Problem Solving Forum

Removing Soluble Salts with Pressure Washing

This Month’s Question

What minimum and maximum water pressures at the nozzle and what distance and angle (maximum and minimum) should be specified to properly remove salt contaminants from steel before abrasive blast cleaning? Is there a simple test to determine if salt contaminants have been removed?

From Jerry P. Woodson, P.E., The Sherwin-Williams Company, Houston, TX:

Removing soluble salts is a complex problem. It cannot be solved by simple procedures such as specifying the angle, pressure, water flow rate, or type of nozzle used for pressure washing or water blasting.

The complexity arises because the contaminants are frequently chloride and sulfur that have reacted with the iron in the steel to form chemical compounds such as ferric chloride and ferrous chloride or iron sulfide and sulfates. Some of the chemical forms of corrosion products are more soluble in water than others and are more easily removed with water alone.

Soluble corrosion products can be removed by washing with large quantities of water to dissolve the salts. Elevating the temperature of the water to 120-140 F (49 C to 60 C) and using a wetting agent, such as some water blast inhibitors, to reduce the surface tension of the water increase the rate at which the soluble salts will dissolve.

Increasing the velocity of the water particles will also be beneficial. Velocity is primarily a function of water pressure and nozzle orifice diameter, but the velocity can be affected by nozzle design, as well. Some nozzles are designed to “pulse” the water. Some fan nozzle and pencil nozzle designs are more efficient than others in converting the potential energy (pressure) to kinetic energy (velocity).

The stand-off distance of the nozzle is determined by water pressure, flow rate, fan width, nozzle design, and the condition of the surface to be cleaned. The angle of impingement, whether nearly parallel to the substrate or nearly perpendicular to the substrate, also depends on these variables.
Thus, the expertise of knowledgeable contractors and the skill of individual operators become important. The operator must be familiar with the types of nozzles that are available and how effective they are on different substrates. For example, a nozzle that produces a 12-inch (30-centimeter) fan at 18 in. (46 cm) from the tip may work fine on one job, whereas a rotating nozzle with a pencil jet may work better on the next job. The technical staff of a nozzle manufacturer is a good source of advice about the alternatives for specific jobs.

Tiers of efficiency are achieved at various pressure levels using conventional fan nozzles. Cleaning efficiency is significantly better at 2,500-3,000 psi (17-20 MPa) than at 1,800-2,000 psi (12-14 MPa). A second tier is reached at 6,000 psi (41 MPa), and a third tier is reached at around 10,000 psi (70 MPa). Substantial improvements in effectiveness and productivity are usually achieved by moving from one tier to the next higher tier.

Now we must again address the state of the corrosion products. The contamination is often in the form of relatively insoluble compounds of iron and chloride or iron and sulfur. These corrosion products often adhere tightly to the base metal and frequently occur in pits of significant depth. The data indicate that, when using water without abrasive, pressures in the range of 20,000-35,000 psi (138-241 MPa) and properly designed nozzles are necessary to remove the corrosion products that contain these contaminants. Some work is being done at even higher pressures.

The higher pressures are necessary because contaminants are often relatively insoluble, tightly adhered corrosion products. Some mechanical abrasion is necessary to dislodge these corrosion products from the surface so that they can be flushed away by the water stream. Mechanical abrasion can be created from elevated water pressures of 20,000+ psi (138+ MPa) or from solid abrasive particles in the waterjets. NACE publication 6G186, “Surface Preparation of Contaminated Steel Surfaces,” reports that wet abrasive blasting using conventional abrasives is more effective at removing iron corrosion products than several cycles of 10,000 psi (70 MPa) water blasting, followed by dry blasting. The simultaneous impact of the abrasive and the waterjet on the surface seems to clean much better than either process by itself.

Now there are new processes that use dry abrasives as the first step to mechanically remove most of the corrosion products. These processes are followed with a wet abrasive blast using pressurized waterjets with sodium bicarbonate. The sodium bicarbonate provides the mechanical abrasion required to dislodge the remaining corrosion products and neutralizes any acids that may be present. After these 2 steps, the surface is rinsed with water having a very high resistivity (which indicates very low chloride content) to dissolve and flush away the remaining bicarbonate residual. This process has been used successfully to clean heavily corroded crude oil storage tank bottoms to non-detectable levels of chloride contamination.

Soluble iron salts can be detected quickly and easily with potassium ferricyanide paper, available from coating inspection equipment suppliers.
This test indicates the presence or absence of iron salts on the surface but gives no quantitative information about the concentration of the salts.

