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Evaluation of Wet Blast Cleaning Units

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It is universally acknowledged that dry abrasive blasting is the most efficient and economical technique for cleaning structural steel for painting in industrial applications. The abrasive blasting unit delivers to the surface a high velocity stream of hard, angular abrasive, which has the ability to rapidly remove existing paints, rust, and millscale to roughen the base metal for improved adhesion. The equipment and techniques for dry blasting have become fairly well standardized and provide a high degree of reliability.

Dry blasting has been restricted in recent years because of health hazards from silica dust inhalation; air quality concerns with visibility, suspended particulates, and fugitive or nuisance dust; and dust contamination of machinery or equipment. There has also been concern about the disposition of the spent abrasive, which may contain lead compounds or other toxic materials from the paint film.

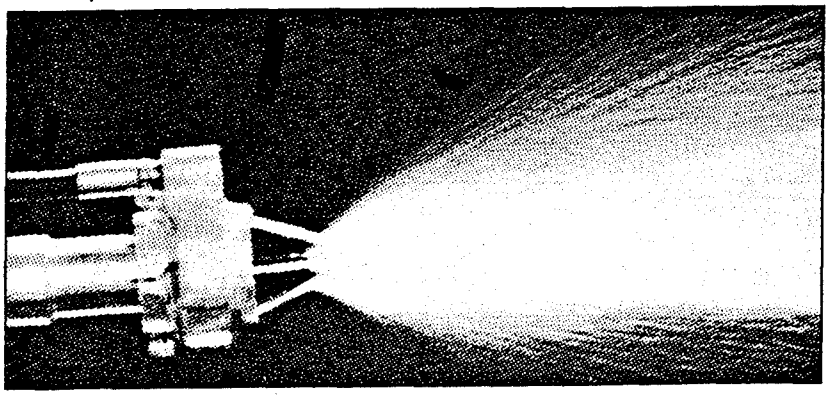
Alternatives to sand blasting include silica-free or low-dusting abrasives, high pressure water blasting, wet sandblasting, and power tool cleaning. Alternative abrasives such as mineral slags often eliminate the silica hazard, but these abrasives may be more expensive or more difficult to obtain than sand, and some have recently been under attack for trace concentrations of toxic heavy metals. High pressure water blasting and hand and power tool cleaning are suitable for removing loose rust and paint. However, high pressure water blasting cannot remove tight millscale, tight rust, and paint, and while some power tools are available for the removal of tight residues, they are less efficient than blast cleaning. Other new techniques have been described, but have not yet proven practical for large scale production cleaning of steel.

Wet abrasive blasting offers the potential to reduce or eliminate many of the problems associated with dry blasting and at the same time offers relatively high production rates and cleaning efficiency.

There are several generic types of wet blasting equipment with large variabilities in operating parameters, reliability, cleaning rates and effectiveness, cost, safety, and user satisfaction. This article describes the results of field evaluations of several different types and manufacturers of equipment for wet blasting.

The emphasis of this study, sponsored by the National Shipbuilding Research Program, the Federal Highway Administration, and the US Army Corps of Engineers, was on field demonstrations rather than literature values or second-hand accounts. From a review of trade and technical literature, and public requests for information, ten different wet blast units were selected for field evaluation. These evaluations were conducted on steel surfaces typically encountered in marine, highway, and water works maintenance, such as rusted and pitted steel, millscale-covered steel, and painted steel. For each demonstration, the representative structures were cleaned using wet blast techniques and dry blast cleaning controls, with careful documentation of cleaning rates, cleanliness, and other factors required for the evaluation.

Fig. 1. Conical water ring (side view)
Courtesy of Clemtex, Inc.



DESCRIPTION OF UNITS AND TECHNOLOGY

Wet blast units can be categorized into four major types as shown in Table 1. Two of these involve air abrasive blasting with water addition. The others are pressurized water blasting with and without abrasives. The basic principles and variations of these types of wet blasting

