coarse media with a wide range of densities, the option to create a profile or clean only, and the ability to synchronize cleaning with blasting by adding cleaners or surfactants.

WAVB technologies remove soluble salts and contaminants, along with the passivating layer of surfaces. Thus, flash rusting is known to occur quickly even on WAVB cleaned surfaces, due to the concurrent exposure of new salts and microcontaminants within metal surfaces that in turn create aggressive electrolyte solutions once in contact with water. The addition of a decontaminating surfactant is needed to remove these inherent salts and microcontaminants.

### ***METAL DECONTAMINATION***

Until the development of a unique Sodium bicarbonate-based decontaminant surfactant technology, no system existed to destroy the strong ionic bonds between non-water soluble and water-soluble contaminants and surfaces. The decontamination surfactant solubilize, react and disperse strongly bonded soluble salts, non-soluble sulfides and microcontaminants, simultaneously producing surfaces reflecting extremely high levels of metal hygiene, with zero ionic contaminants detected (as determined by sensitive potassium ferricyanide testing), both improving and stabilizing metal substrate conditions to create an optimally receptive surface proven to promote maximum coating and lining adhesion and performance, including under insulation.

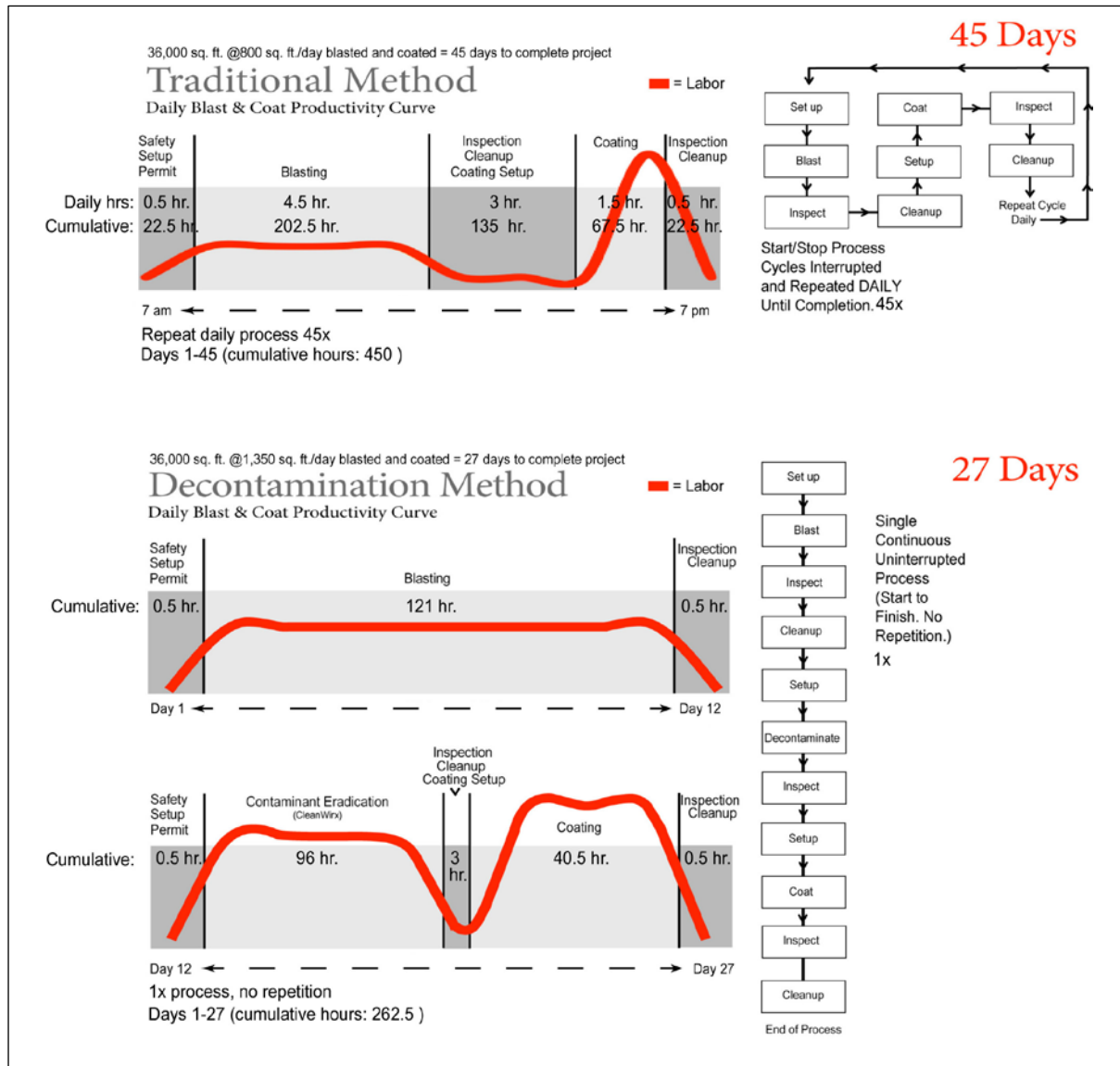
Such hygiene results are well above SSPC/NACE and industry standards (**Table 1**). Decontamination surfactants permanently eradicate microcontaminants, though a uniform film of oxidation may develop on exposed treated surfaces left uncoated for long periods of time. Case studies and pilot tests (see appendix) of first- and second-generation decontamination surfactants conducted between 1992 and 2011 on crude oil tanks, brine pit facility piping and fuel storage tanks in Wyoming, Texas and California suggest significantly improved surface hygiene results and direct correlations between metal decontamination process and coating and lining performance.