Test kits are also available to measure the level of chloride contamination on a surface. The procedure requires washing a known area with high purity water, collecting the water, and measuring the concentration of dissolved chlorides in the water. This information can be used to calculate contamination levels in micrograms per square centimeter (or other units of weight per unit area).

There is no standard for how much or how little contamination is harmful. Tolerable levels depend on the environment and the coating. Barrier coatings will be more tolerant than porous coatings. Blistering will be more likely to occur in submersion than in atmospheric exposure.

In summary, removal of chemical contaminants such as chloride and sulfur compounds from the surface of steel is complex. It is affected by the chemical nature of the corrosion product, the difficulty of mechanically dislodging the corrosion product, pitting, and other factors varying from job site to job site. It is not possible to simply specify a water flow rate, angle, and nozzle type that will be effective for every job. A specification should state the level of surface cleanliness required for the coating system to perform satisfactorily in the environment. The exact procedures for meeting the specification will vary from project to project.

From Spence Johnson, Jet Edge, Inc., Minneapolis, MN:

The question of what water pressure, stand-off distance, and angle of attack to use when removing chlorides from steel remains a subject of great debate within the waterjet industry, though it is known that each parameter is important to the effectiveness of a waterjet decontamination project.

Two of the major concerns contractors face when evaluating surface decontamination by waterjetting are environmental impact and operator safety. Obviously, the method that minimizes water usage and simplifies containment is desirable from an environmental perspective. The method that causes the least operator fatigue while maintaining high production rates is also very desirable.

The effectiveness of the cleaning process is determined by the amount of energy applied to the contaminated surface. The energy transmitted to the contaminated surface is determined by water pressure and water flow rate. We can choose either the high pressure/low flow solution or the low pressure/high flow solution. Either method will generate technically satisfactory results.

However, from a practical perspective, the high pressure solution offers greater potential for use in the field. A 36,000-psi (248-MPa) jet with a three-gallon per minute (11-liter per minute) flow rate carries the same energy as a 5,000-psi (34-MPa) jet flowing over 43 gal. (163 liters) of water per minute. At the same time, the 36,000-psi (248 MPa) jet has less
than 30 lbs (14 kg) of reaction force, while the low pressure/high volume jet has an 81-pound (36-kilogram) kick. Job writers and contractors need to examine these factors closely before specifying a particular set of parameters. For hand-held operation inside containment, the high pressure solution is mandatory. When water usage and containment are not critical and equipment suitable for restraining the high reaction forces is available, lower water pressure may be an option.

In either case, water is the key to achieving a truly clean surface. All other current processes and procedures using the impact of media or tools result only in a change of surface appearance, which should never be confused with “cleanliness.” Surface contamination can be reduced by these methods only when entire layers of base metal are removed or when the contaminants are driven so far into the metal that they cannot leach back to the surface for several years.

From Lydia Frenzel, Ph.D., CCI Training Services, The Woodlands, TX:

Other conditions must be stated before an answer can be formulated. Significant pressure is not required to remove salt contaminants from an otherwise clean surface. A garden hose with a fireman’s style spray nozzle will wash off salt. Ken Trimber presented a paper on steam cleaning to remove salt contaminants in 1988.¹

Typically, this question is asked because heavily pitted in-service steel is to be cleaned. The project manager wants to avoid the situation where a 10,000- to 20,000-psi (69- to 138-MPa) waterjetting unit is used at a stand-off distance of 12-18 in. (30-45 cm). The jetting effect is dissipated before the water hits the surface. Water goes everywhere, but the surface is not cleaned. Gelatinous iron oxide has formed protective caps over the holes where the salt contaminants have been concentrated. The effect is to clean salt from the upper layers of the rust but leave the underlying salt pockets on the substrate.

A more pertinent question is how much pressure does it take to get the rust off and reveal the crevices. In presentations given in 1985²,³, I explained that 7,000 psi (48 MPa) removes loose materials but leaves a heavy, tightly adherent rust layer on the surface; 10,000 psi (69 MPa) removes the rust slowly; 20,000 psi (138 MPa) removes the tightly adherent rust much more rapidly. Increasing the dwell time at lower pressures did not necessarily remove additional material. In current terms, this cleaning pressure would be described as the “threshold critical pressure.” As a general guideline, the minimum cleaning pressure for loose rust and paint is 4,500 psi (31 MPa); for most paints and moderate rust, it is 10,000-15,000 psi (69-103 MPa); for heavy rust, it is 15,000 psi to 30,000 psi (103-207 MPa). If the head is moving faster, the threshold critical pressure will be greater.