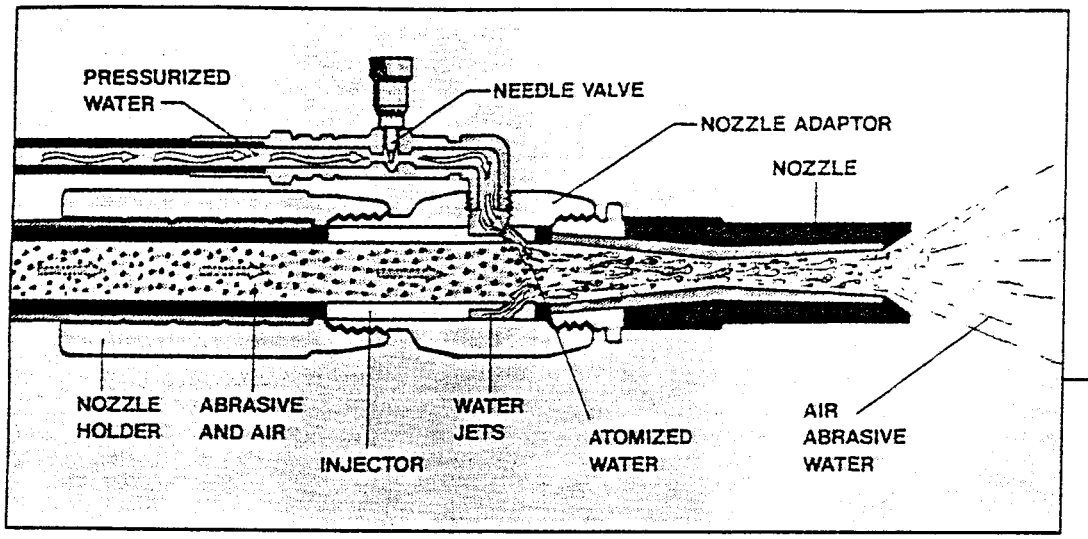


Fig. 2. Nozzle for air abrasive wet blast
Courtesy of Clemco Industries

Table 1
Classification of Wet Blasting Units

Air Abrasive Wet Blasting

Air/Water/Abrasive Slurry Blasting

Pressurized Water Abrasive Blasting
- High Pressure Water
  6,000 psi to 15,000 psi
- Low Pressure Water
  2,000 psi to 4,000 psi

Ultra High Pressure Water Jetting
20,000 psi to 50,000 psi

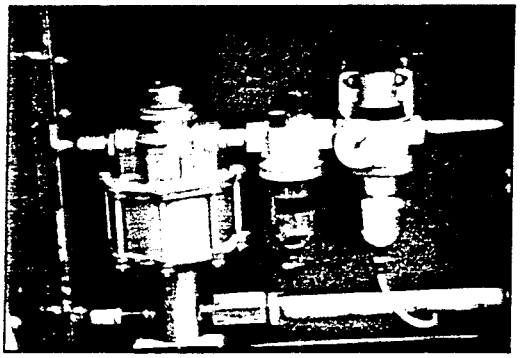


Fig. 3. Control unit for retrofit air abrasive wet blast
Courtesy of Clemco Industries

will be reviewed briefly. The discussion will also review the most important features and components of the various types of systems investigated.

Air Abrasive Wet Blasting

The air abrasive wet blasting units vary with respect to the method and location of water addition, the type of control system, the device for adding and monitoring inhibitor, and the design of the nozzle and the overall system. Water can be added downstream of the nozzle, just before the sand enters the nozzle, or at the source of the abrasive (air/water/abrasive slurry blasting). One of the earliest methods was the water envelopment process or "water curtain method," which projects a cone of water around the stream of air and abrasive as it leaves the nozzle. A simple water ring adaptor fits around the blasting hoze nozzle. This technique is reported to reduce the airborne dust by about 50 percent to 75 percent. It has a minimal effect on the cleaning rate because the water does not mix with the abrasive. It does make the unit slightly more unwieldy and could affect cleaning rate in that manner.

The water stream could also be sprayed into the abrasive stream beyond the nozzle (Fig. 1). This gives a greater degree of dust control than the water envelope method because the abrasive is wet before it reaches the surface.

In the second type of air abrasive wet blasting, the water is added to the abrasive just before it reaches the nozzle. In one version, a nozzle adaptor is mounted between the nozzle holder and nozzle (Fig. 2). Pressurized water from an air-operated pump is controlled with a needle valve. The water pressure is normally on the order of 300 psi to 800 psi. For many of these units, the water and sand can be operated independently. Thus, for example, by closing the needle valve, one can dry sandblast in areas where wet blasting may not be needed. Also, by releasing the nozzle handle, one can use low pressure water to wash off the sand from the surface.

These units may be designed as retrofits (Fig. 3) for existing abrasive blasting units or sold as complete units, including abrasive blast machine, air powered pump, and a mixing tank (Fig. 4). These types of units are also very effective in reducing the amount of dust.