The decontamination surfactant system is integrated into surface preparation procedures following blast cleaning or concurrently in WAVB operations, in fabrication, workshop, or field maintenance situations where they are especially suited as they are easily and quickly applied and require no dehumidification or additional cleanup procedures. Acid gel is applied to surfaces and allowed to dwell approximately thirty minutes to solubilize and disperse contaminants, followed by short alkaline rinse step to stabilize surface. Resulting air-dried surface is ready for coating reception with no additional wash or rinse required.

Decontamination benefits extend to health and environmental safety as the decontamination system is biodegradable, contains less than 1% volatile organic compound and does not fall under DOT/IATA/ICAO and IMO (hazardous goods) transportation regulation. Dry decontamination surfactant formulations may be mixed onsite, decreasing overall shipping costs and storage space for offshore, field repair and maintenance.

In addition, labor, consumables, and energy costs are reduced through process simplification inherent to surfactant decontamination, allowing the entire surface preparation process to accomplish in 10 hours an optimized version of the results one would expect following 100 hours or more of more conventional methods. This decontamination allows surface preparation and coating processes to proceed in a single, uninterrupted phase rather than the current model of time-consuming daily repetition. (**Illustration 1**, next page.)

## Illustration 1



## SEM EVIDENCE OF EFFICACY

### Methodology

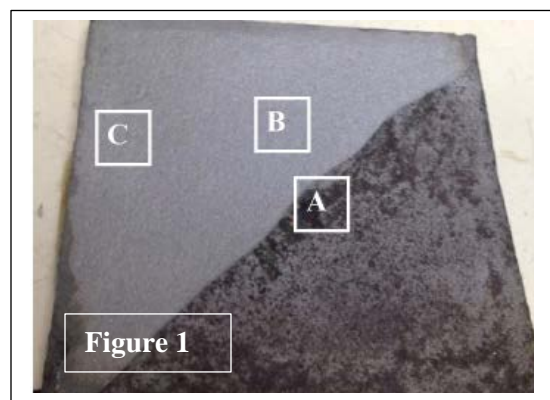
Analysis was conducted in January 2012 by a third-party laboratory, Anastas Technical Services, Houston TX. Coupon samples were analyzed using Scanning Electron Microscopy (SEM\_ and Energy Dispersive X-ray Spectrometry (EDS). To capture an SEM image, a small coupon, approximately 3"x3", was rigidly mounted on a specimen holder in a small chamber and then locked inside. The chamber was then pressurized and bombarded with electrons. SEM can specifically identify and observe elements (such as Iron, Sulfur, Chlorine, etc.,) but not compounds such as "Ferric Chlorides" or "Ferric Sulfides."

