Ultra-high-pressure waterjetting (UHP WJ) is defined by SSPC and NACE as cleaning with water pressures above 30,000 psi. While these high pressures can be effective for cleaning, they are also dangerous.

The Basics
UHP WJ systems consist of a high-pressure pump, hoses and various tools. The hydraulic hoses used must have a bursting strength of 2.5 times the maximum-rated operating capacity; a 30,000 psi unit requires hoses with a minimum bursting strength of 75,000 psi. The tools used in field surface preparation consist of a control valve, lance (wand) and nozzle assembly. These tools can be manual or robotic (automated). In manually operated systems, this nozzle is usually referred to as the jetting gun. The control valve is operated by a trigger, which is protected by a trigger guard. The lance is a section of metal pipe that allows the operator to point the nozzle assembly at the surface. Robotic systems use tools such as wall crawlers or articulating arms to direct the high pressure water, and can also include a vacuum system to contain water and debris. The nozzle assembly contains the jets, which are orifices or tips that have very small openings. Tools can have a single jet, a fan-shaped jet or multiple rotating jets. The most common arrangement on UHP WJ equipment for cleaning steel is a rotating multiple-jet assembly. A single jet has a very small blast pattern. Multiple jets on a rotating head increase the size of the blast pattern to increase productivity. Rotation also increases the cutting action.

With UHP WJ, the pressure (i.e., velocity) of the water is the main energy characteristic that performs the cleaning. This is different from high-pressure waterjetting (HP WJ) units that operate between 10,000 and 30,000 psi, where flow rate plays a role equal to water velocity in cleaning. Pressure falls off quickly with distance. Productive cleaning with UHP WJ requires keeping the nozzle .25 to .5 inches from the surface. HP WJ units, where flow rate contributes to cleaning, are normally held 2 to 10 inches from the surface. UHP WJ requires closer stand-off distance, yet is, however, especially dangerous at close distances. The closer you are to the surface, the closer the wand end is to your body and the more you are at risk.

Safety Hazards
Water pressure of 30,000 psi is extremely powerful and dangerous. The main safety hazards associated with UHP WJ are injection and fatigue.

UHP WJ can cut skin and bones at close distances. Air injection equipment used to give vaccinations operates at about 600 psi; UHP WJ units use pressures about 50 to 90 times higher. A waterjet striking you from several centimeters can easily pene-

Editor’s Note: This Applicator Training Bulletin was originally written by Lloyd Smith, Ph.D., of Corrosion Control Consultants and Labs and appeared in the December 2005 issue of JPCL. The article was updated for this issue by Peter Wright of the WaterJet Technology Association-Industrial & Municipal Cleaning Association (WJTA-IMCA).
trate the skin. If this happens, you may not see the full extent of the injury. The entry wound may be quite small and may not bleed, but there is no telling how much water was injected into the body or if any internal damage was done. Microorganisms can enter through the wound and spread inside the body.

If an accident occurs that penetrates the skin, medical attention should be sought immediately. If it is not possible to have the injury treated immediately, restrict first aid to dressing the wound and observing the person until a medical examination can be performed. The injury should be monitored by a physician for several days to make sure that infection does not occur. Because physicians may not be immediately familiar with the dangers of a high-pressure injection injury and may treat only the superficial wound, it is recommended that operators carry a card detailing dangers and emergency treatment of a waterjet injection injury. These cards are available from the WJTA-IMCA.

Another possibility in addition to injection is that skin or flesh can be removed. This takes less than 0.1 seconds if the wand is swept past an unprotected body part.

An associated safety hazard is a hose rupture. Experience has shown that 90 to 95 percent of hose ruptures occur 5 to 10 inches from the connection to the lance. A hit from a waterjet at close distance to the abdomen or neck can be fatal. Special hose protection that is attached to the hose near the lance is available to protect against being hit by these types of hose ruptures.