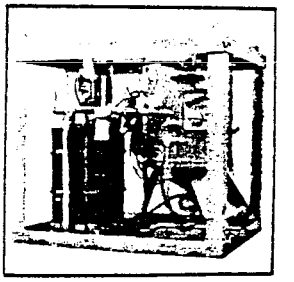


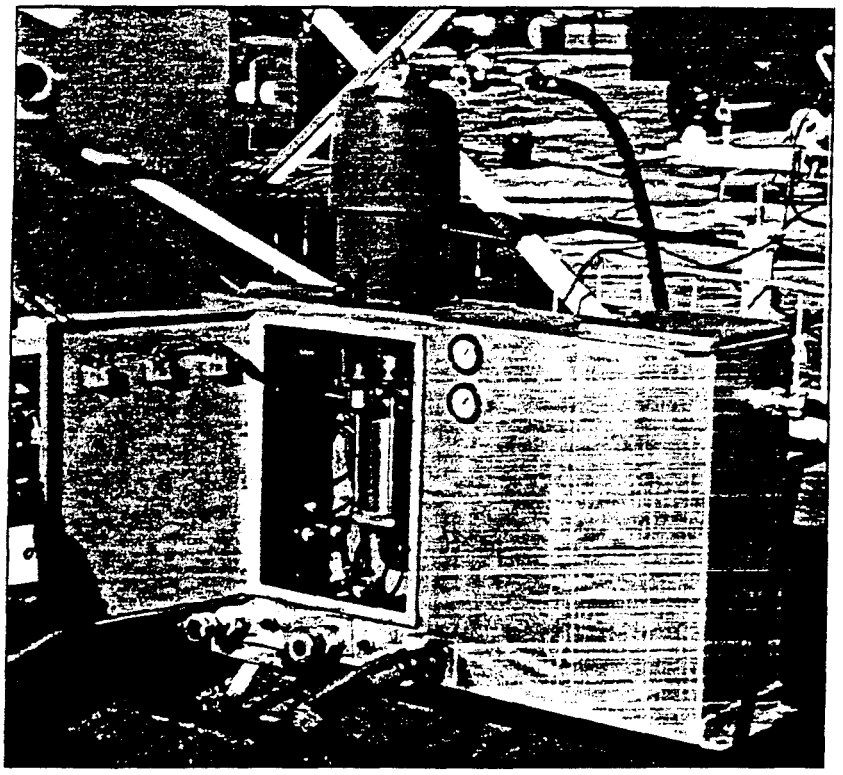
Fig. 4. Control unit for air abrasive wet blast (complete system)
Courtesy of Clemtex, Inc.

Air/Water/Abrasive Slurry Blasting

Another technique is addition of water to the abrasive stream at the control unit upstream of the nozzle. In these systems, the mixture of air, water, and sand is propelled through the

hose to the nozzle without any additional coupling at the nozzle. In several of these units the air, water, and sand can be independently controlled by the operator, either by microswitches at his control, or remotely, by another operator, who may be in audio contact with the blaster. As with the previous types of systems, these units allow the operator to rinse off the wet sand from the surface with pure water, often containing an inhibitor. Certain units can be used to feather back paint by reducing the air pressure, resulting in a less erosive slurry stream. Because the sand is intimately mixed with the water, these units are extremely effective in reducing the amount of dust (Fig. 5).

Fig. 5. Control unit for air/water/abrasive slurry blast
Courtesy of Williams Contracting Group, Inc.



High Pressure Water Blasting

High pressure water blasting is a technique which produces a high velocity stream of water by passing a flow of pressurized water through a specially designed small orifice nozzle. This jet has some erosive force and has been utilized for removing paints and corrosion products from structural steel. The principal focus of this evaluation is on water blasting with abrasives rather than on pure water blasting. However, for comparison purposes, several of the high pressure units were operated without abrasives. In addition, one unit was observed that was designed to be operated without sand because of the extremely high pressures attained.

The major components of a water blasting unit are

- positive displacement pump and appropriate power unit,
- high pressure hydraulic delivery hose,
- high pressure nozzle, and
- control valve system.

Other components include water filter, pressure gauge, flow meter, inhibitor, and metering and monitoring attachments.

High pressure water blasting without sand has not shown the capability of removing tight rust or intact millscale from steel except at exceedingly slow rates or at ultra high pressures (> 30,000 psi). In addition, it cannot produce a profile (surface roughening) of the steel itself. In order to introduce additional erosive force into water blasting, abrasives must be incorporated into the water jet.

Pressurized Water Abrasive Blasting

High pressure units use water pressures from 6,000 psi to 20,000 psi. The flow rates are normally 5 gallons to 15 gallons of water per minute. These units require a different type of nozzle than used for straight high pressure water jetting. The nozzle orifice must be large enough (typically 3/8 in.) to permit the abrasive to pass through.

