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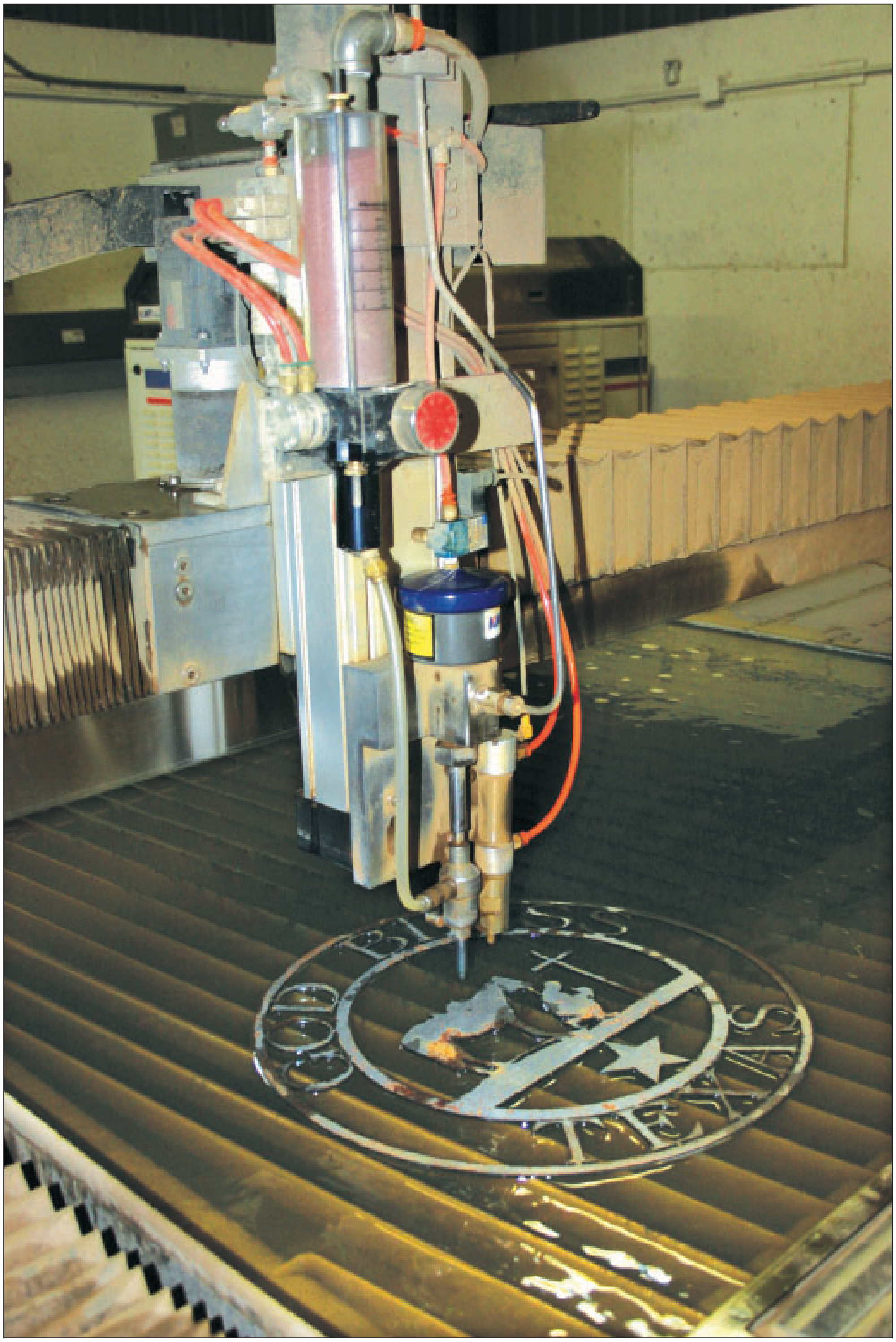

Abrasive Jet Cutting In Texas

Carbon steel (3/16 inch thick) cut with an abrasive jet (60,000 psi, 1.2 gpm with 0.6 pounds per minute of 80 HPA garnet) generated by a 75 hp HydraJet Accura 610 System.

Photograph courtesy of Mark Gillespie, GT Brentmark/GT WaterBlast Technologies, Houston, Texas.

On the inside

Parameters Affecting Surface Preparation

D. Wright, J. Wolgamott, G. Zink ● StoneAge, Inc. ● Durango, Colorado, U.S.A.

ABSTRACT

Waterjet surface preparation is typically performed using pressures from 20,000 to 40,000 psi, with rotating nozzle heads varying in diameter from 2 inches to 16 inches. Materials being removed include coatings, oxidation, or scales. The purpose of this research was to determine the effects of variables such as standoff distance, traverse speed, surface speed, rotation speed, and the head design on the effectiveness of surface preparation.

