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EVALUATION OF WET BLASTING FOR SHIP APPLICATION

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ABSTRACT

This paper presents the results of a field investigation of equipment and technology for wet abrasive blasting as a technique for preparation of structural steel for painting. Ten different commercially available wet blasting units were selected for field evaluation. The units selected included the following generic types: air abrasive wet blasting (addition of water at the nozzle to conventional dry blasting equipment); air/water/abrasive slurry blasting (mixing of water with the abrasive at a control unit upstream of the nozzle); pressurized water abrasive blasting (abrasive added to high or low pressure water jetting stream); and ultra high pressure water jetting (20,000 psi or greater). These evaluations were conducted on steel surfaces, typically encountered in shipyards and industrial environments, including rusted and pitted steel, milscale steel, and painted steel. The investigation considered factors such as the cleaning rates, abrasive and water consumption, operator thrust, portability, safety procedures required, use of inhibitors, and overall practicability and reliability. The paper discusses each of these factors and provides a tabulation of advantages and disadvantages for each unit observed.

BACKGROUND

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 for improved adhesion. The equipment and techniques for dry blasting have become standardized to a high degree 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 low-dusting abrasives, high pressure water blasting, wet sandblasting, power tool cleaning, and chemical cleaning. Alternative abrasives such as mineral slags often eliminate the silica hazard, but these abrasives may be more expensive or difficult to obtain than sand and have recently been under attack for some trace concentrations of toxic heavy metals. High pressure water blasting and hand and power tool cleaning are suitable for removing loose rust and paint, but cannot remove tight mill scale, tight rust, and paint. 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 was the observation and evaluation of field demonstrations rather than obtaining data 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 evaluation. These evaluations were conducted on steel surfaces typically encountered in marine, highway, and water works maintenance, such as rusted and pitted steel, mill scale 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.

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 will be reviewed briefly. The discussion will also review the most important parameters and 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

TABLE 1
CLASSIFICATION OF WET BLASTING UNITS

Air Abrasive Wet Blasting
Air/Water/Abrasive Slurry Blasting
Pressurized Water Abrasive Blasting
High Pressure Water (6,000-15,000 psi)
Low Pressure Water (2,000-4,000 psi)
Ultra High Pressure Water Jetting-
(20,000-50,000 psi)

system, the device for adding and monitoring inhibitor, and the design of the nozzle and the overall system. Water can be added at the source of the abrasive, just before the sand enters the nozzle, or downstream of the nozzle. 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 adapter fits around the blasting hose nozzle. This technique is reported to reduce the airborne dust by 50-75%. 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. 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 adapter is mounted between the nozzle holder and nozzle. Pressurized water from an air-operated pump is controlled with a needle valve. The water pressure is normally on the order of 300-800 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 the low pressure water to wash off the sand from the surface.

These units may be designed as a retro-fit for existing abrasive blasting units or complete unit, including abrasive blast machine, air powered pump, and a mixing tank. These types of units are extremely effective in reducing the amount of dust.

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 also very effective in reducing the amount of dust.

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 study is on water blasting with abrasives rather than on pure water blasting. However, for comparison purposes, observations were made of several high pressure units operating without abrasives. In addition, a unit that was designed to be operated without sand because of the extremely high pressures attained was observed.

The major components of a water blasting unit are as follows:

- :: Positive displacement pump and appropriate power unit
- * High pressure hydraulic delivery hose
- # High pressure nozzle
- # 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 mill scale from steel except at exceedingly slow rates or at ultra high pressures (greater than 3,000 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 6,000-20,000 psi. The

flow rates are normally five to fifteen gallons of water per minute. These units require a different type of nozzle than that used for straight high pressure water jetting. The nozzle orifice must be large enough (typically 3/8") to permit the abrasives to pass through.

Also observed were several units which operated at substantially lower pressures and rates than those given above. Water blasters with pressures of 3,000-4,000 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 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. Table 2 shows typical thrusts for several pressures and flow rates. It is noted that an operator thrust of greater than about 35-40 pounds can become very fatiguing after a relatively short period of time. Thrusts above 50 pounds cannot be controlled manually.