Also observed were several units which operated at substantially lower pressures and thrust rates than those given above (Fig. 6). Water blasters with pressures of 3,000 psi to 4,000 psi would be expected to provide much greater ease of handling and safety than the high pressure units. A few of these were simply high pressure units operated at reduced

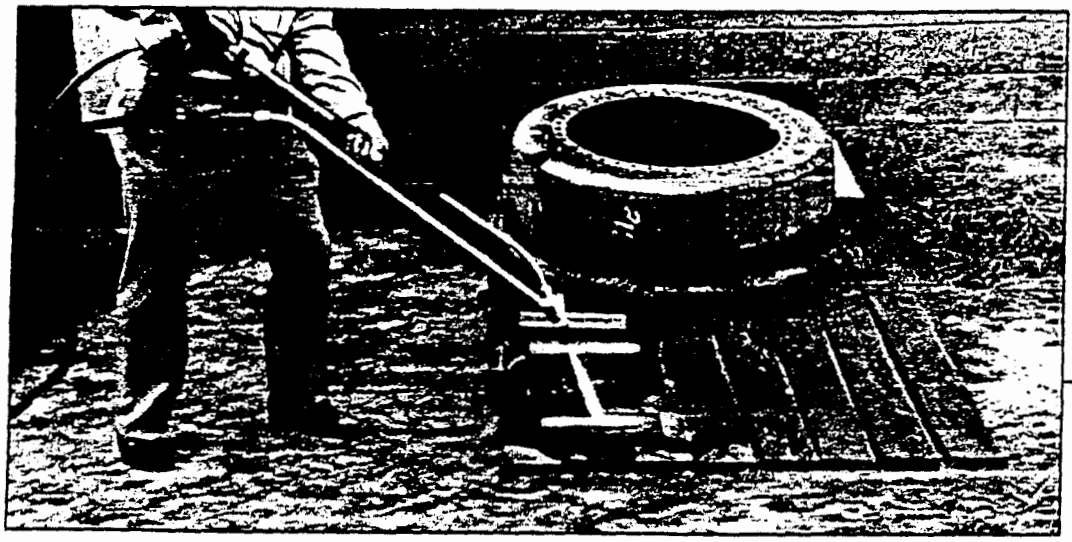


Fig. 6. Low pressure water sand blasting (patented nozzle design); note path width.

pressures. Others were designed for use at lower pressures.

Operator Back Thrust

An important consideration is the amount of thrust that the operator must withstand in using a high pressure water blaster; thrust depends on the pressure, flow rate, and the nozzle orifice. It is noted that an operator thrust of greater than about 35 or 40 lbs can become very fatiguing after a relatively short period of time. Thrusts above 50 lbs cannot be controlled manually.

Table 2
Operator Back Thrust with Water Jet

Pressure (psi)	Flow Rate (gpm)	Thrust[a] (lbs)
20,000	10	75
20,000	7	52
10,000	10	53
10,000	6	32
5,000	8	30
5,000	4	15
3,000	4	12

[a]Computed from 0.053 × flow rate (gpm) × $\sqrt{\text{pressure (psi)}}$; Sullivan, J. A., *Fundamentals of Fluid Machines*, Prentice Hall, 1978.

Water-Abrasive Nozzles

There are several nozzle designs available which introduce the abrasive into the water stream. Most of these rely on suction by the water stream to pull the abrasives into the nozzle.

In a typical design for introducing abrasives into the water stream, water enters the nozzle at a 90-degree angle through tiny orifice inserts (Fig. 7). A recently patented alternate design is claimed to make it possible for the water to maintain the maximum velocity, minimize the loss of energy, and deliver more abrasive at higher impact (Fig. 8).

A discussion of the relative merits of these nozzles is beyond the scope of this investigation. However, it was noted that there were considerable differences in the cleaning rates of several of the units tested, which could be attributable to the design variables.

Another important parameter in water blasting, both with and without abrasive, is the standoff distance. At a small standoff (less than 2 in.), the force of the jet on the surface is greatest, resulting in the highest degree of erosion. However, this also results in a smaller path width and a lower overall cleaning rate.