Above 10,000 psi (69 MPa), the water stream possesses “jet” properties. Upon exiting the nozzle, the water jet starts to degrade, so the stand-off distance should be within 1-2 in. (25-50 mm). To make the cleaning path
wider, a “fan” nozzle or multiple orifice spinning nozzle is used. The fan nozzle dissipates the effectiveness of the jet rapidly and spreads the cleaning pattern by creating an array of small droplets. It is difficult to maintain the shape on the fan nozzle, but the fan nozzle has the advantage of providing a straightforward method to achieve a wider path. The spinning head uses multiple straight bore orifices set at angles. The wear is not so great. The spinning head provides a wider path, but the pump is now delivering flow to multiple orifices. In either event, the head should be within 6 in. (150 mm) or closer if solid material is being removed from the substrate.

The angle of attack depends on the material being removed. Generally, the angle should be 18-20 degrees from perpendicular. When removing coatings, you should experiment. An attack angle of 45 degrees might allow the coating (or layers of rust) to be lifted from the good substrate.

I prefer ferricyanide paper, but its use requires caution. The paper turns blue in the presence of ferrous salts. This test indicates the presence/absence of active ferrous-ferric interaction, not the presence of salts. A heavily corroded plate can be pressure washed, still with much rust remaining, and a “false negative” indicator is obtained from the test. You are measuring the surface that has been washed free of salts and active corrosion cells even though there are still salt pockets under the rust. If rust-tolerant coatings are used, those active, buried pockets of salt may lead to premature failure.

It is common when waterjetting at 20,000 psi (140 MPa) or above for the entire ferricyanide paper test to turn blue, particularly when the hot water steams from the surface and the steel metal is undergoing the rapid transition to the refractive “golden” hue. This is a “false positive” response. The surface is very clean with multiple sharp spikes, and placing a damp paper on the surface initiates the formation of ferrous ions on the surface. When the ferricyanide paper turns blue in isolated patches or spots, there are still active sites of corrosion. This corrosion activity is in the pits and crevices. The prudent contractor will go back and clean those pits with subsequent waterjetting at 5,000 to 10,000 psi (35-69 MPa).

It is my opinion that the rapid formation of a “golden” hue indicative of a thin film refraction phenomenon means that the metal surface is “cleaned” and ready for the final anchor pattern or repainting. This hue is not the darker brown color of a uniform rusting, but a thin film “color” such as one sees in the film surface of soap bubbles. If the surface exhibits splotchy, non-uniform black oxidation patches (generally within 24 hours), there are still enough salt contaminants to cause premature failure.

One last comment: use a complete engineered waterjetting unit with pump, nozzle, high pressure fittings, and proper hoses. The hoses should be as short and large in diameter as practical to minimize the pressure loss between the pump and the nozzle.
References


From Wallace P. Cathcart, Trinity Industries, Inc., Pittsburgh, PA:

Water washing at 2,000-3,000 psi (14-21 MPa) in conjunction with sand and air at 90-100 psi (0.6-0.7 MPa) has demonstrated good removal and work rates. It leaves, however, the mess of mud-like sand and much water.

Water alone at a pressure of 20,000 psi (140 MPa) also cleans well, except possibly when salt is in and under heavy scale or thick rust nodules. Work rates are deemed by some to be slow. This method avoids the mud problem, but it involves handling and disposal of sizable quantities of water.

Ultra high pressure waterjetting at 34,000-35,000 psi (234-241 MPa) rapidly removes virtually all soluble salt contamination from even heavily encrusted surfaces. Because most of the water vaporizes, mud and residual water problems are avoided, but ultra high pressure does present visibility problems in enclosed areas.

I am not aware of any work at higher pressures other than a few at 40,000 psi (276 MPa). Work rates would probably improve as pressure increases, but I cannot suggest that the improvement would be proportionate.

The rest of my answer is much less specific. The best angle of attack and the best distance from the surface are what appear to perform best for the particular condition of steel: whether it is pitted, cratered, or scale-encrusted, or whether the old coating is also being removed, for example.

Generally, however, the angle is at or just off the vertical. As the pressure goes up, the nozzle is moved closer to the surface until the distance is a maximum of 6 in. (150 mm) at maximum pressure.

An adequate test for measuring the removal of soluble salts, in my judgment, does not exist. All of the field tests with which I am familiar are only a means of measuring how much soluble contaminant the testing technique has removed per unit area.
The tests do not disclose how much contamination is or was in a specific spot. The test procedures vary, but they remove some portion, maybe a sizable portion, of the soluble matter that was present.