Fatigue is another problem associated with waterjetting. This results from the back

Fig. 2: Automated systems, such as this robotic wall crawler, allow operators to keep a safe distance from the surface being cleaned during UHP waterjetting. Photo courtesy of NLB Corp.
thrust of the equipment. Back thrust can be calculated from the equation:

\[
\text{Back thrust (lbs.)} = 0.052 \times Q \times P^{1/2}
\]

where:

\(Q\) = flow rate (U.S. gal./min)

\(P\) = jet pressure (psi)

For example, an operator working with a jet at 30,000 psi and using 6 gal./min. will experience a force equal to 54 lbs. It is recommended for a person to be able to withstand a back thrust of up to one-third of his or her body weight. Fatigue can happen in minutes or less, depending on the worker. Therefore, the operator for this example should weigh at least 162 lbs.

Safety Equipment

Proper personal protective equipment (PPE) should be worn when using UHP WJ equipment. This includes head, eye, body, foot, hand, hearing and respiratory protection.

Head and eye protection should be worn at all times. The head protection should include a full face shield and/or eye protection such as goggles for visibility. Water droplets forming on goggles or face shields may be a nuisance, but it is still easier to see through wet goggles than it is when you get water directly in your eyes. In addition, material removed from the surface can get into the eyes if they are not protected.

Waterproof clothing must be worn to protect the body. The garment should completely cover the operator, including the arms and legs. Regular work clothes will quickly become saturated with water. The protective clothing should have an outer layer that repels rebounding water and provides protection from rebounding debris. Most typical wet suits worn by operators will not stop penetration of the waterjet into the skin if the nozzle gets too close to the body.

PPE designed and certified specifically for UHP WJ is recommended for the operator. This special UHP WJ protective clothing is made from high-strength materials that can take the sweep of the jet at a distance of 3 inches and up to 43,500 psi without penetration. The type of nozzle and time duration that the nozzle is directed at the material is also important. Rotary nozzles disperse water over a larger area, and a single-orifice nozzle is a more concentrated force on a smaller area. The faster that the nozzle is swept over the surface, the lower the chance for injury.

Feet are especially susceptible to inadvertent exposure to the waterjets at close distance if the operator should point the lance down without shutting off the equipment. Waterproof boots with steel toe caps should
be worn by everyone on the job. The operator should also wear a metatarsal guard atop the boots and hands should be protected with plastic-coated or rubber gloves.

Hearing protection is also needed because UHP WJ can generate over 90 decibels in the operator’s hearing zone.

Respiratory protection may be required, depending on the hazards associated with the materials being removed. The selection of respirator type depends on the severity of the hazard. Water does suppress dust, so the need for respiratory protection is reduced compared to using dry methods of surface preparation. A qualified safety or health professional should be involved in risk assessment and selection of respirator type. Be aware that filter cartridge respirators can become saturated with water for anyone close to the waterjetting, especially the operator, which can lead to difficulty breathing. Because of this, supplied-air respirators are recommended for UHP WJ if respiratory protection is needed. Note also that other aspects of a worker protection program may be required if a hazardous material is being removed.

**Equipment Operation**

Safety in UHP WJ includes proper care and operation of equipment. The equipment should be inspected before use. Hoses should be checked for evidence of damage, wear or imperfections. This can include compromised wire braids, mechanical damage such as flat spots, crimping or damage to the threads on the hose end. All hoses and hose connections should be checked to make sure they are rated for use at the pressures to be used. WJTA-IMCA has recommended a color coding scheme for pressure hoses to help identify their maximum allowable working pressure. Hoses should also be marked with their maximum working pressure. Hoses should be laid out to avoid creating tripping hazards, and they should be protected from being run over and crushed by forklifts or other vehicles and to avoid or minimize abrasive wear. The fittings should be cleaned before installing them into the system.