Elements had to be located (i.e. "found" or "discovered") prior to identification to eliminate "false negatives" in relation to corrosion control and contaminant (corrosive compound) detection in surface preparation methods. To properly analyze the efficacy of surfactant decontamination, it was necessary to first prepare a control polluted surface, mark areas of discovered and identified contamination first, then

apply the surfactant decontaminant being tested to those identified contaminated areas. Treated areas and untreated control areas of identified contamination were then compared against initial discovery and images of the same, previously identified polluted areas to determine if there was change in the level or presence of contaminants.

## Results

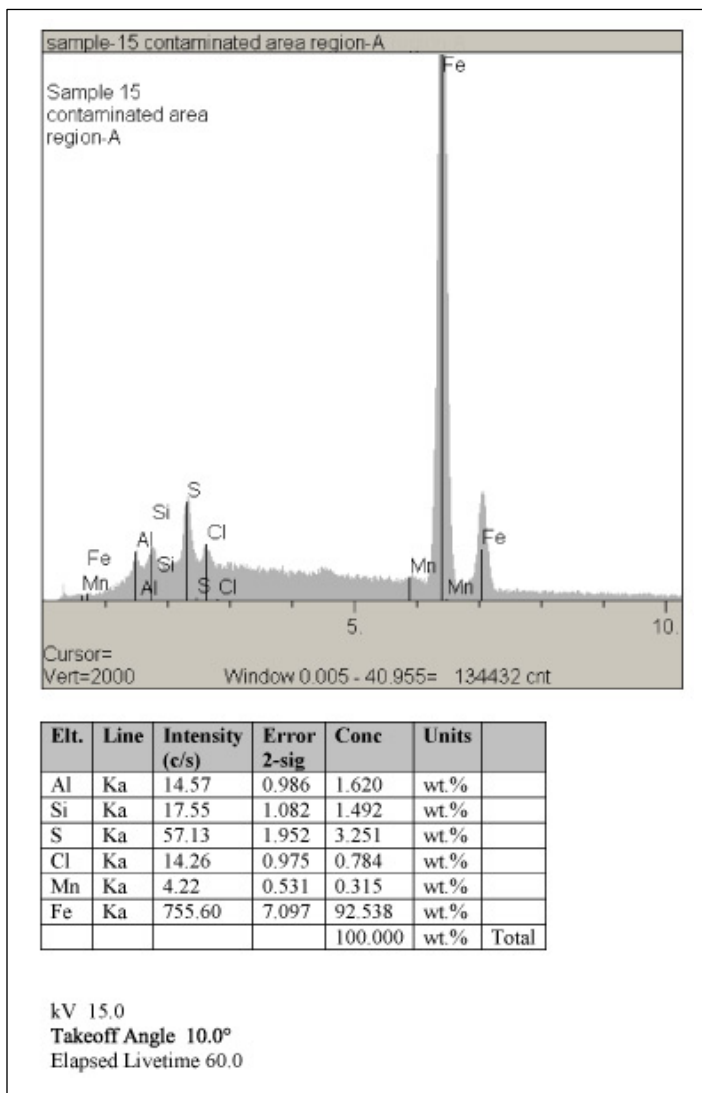
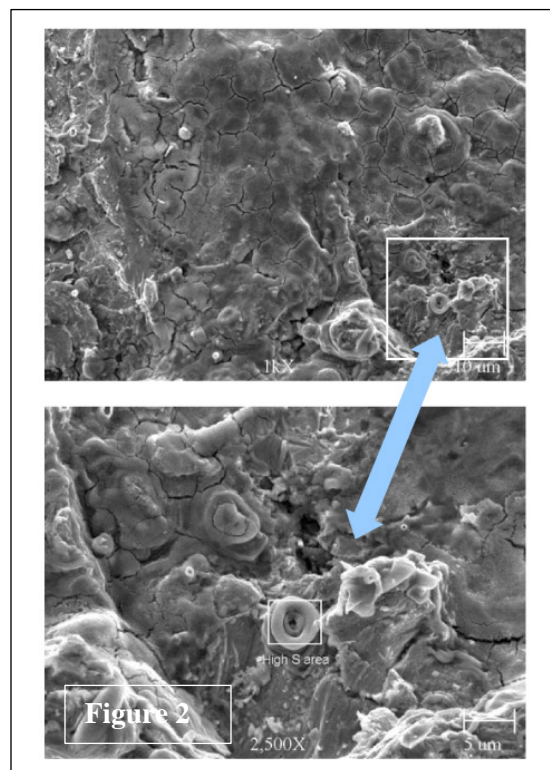
The locations on the untreated side showed varying amounts of detectable Sulfur and Chlorine, in addition to Aluminum and Silicon, along with Manganese and Iron that were components of the coupon base material. Deposits on the surface were typical for corrosion products and oxides. Examination of the locations on the treated side of the coupon showed no detectable Sulfur or Chlorine in any of the locations examined. There was evidence of embedded Aluminum and Silicon material that appeared to be some type of abrasive blasting media. Several representative locations were documented and SEM and EDS spectra were submitted with the sample.