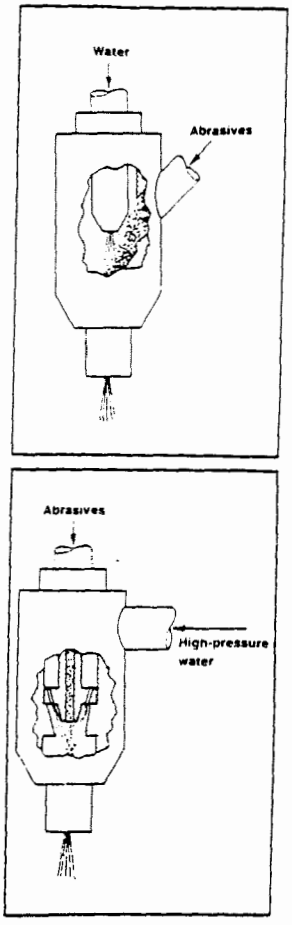


Fig. 7. Comparison of single- (above) and multi-orifice nozzle (below) Courtesy of ECEC Cleaning

Inhibitors

Because of the tendency of wet steel to corrode rapidly (flash rust), inhibiting chemicals are often applied to the freshly blasted steel surface. The inhibitors are usually water soluble chemicals which prevent corrosion by passivating the steel surface (slow down corrosion by increasing the polarization).

Many commercial inhibitors use a combination of nitrite and phosphate. The use of chromate inhibitors has greatly diminished because of the problems of chromate disposal.

There are as yet no standard or prescribed concentrations for the nitrite and phosphate inhibitors in water or wet blasting. Typical values recommended by equipment manufacturers range from 100 to 3,000 parts per million (ppm). There is little data relating the quantity of inhibitor needed per area to the time of protection afforded in environments of varying degrees of severity. There is also little data comparing the merits of the different inhibitors. In several of the demonstrations, the inhibitor did prevent the flash rusting that was observed to

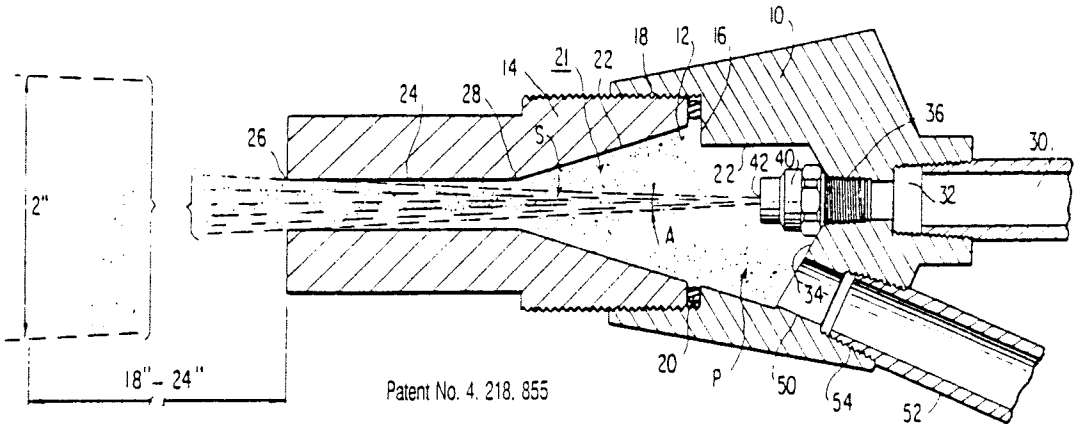


Fig. 8. Low pressure water abrasive nozzle (single orifice)
Courtesy of Hydrosander, Inc.

occur in the absence of the inhibitor.

Another important criterion of the inhibitor is its effect on the performance of the paint applied over it. The inhibitors are water soluble species which tend to form crystalline materials upon evaporation of the water. Thus, osmotic blistering may result from the soluble salt on the surface. There is as yet little substantiated data to show what, if any, effect these inhibitors have on paint performance.

FIELD DEMONSTRATIONS

A total of ten different wet blast units were observed in field demonstrations. At several of these demonstrations wet blast units were compared directly with dry blast units on equivalent surfaces. These data were considered most reliable. Data were also obtained from other field demonstrations in which only small surface areas were cleaned, or in which the dry blast control was inadequate or nonexistent. Data from these latter demonstrations and from evaluations by other users or manufacturers were given less weight in assessing the relative merits of the various wet blast units.

Two of the major demonstrations included direct comparisons of high-pressure water sandblasting (Fig. 9), air abrasive wet blasting (Fig. 10), and dry blasting. At the first of these, conducted at a painting contractor's yard facility, areas of approximately 12 sq ft were cleaned to near white metal; original surfaces included slightly rusting inorganic zinc, rusted and pitted steel, and plates with heavy layers of paint. The data showed that the two air abrasive wet blast units and the dry sand units had fairly comparable cleaning rates while the high pressure water-sandblaster was considerably slower. The water ring unit gave higher cleaning rates than the dry sand for the thick paint film.