Once installed, the fittings should be checked to make sure the connections are leak free. The point where the hose connects to the gun should be fitted with a hose shroud that will protect the operator from high-pressure water if the hose, pipe or fitting breaks open. A hose shroud consists of a length of heavy-duty hose or a shoulder guard, generally 6 feet, but sometimes longer. The shroud should be inspect-
ed before each use and removed from service if a hose burst occurs within it.

The system should be flushed with clean water before use to remove any contaminants that may clog the nozzles. The orifices in the nozzles should be checked for blockage, damage or imperfections. The orifices do wear out and need to be replaced regularly. After the system has been checked, it should be slowly pressurized to make sure the nozzle openings are open and clear. A clogged orifice, especially on a setup with multiple nozzles or a self-rotating nozzle assembly, can be very dangerous. When a nozzle assembly contains multiple offset nozzles, clogging of one nozzle puts the sideways forces off-balance, causing the tool to suddenly be thrust to one side and the worker to lose his or her balance.

In addition to the hoses, the unit should be visually checked. All fittings should be tight and leak free. UHP WJ units are equipped with a bursting or rupture disc located on the pump. This is normally a metal disc in a specially designed holder. The disc is similar in purpose to a relief valve on a hot water heater. The disc is meant to fail (burst or rupture) if the pressure applied to it exceeds a set level. A properly sized disc must be used for a given operating pressure.

While the system is under pressure, no nut, hose connection, fitting or other component of the equipment should be tightened or otherwise adjusted apart from the normal adjusting of valves and other components required for proper equipment operation. The pumps must be stopped, and any pressure in the lines must be discharged before adjustments or repairs are made.

Waterjetting requires at least two people. One operates the pump, and the other operates the gun. There are no controls on the gun except the trigger and a dump valve. The dump valve is a safety device similar to a deadman switch on a dry abrasive blast setup that controls a dump system that will shut down the pump, idle it to low speed, bypass the water flow or reduce the discharge pressure to a low level. This is a very important safety device for the personal protection of the gun operator. It should be on every gun, and it should be operational.

There needs to be good coordination between the pump and gun operators. The pump operator should bring the pressure up slowly, and only after the gun operator has signaled that he or she is ready. The gun operator needs firm footing and should hold the gun in the operating position. Some
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guns have a shoulder stock that needs to be in position before pressurizing begins. The operator must be prepared for the back thrust that will develop as the pressure increases. Preparation usually consists of leaning forward and letting the back thrust straighten you up. The pump operator should not change the operating pressure unless the nozzle operator is aware that an adjustment is going to occur. The pressure should be slowly reduced at shutdown so the gun operator does not lose his or her balance.

The gun operator needs to be aware of the change in thrust if the system fails or if the dump valve is activated. This awareness comes from experience, i.e., activate the dump valve a few times until you are familiar with how to position yourself to withstand the change in thrust.

The work area should have a warning barrier such as a barricade or tape when UHP WJ is in operation. Warning signs should be posted to tell others to stay out of this hazardous area. No unauthorized person should be allowed in the work area. If two or more gun operators are working in an area, a physical barrier should be installed or the workers should be adequately spaced to prevent one worker from accidentally injuring another.

The pump operator should be in visual contact with the gun operator at all times. If this is not possible due to layout of the site, another worker should be positioned where both operators are in sight to relay signals, such as the gun operator signaling the pump operator to shut down the system. The pump and gun operators should establish hand signals to use because the equipment and operation are so noisy.

Whenever work stops, the system should be depressurized. Even though there is a trigger guard to protect against accidental operation of the system, there is a small possibility of accidental actuation if the gun were to fall or move. If the system is not depressurized, there is a greater possibility of a hose rupture or leak that cannot be reacted to immediately if workers are on break.

**Conclusion**

UHP WJ has inherent dangers because of the high pressures involved. Serious bodily harm can occur if the equipment is not used properly or proper personal protective equipment is not worn. A good source of information is “Recommended Practices for the Use of High Pressure Water Jetting Equipment,” published by the WJTA-IMCA (www.wjeta.org).