**Figure 1:** Contaminated coupon, post treatment of upper left half.

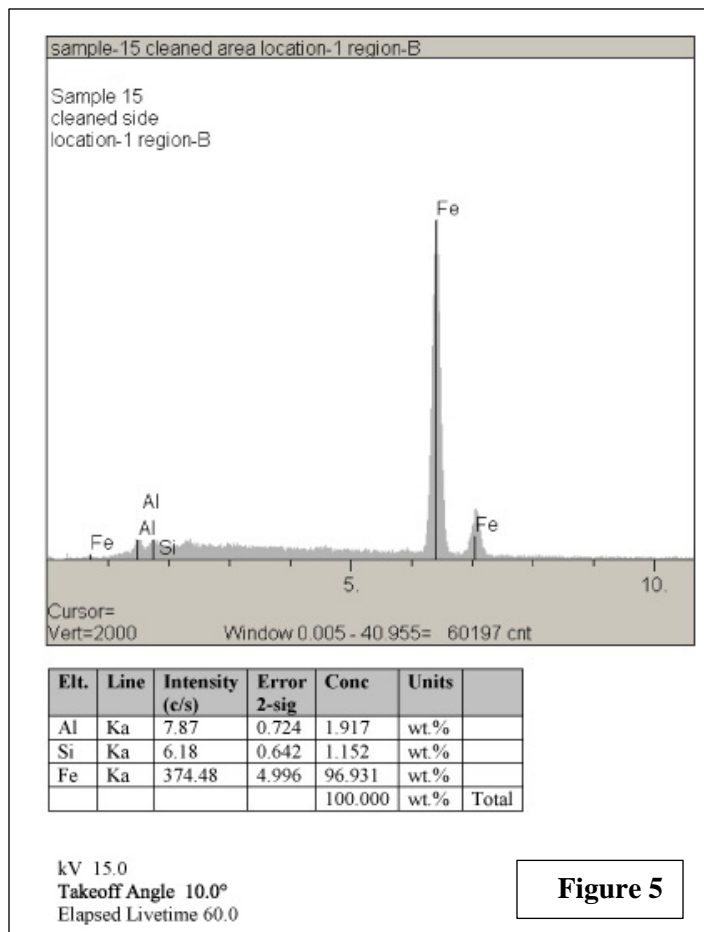
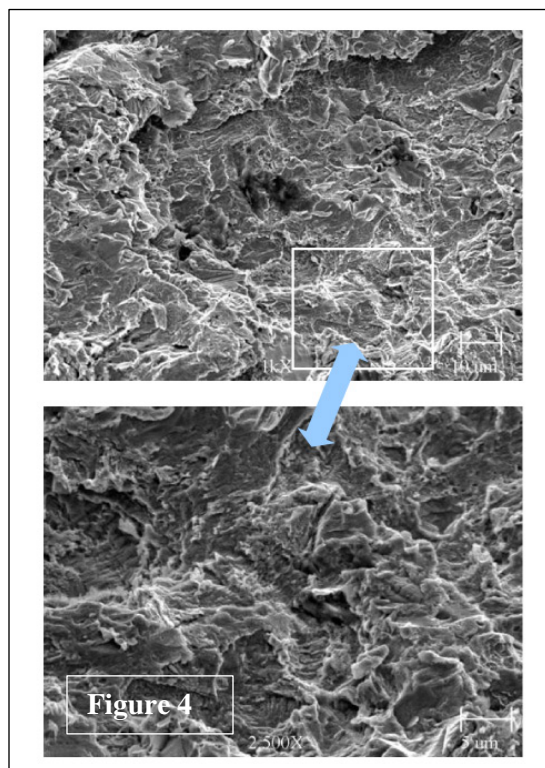
**Figure 2:** SEM imagery of contaminated control region A.