The second major demonstration was held at a distributor's yard in Houston, TX. The three units were evaluated on flat steel containing millscale and moderate rust, and on a heavily rusted steel beam. In this test, the air abrasive wet blaster cleaned at a slightly higher rate than the dry blast. Again, the high pressure water-sand blast was considerably slower. Sand consumption rates of the latter were also higher than the former two.

An air/water/sand unit (Fig. 11) was compared to dry sand blasting at a yard facility in Atlanta, GA. The substrates were steel plates with two grades of rust and some structural pieces. In these, the dry sand was 20 percent to 40 percent more efficient in cleaning. In this evaluation, the time for cleaning the sand from the surface was included in the rate. The dry sandblasted surfaces were slightly better cleaned than the wet blasted surfaces.

Another air/water/sand unit was compared to dry blasting on a highway bridge in New Orleans, LA. In this case the dry abrasives (both sand and coal slag) were several times more efficient than the air/water/sand unit. The lower cleaning rate obtained with the air/water/sand unit can be partly attributed to the operator inexperience and some variability in the surface condition of the bridge. Even making these allowances, however, air/water/sand was much slower for this type of cleaning than the dry blast units.

The results of these and other field demonstrations are summarized in Table 3.

DISCUSSION OF FINDINGS

In selecting a surface preparation unit, or evaluating such units, there are several factors that must be considered. These include the following: cleaning rates, cleaning effectiveness, equipment reliability, safety, portability and versatility of equipment, and cost.

Cleaning Rates

Overall, the cleaning rates with the air abrasive wet blasting were considerably higher than those using high pressure water. The former were approximately in the range of 80 percent to 90 percent the rates of dry blasting. The cleaning rates with high pressure water abrasive blasting were about 30 percent to 50



Fig. 9. High pressure water sand blasting

percent that of dry blasting, but were not as well documented as the air-driven systems. The cleaning rate is increased at higher pressures or flow rates, but these also increase the thrust and the difficulty of controlling.

Most of the rates quoted in the tables did not include times for setup and cleanup. In most cases, the clean-up rate and expense are expected to be higher for the wet cleaning methods than for dry blasting.

Cleaning rates also depend on the skill of the operator. The high pressure water/sand-blaster and, to a lesser degree, the air abrasive wet blasting reduce visibility. This often decreases cleaning rates because the operator cannot judge when he has sufficiently cleaned the surface and may repeat or miss some areas. In addition, for the high pressure abrasive blaster, the stand-off distance and the angle of blasting affect cleaning rates. They will vary with the velocity of the jet (water pressure), nature of substrate, and the type of cleaning (e.g., removing of topcoat or cleaning to bare metal). The slurry blasting and the air abrasive wet blasting cleaning rates, as with any air blasting, depend on the air pressure.

Several of the lower pressure water abrasive blasting units gave cleaning rates that would be acceptable for many small to medium sized jobs. This would be particularly true for cleaning intricate structures or for maintenance crews. The rates for these units are estimated at 15 percent to 25 percent that of dry blasting.

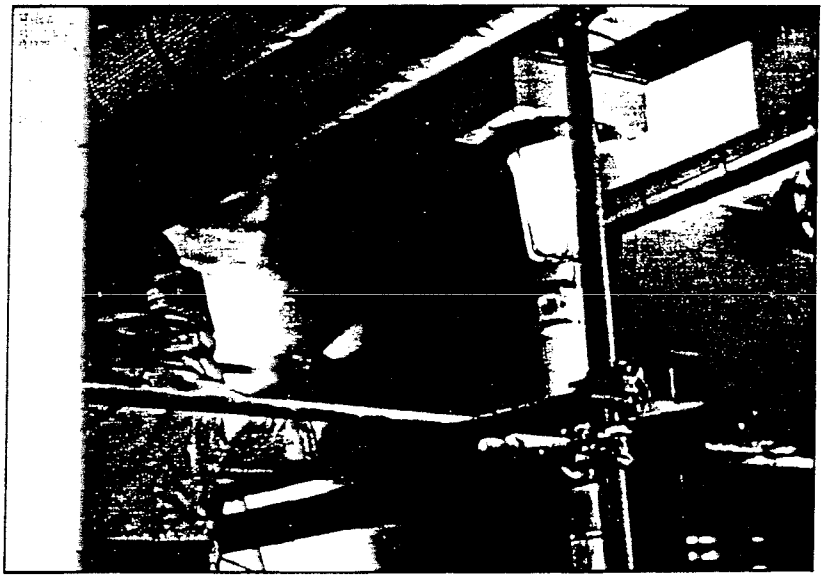


Fig. 10. Air abrasive wet blasting (retrofit model)



Fig. 11. Air water sand blasting

Cleaning Effectiveness

The major factors in determining effectiveness are

- visual cleanliness (removal of rust, millscale, paint, and dirt);
- chemical cleanliness (removal of oil film and soluble salts such as chlorides and sulfate); and
- surface profile.