That portion must be assumed to have come from the whole area from which it was extracted. If, for example, we extract 40 micrograms of a salt from an area of 20 square centimeters (3 square inches), we would report it as 2 micrograms per square centimeter, which is, possibly, a tolerable amount of contamination.

However, it is conceivable that the 20-square centimeter (3-square-inch) area was clean of contamination except for the bottom of one crater or one pit, with an area a fraction of 1 square centimeter (0.4 square inches) in size. From that crater, we could have extracted only a little bit of the entrapped salt.

The contamination at that point could well have been 40 or even 100 micrograms, and a coating would fail by blistering (which might later be deemed a pinhole failure) at that particular point.

The only really indicative test is not very practical or very scientific, but it works. Use the removal procedure you selected on an area of a few square feet that you deem to be typical or the worst case. Let that area dry or dry it, and then abrasive blast with an abrasive known to be clean and salt free. Wait about 72 hours and examine the area for bloom or rustback. If none is evident, that area can be rated “free enough of salt contamination to be safe for even severe coating service.” Then, when an identical procedure is used to clean similar surfaces and is followed by abrasive blasting, the procedure can safely be presumed to adequately remove contamination.

I feel compelled to point out that this is a go-no go test and not a recommended procedure. Do not wait 72 hours after blasting before applying the first coat of paint as a routine painting practice. This test does seem to contradict the common specification requirement to apply the first coat immediately after blasting and before any rustback occurs. But clean steel does not form rustback unless water impinges or condenses upon it. Salt-contaminated steel rusts back at a rate dependent only upon the amount of contamination and the level of moisture available in the air. Nevertheless, it is still the best painting practice to get the first coat on clean steel as soon as possible, because virtually all air includes some contaminants.

Our industry is moving closer to the day that steel known to have corroded from salt and/or steel known to have been exposed to salt atmospheres will routinely be washed with water at some elevated pressure prior to abrasive blasting. As this technology progresses, we will also learn whether our reservations about coating over rust and the resulting failures came from the rust being dirty or contaminated.

The reader should note that NACE International is adding the following definitions to its glossaries, and I hope and expect that SSPC will follow suit.
Pit—a surface anomaly, usually round in shape, a cavity equal to or greater in depth than the diameter at the opening.

Crater—a surface anomaly with the minimum dimension at the opening greater than the depth.

Reader Response

On Overspray from Epoxy Mastics when Overcoating Lead Paint

From Melvin Y. Zucker, Yale Corporation, Portland, ME:

If it were not for the presence of lead, we would not be giving much thought to overcoating “old” alkyd systems, as discussed in the August 1993 Problem Solving Forum. If the alkyd system is really old, it probably has not much useful life remaining. I have not found that putting good material on top of old, failing material provides service life worth the effort. I view an old system as an impurity that should be removed, not overcoated. (Most persons wouldn’t be doing anything to it if it weren’t demonstrating signs of failure.) If the system is basically sound with some signs of chalking or if the color has faded, I might consider overcoating, but before I do so, I would test to determine the remaining useful life and weigh the economics of recoating with a shortened service life against removal with a longer service life.

One major drawback attendant to the decision to overcoat is that we still have to face the issue of lead removal. Although contractors are becoming more knowledgeable about lead removal, the prices have been going up, probably because the more they know, the more cautious they become. Certification programs will drive the prices higher.

Overcoating of lead does not relieve us of containment responsibilities. Most overcoat jobs are on surfaces with many failed areas that require removal in those areas. With many such areas, the containment requirements may not consume that many fewer labor hours than full containment.

I have seen overcoating after a sweep blast where there was an assumption, without testing, that only the primer contained lead.

I was surprised to read that one respondent had such bad results overcoating with epoxy mastics. I tested several materials, including a high solids, amine adduct-cured epoxy mastic and a single-component, moisture-curing urethane (MCU). The MCU performed well but not as well as the epoxy mastic. Moreover, when you use MCU as a “primer” over an old system, you must be mindful of the MCU’s limited recoat window. On a very large structure, many days or weeks may be required between the primer application and the topcoat application.
As far as overspray is concerned, epoxies and urethanes are both damaging. If there is a difference, I have never noticed it. If you spray and there’s any wind, you’d better use containment or have a low per occurrence deductible. If you try to contain by a screen downwind of your spraying operation, use a mesh rather than a solid tarp. The drift seems to go around the solid tarps whereas it goes through the woven meshes and deposits the overspray in the mesh.

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