**Figure 3:** Region A (contaminated control) EDS results.



**Figure 4:** SEM imagery of contaminated control region A.

**Figure 5:** Region A (contaminated control) EDS results.



### ***HIGH-PERFORMANCE REMOVABLE PAINT***

Once decontamination with a level of zero detectable contaminants has been achieved, protection of some sort is needed to maintain the pristine condition of metal surfaces. Metal surfaces treated with decontamination surfactants are optimally receptive for strong, uniform bonds with coatings and paints. Uniform bonding results in consistent paint or coating performance across surfaces, successfully addressing the issue of underfilm / osmotic corrosion. In situations such as storage, transportation and prior to interstage production processes, where immediate permanent coating is neither feasible nor desirable, an interim solution to external contamination from environmental factors is needed. High-performance removable paint, the latest evolution of removable paint technology, presents a viable and desirable option for such temporary protection.

Conventional temporary protection methods such as soft film formers and solvent-based hard films cannot compete with high-performance technologies in protecting metal. The waxy/oily characteristics of soft films attract dust and dirt that combine with residues and stains (remaining even after solvent soft film removal processes) contaminate and interfere with permanent coating adhesion or interstage processes, thus necessitating cleaning and decontamination steps are repeated after removal. Hard films also require difficult and often ineffective solvent removal that likewise requires a repeat of cleaning and decontamination steps prior to permanent coating. Thus, such conventional protectant technologies negate

previous surface preparation efforts and add to overall costs. In addition, resistance to delamination, abrasion, peeling, and disbondment in aggressive environments is limited.

The latest high-performance removable paint system is engineered specifically to avoid these shortcomings in temporary protectants. The quick dry characteristic of high-performance removable paint closes the environmental contamination window sooner to better achieve the objective of maintaining pristine surfaces. The combination of durability and resistance of the paint product allows high-performance removable paint to perform well in aggressive acidic, alkaline or chloride prone environments, while the chemical trigger needed to release the paint contains no methyl chloride, chlorinated solvents, methanol, toluene or acetone.

In addition to the health and safety benefits solvent-free operation offers, the trigger is uniquely specific; the protectant will not come off until the specific trigger is applied, even if exposed to oils, fuels, fluids, humidity, or abrasion. The specificity of the removal product conjointly ensures total release of the paint product so no residue, solvent, or film remains on surfaces to delay, impede permanent coating, or interstage production procedures.

While unrelated to surface preparation scenarios, it is worth noting that temporary protectants are also widely employed to protect post-production, permanently coated static, moving, or vehicular metal items. Because solvent-based removal methods can damage or remove underlying paint or coatings, the non-solvent chemical trigger key to high-performance removable paint systems leads to fewer issues in post-production situations as well.