Each of the types of wet blast units was capable of producing near white metal. However, in most of the observed demonstrations, the operator did not achieve a surface of 100 percent near white (SSPC-SP 10). Portions of the surface were rated as commercial blast

Table 3
Summary of Field Demonstrations

Air Pressured Units

Type of Unit	Nozzle Pressure (psi)	Nozzle Diameter (in.)	Water Flow (gpm)	Sand Consumption (lbs/sq ft)	Total Area Cleaned (sq ft)	Cleaning Rates Versus Dry Blast (%)	Comments
Air Wet Blast	90 to 100	0.5	0.5	5	60	70 to 140	2 separate demos
Air Wet Blast	90 to 100	0.5	5 to 10	—	36	90 to 200+	water ring
Air Wet Blast	~100	0.375	1	—	~100	60 to 70	retrofit to dry blast
Slurry Blast	85	0.375	2	—	50	60 to 80	micro switch control
Slurry Blast	90	0.5	0.5	—	10	20	easy to maneuver; walkie-talkie control

Water Pressured Units

Type of Unit	Nozzle Design	Water Pressure/Flow (psi)	Water Pressure/Flow (gpm)	Thrust Compute (lbs)	Sand Consumption (lbs/sq ft)	Total Area Cleaned (sq ft)	Cleaning Rate Versus Dry Blast (%)	Comments
Sand Suction	multi-orifice	10,000	10	50[a]	11	16	30 to 40	highly fatiguing; 2 demonstrations
Sand Suction	—	10,000	8 to 10	40 to 50[a]	4 to 6	30	30 to 80	highly fatiguing
Low Pressure	multi-orifice	4,000	—	—	—	7	[b]	easy to control
Low Pressure Sand Suction	single orifice 4° cone	3,000	—	11[a]	600 lbs/hr	4	[b]	easy to control; efficient cleaning
Water Jet No Sand	straight or fan jet	20,000	9 to 10	65	—	10	[b]	could not remove tight millscale; extremely fatiguing

[a] Using formula for pure water
[b] Suitable dry blast unit not available

(SSPC-SP 6) or brush-off blast (SSPC-SP 7). This is attributed primarily to the lack of visibility.

Thus, the lesser degrees of cleaning were obtained on corners and bottom edges where visibility was poorest. Overall, the air/water/abrasive slurry blasters gave the best visibility and slightly more thorough cleaning than air abrasive wet blasting. For the high pressure water-abrasive blasters, the operator fatigue and poor visibility resulted in less well cleaned surfaces.

A number of technical articles and trade literature have asserted that wet blasting methods are superior to dry blasting in removing soluble salts from steel. These salts are often considered to contribute to early rusting of previously exposed structures. However, determining the presence, levels, or effects of the soluble salts was beyond the scope of the present investigation.

For most of the demonstrations, surface profile of the blasted steel was measured using

Although air abrasive wet blasting does cut down considerably on the dust, the use of air-fed respirators is still strongly recommended.

replica tape and/or comparator. The data did not show any difference in profile obtained with wet blasting versus dry blasting.

Safety

• *Pressurized Water-Abrasive Blasting* — The use of high pressure water jetting or air abrasive blasting can be dangerous. The same is obviously true for the wet blasting techniques and most of the same precautions must be observed. General safety requirements include dead-man controls on pressurized units, operating within the recommended limits of the air compressor or pump, properly reinforced hose, proper scaffolding, removing unnecessary clutter or obstructions from work area, cordoning off work areas, and properly trained operators.

Some of the most important safety factors for high pressure water jetting are as follows.

- Ear Protection — Typical noise levels are in the range of 90 decibels.
- Team Versus Single Operation — One organization recommends that a single operator be allowed to operate units only up to 2,000 psi; above that at least two persons are required.
- Eye and Head Protection — At the minimum, goggles and face shield are required. Full over-the-head hoods may be required in some cases.
- Safety Fluid Shutoff — This should be a dump device which cuts off the pressure when the handle is released.
- Gradual Increase of Thrust — The operators should experience the reaction force (thrust) progressively rather than all at once to start the operation.
- Steel Toed Shoes.

Several instances have occurred where operators have lost a toe or an eye from high pressure water jetting. It should be emphasized that the high pressure flow rate units have a high operator thrust (40 lbs to 50 lbs) and may be very difficult to control safely on a platform or other area of precarious footing.