TABLE 2
OPERATOR BACK THRUST WITH WATER JET

| Pressure (psi) | Flow Rate (gpm) | Thrust (lbs) |
|----------------|-----------------|--------------|
| 20,000 | 10 | 74 |
| 20,000 | | |
| 10,000 | 10 | 53 |
| 10,000 | 6 | |
| 5,000 | 8 | 30 |
| 5,000 | | |
| 3,000 | 4 | 14 |

WATER-ABBRASIVE 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. 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.

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 parameters.

Another important parameter in water blasting, both with and without abrasive, is the standoff distance. At a small standoff (2-3 inches), 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.

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 type inhibitors has greatly diminished because of the problems of chromate disposal.

There are as yet no standard or prescribed concentrations the nitrite and phosphate inhibitors in water or wet blasting. Typical values recommended by equipment manufacturers range from 100-3,000 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 aid prevent the flash rusting which was observed to 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 was 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, air abrasive wet blasting, and dry blasting. In one demonstration, conducted at a painting contractor's yard facility, areas of approximately twelve square feet were cleaned to near-white metal; the original surfaces included plates with slightly rusting inorganic zinc-rich coating, rusted and pitted surfaces, and 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 pressure sandblaster was considerably slower. The water ring unit gave higher cleaning rates than the dry sand for the thick paint film.

Another demonstration was held at a distributor's yard. The three units were evaluated on flat steel containing mill scale 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 were also higher.

An air/water/sand unit was compared to dry sand blasting at a yard facility. The substrates were two grades of rust steel plate and some structural pieces. In these, the dry sand cleaning rate was 20-40% faster. In this evaluation, the time for washing the wet 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 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.

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 80-90% the rates of dry blasting. The cleaning rates with high pressure water abrasive blasting were about 30-50% 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. In most cases, the cleanup 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/sandblaster, 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 standoff 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 15-25% that of dry blasting.

CLEANING EFFECTIVENESS The major factors in determining effectiveness are:

- # Visual Cleanliness (removal of rust, mill scale, paint and dirt)
- # Chemical Cleanliness (removal of oil film and soluble salts such as chlorides and sulfate)
- # 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% near-white (SSPC-SP 10). Portions of the

surface were rated as commercial blast (SSPC-SP 6) or brush-off blast (SSPC-SP 71). This is attributed primarily to the lack of visibility.

Thus, the poorest cleaning was obtained for 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.

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

SAFETY

- The use of high pressure water jetting abrasive blasting can be dangerous. The same is 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, removal of unnecessary clutter obstructions from work area, cordoning off of 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 single operator be allowed to operate units up to only 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 operator should experience the reaction force (thrust) progressively rather than all at once to start the operation.

Steel Toed Shoes.

There have been several recorded instances 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 (40-50 pounds) 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, operators using defective nozzles were observed. The safety lock, designed to shut off the flow when the grip was released, failed to do so, or aid so sporadically. This demonstrates the importance of proper maintenance of equipment and enforcement of safety procedure.

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 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 - This 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 100-200 feet unless very large compressors are used. 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 evaluations 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, mill scale, and rust, typically 10-15 square feet per trial. from the field evaluations were supplemented by data and information from equipment 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 80-90% 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 (6,000-20,000 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 (3,000-4,000 psi) water blasters with abrasive addition have demonstrated the ability to remove rust, paint, and mill scale with little operator fatigue. The cleaning rates, however, are considerably lower than that for conventional dry blasting.
- # High pressure water blasting without sand is not capable of removing tight rust and mill scale 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 the type of job and the 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 3. Additional details are provided in the full report available from the U.S. Maritime Administration or the Steel Structures Painting Council.

TABLE 3
WET BLAST UNITS:
ADVANTAGES & DISADVANTAGES

| Unit | 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 Abra- sive | Lower Rates High Thrust Poor Visi- bility High Water Higher cost |
| Low Pressure Water/Abrasive | Easy to Use Low cost Low Abra- sive Low Thrust | Low Rates Short Hose |
| Ultra High Pressure Water Jetting | No Abra- sive Simple Design Cleanest Surface | No Profile Leaves Mill Scale High Water High Thrust |

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