## ***ADVANCED TECHNOLOGIES SUMMARY***

### **Potential Advantages for Steel Asset Maintenance Operations**

- More effective osmotic corrosion prevention
- Enhanced protection during interstage processes, storage and transportation
- Streamlined surface preparation in field, shop and fabrication situations
- More flexible scheduling window due to less sensitivity to humidity
- Lower up-front investment, higher return on investment
- Less maintenance due to enhanced adhesion and performance of linings and coatings
- Pass inspections first time, eliminate delays and repeat of processes
- Significant labor and materials savings
- Reduced health and safety liabilities
- Reduced environmental impact

### **Impact on Energy Industry**

As stakeholders are well aware, the challenge of maintaining a thriving Energy Industry under increasing constraint from regulatory changes, public pressure for more reliability in structural integrity, and the rising costs of labor and materials is best met through continuous commitment to engaging in the testing and implementation of new technologies. Case studies prove that early adoption of advanced surface preparation technologies confers significant advantages (in terms of enhanced permanent protective coating adhesion, effective prevention and/or protection against osmotic and environmental corrosion factors, reduction of economic investment, and reduction of health and safety liabilities) from long-term reliability, overall metal asset service life, and minimization of associated corrosion-related protective coating failures. Implementation of advanced surface preparation technologies can be seen as a key factor achieving the objectives of optimal corrosion control and prevention.

## **APPENDIX:**

### ***CASE STUDIES***

The decontaminant surfactant has been successfully used on several major projects. Metal hygiene (cleanliness) was confirmed using potassium ferricyanide test procedures with results as noted.

#### **First Generation Decontamination Surfactant**

1. The first project was the interior of an 8-foot diameter steel circulating water pipe at Public Service Company of New Mexico's San Juan Generating Station, Waterflow, NM. The total surface area cleaned totaled approximately 49,000 square feet. Decontaminant surfactant was applied post blast to the interior pipe surface using "wet jet" abrasive blast equipment and deionized water. A production rate as high as 500 square feet per nozzle hour was achieved. The surfactant decontaminant blast was followed by an 8,000-psig wash with deionized water. The wash rate was approximately 750 square feet per nozzle hour. The pipe interior was then tested for soluble salts using a potassium ferricyanide test procedure and a "zero-detectable" level was confirmed.
2. A later project was the interior of 135-foot diameter steel floating top crude tank at Sinclair Oil Corporation's Refinery at Sinclair, Wyoming. Decontaminant surfactant was applied post blast to the interior tank surface using the "wet jet" blast equipment and deionized water. A production rate of over 330 square feet per nozzle hour was achieved. Decontaminant surfactant blast was followed by a 5,000-psig wash with deionized water. A potassium ferricyanide test procedure confirmed that a "zero-detectable" level of ionic contamination was achieved.
3. Sinclair Pipeline Company, Sinclair WY (conducted in 1992, using first generation decontamination surfactant): Repeated abrasive blasting cycles (NACE #2) on a 150-foot diameter crude oil tank could not maintain visual standard required for the installation of lining/coating per the coating manufacturer's specifications. Decontamination surfactant was applied, with the subsequent result of zero detectable levels of ionic contaminants as determined by sensitive potassium ferricyanide testing. Lining/coating was applied without incident on decontaminated surface. 15 years later tank was opened for inspection, but required no recoating or repair maintenance of lining/coating.
4. Pilot Test, Equistar Brine Pit Facility Piping, Markham TX (conducted in 1995, using first generation decontamination surfactant): Refurbishing and re-coating of three similar brine pit project sites was chosen for a pilot test of the effect of surfactant decontamination on protective coating performance. Traditional blast cleaning and coating was completed on two sites. Third site was subjected to traditional blast clean, surfactant decontamination, and identical coating. Across eleven years of monitoring, the two control sites had required three maintenance recoats. The decontaminated site required no coating maintenance.

#### **Second Generation Decontamination Surfactant**

5. Contractor for USN Fuel Storage, San Diego CA (conducted in 2011, using second generation decontamination surfactant): Eight 125,000 barrel tanks had been extremely contaminated resulting in extreme corrosion. Months of multiple abrasive applications and alternative solutions were attempted with no progress in meeting inspection standards for coating. Standards were finally met after first application of decontamination surfactant.

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