• *Air Abrasive Wet Blasting* — One of the most important safety features is the cutoff valve for the air blast nozzle. In at least one of the demonstrations, we observed operators using defective nozzles. The safety lock, designed to shut off the flow when the grip is released, failed to do so, or did so sporadically. This demonstrates the importance of proper maintenance of equipment and enforcement of safety procedures.

Although air abrasive wet blasting does cut down considerably on the dust, the use of air-fed respirators is still strongly recommended. There is little documentation on the effect of wet blasting on reducing the level of micron-sized particulates in the area immediately around the blaster. Thus, whereas these units apparently are successful in controlling environmental problems, they are still considered a possible hazard for worker health. This is particularly relevant in light of the numerous claims on silicosis currently existing against manufacturers of abrasive equipment.

There is little evidence that the use of wet abrasive blasting in any way reduces the risk of sparking from the blast nozzle. Thus, their use in tanks or vessels containing volatile materials must still be closely controlled and monitored.

Portability and Versatility

The present investigation was directed at field cleaning of steel. The ease with which various units can be transported, assembled, and transferred is an important factor in their suitability for certain jobs.

Naturally, smaller cleaning units will require smaller compressors, pumps, and sand pots and therefore be more easily transported. Weighed against that is the lower productivity rate and efficiency of the low-powered units.

The high pressure water hoses experience a relatively small loss of pressure. This enables the operator to reach several hundred feet without relocating the pump. For water jetting at elevated heights, supplemental boosters are available to maintain the high pressure. In addition, pressurized sand hoppers can be used to force the sand over large distances of hose.

Air blast hoses for wet or dry abrasive blasting are normally limited to about 100 ft to 200 ft unless very large compressors are used.

Table 4
Advantages and Disadvantages of Wet Blast Units

	Advantages	Disadvantages
Air Wet Blast	high rates reduce dust retrofit	extra hose sludge cleanup
Slurry Blast	high rates multi nozzles reduce dust low water	higher cost additional operator sludge cleanup
High Pressure Water/Abrasive	greatly reduce dust long hose low abrasive	lower rates high thrust poor visibility high water higher cost
Low Pressure Water/Abrasive	easy to use low cost low abrasive low thrust	low rates short hose
Ultra Pressure Water Jetting	no abrasive simple design cleanest surface	no profile leaves millscale high water high thrust

It is generally advisable to place the sand pot as close to the nozzle as possible.

SUMMARY AND CONCLUSIONS

This article described a field evaluation of commercially available wet blast units for cleaning structural steel for painting. The evaluation included, where possible, direct comparison of the candidate wet blast unit with conventional dry sandblasting. The cleaning was conducted on flat surfaces with varying conditions including paint, millscale, and rust, typically about 10 sq ft to 15 sq ft per trial. The data from the field evaluations was supplemented by data and information from equipment users and manufacturers.

The principal conclusions of this work are as follows.

- Dry sandblasting is overall faster and more effective than any of the wet sandblasting techniques.
- The units which incorporate water into air abrasive blasting produced cleaning rates up to 80 percent to 90 percent of those of dry blasting, and proved very practical for field applications.
- The units which incorporated abrasives into a medium to high pressure water blast (6,000 psi to 20,000 psi) gave cleaning rates which were only about one-third to one-half that of dry blasting. Because of the high thrust of these units, they would not be practical for extended field use as hand held units.
- Certain low pressure (3,000 psi to 4,000 psi) water blasters with abrasive addition have demonstrated the ability to remove rust, paint, and millscale with little operator fatigue. The cleaning rates, however, are considerably lower than conventional dry blasting.
- High pressure water blasting without sand is not capable of removing tight rust and millscale under normal conditions.
- All the wet blast units observed produced a significant reduction in the dust.
- The units observed varied considerably in cost, portability, production capability, and adaptability to existing blast cleaning equipment. The specific unit to be chosen depends on the size and type of job and availability of support equipment.
- Inhibitors are required in the water to prevent flash rusting in most locations. Several types were proven to be effective in controlling flash rusting for at least several hours. The advantages and disadvantages of the various types of units are listed in Table 4. Additional details are provided in the full report available from the US Maritime Administration or the Steel Structures Painting Council. ■

On page 51 of this issue, readers will find a Product Directory describing the wet blast equipment of a number of manufacturers. The Product Directory is a new feature of the Journal *intended to be a monthly buyers' guide for a specific type of product. Typically, the Product Directory will contain descriptions of materials or equipment discussed in one of the* Journal's *feature articles.*