1. INTRODUCTION

A wide variety of equipment is available for waterjet surface preparation. Most equipment now includes rotating nozzle heads, with handheld rotating guns being the most basic, to self-propelled machines cleaning much wider paths at controlled feed rates. This research was conducted to determine the relative effects of standoff distance, rotation speed, feed rate, and nozzle head design on jet performance and cleaning efficiency in surface preparation. Previous research focused on massive material removal at lower pressures and higher flow rates (Wright et al 1997) but questions have risen whether these results apply at higher pressures and to thin coating removal.

2. TESTING

Tests were performed using an air powered rotating assembly that allowed the use of various heads. This assembly was attached to a traversing mechanism with adjustable feed rates; the test arrangement is shown in Figure 1. Test samples were placed underneath at an angle to vary the standoff distance from 9 to 90 mm (.37 to 3.5 inches). Commercial grade coated steel siding trim sections were used as test samples (Figure 2). Effectiveness was rated by visually estimating the percentage removal of the top coating and the primer.

All tests were conducted at 240 MPa (35,000 psi), with flow rates of 11 to 22 lpm (3 to 6 gpm). Jet path diameters of 91, 213, 305, and 366 mm (3.6, 8.4, 12, and 14.4 inches) were used, with rotation speeds from 500 to 3200 rpm. In addition to the different path diameters, two general head types were compared: a one piece bar type (Figure 3) and a multiple piece with individual bent jet arms (Figure 4). The bar heads had each jet port spaced 9.4 mm (.37 inches) apart; the diameters given above are the largest of the jet paths. The majority of the tests were conducted using four .51 mm (.020 inch) or four .38 mm (.015 inch) diameter sapphire orifices. Jet angles exiting the bar head and the quantity of jets were also compared.

3. RESULTS

3.1 Standoff Distance

The majority of the tests were conducted with the test sample placed at an angle to produce a varying standoff distance. The predominant effect was the ineffectiveness of removing the coating when the standoff distance was too small; every test showed this to some degree. This region of ineffectiveness is attributed to the jet still being coherent, and not having yet broken into droplets. The other measurable effect of standoff distance occurred in relation with rotation speed. The effect of standoff distance relative to multiples of orifice diameter at two different rotation speeds is shown in Figure 5.

The maximum "too close" range varied from 13 to 16 mm (.5 to .63 inches) with the bar head but increased to as much as 25 mm (1 inch) with the bent arm head. In terms of multiples of nozzle diameters, this range varied from 18 to 42 times the orifice diameter for the bar heads and up to 67 times the orifice diameter for the bent arms.

The most effective removal with the bar head occurred beyond 65 to 95

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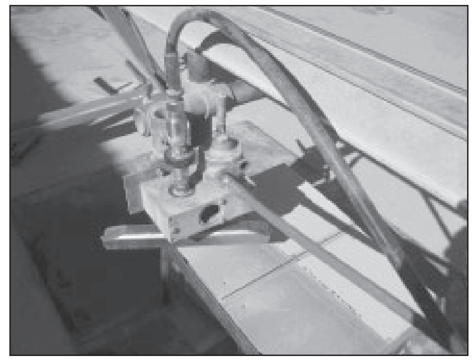


Figure 1. Test Arrangement Consisting of a Rotating Head and Traversing Mechanism.

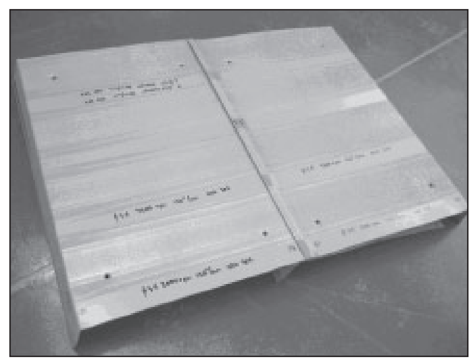


Figure 2. Test Samples of Coated Steel Siding Material.

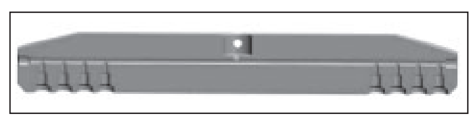


Figure 3. Bar Head Design

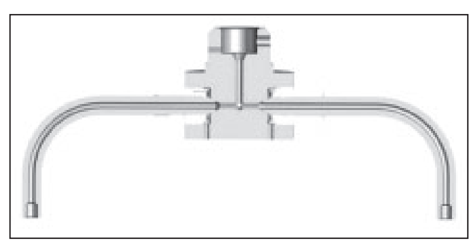


Figure 4. Bent Arm Design

Safety Committee Solicits Comments On Improvements To *Recommended Practices*

The WJTA Safety Committee hereby solicits comments regarding improvements to the publication, *Recommended Practices for the Use of Manually Operated High Pressure Waterjetting Equipment*. While *Recommended Practices* is reviewed periodically at the biennial conferences of the WaterJet Technology Association, your comments and suggestions for improving the publication are invited and welcome anytime.

Please address your comments and suggestions to: Safety Committee, c/o WJTA, 906 Olive Street, Suite 1200, St. Louis, MO 63101-1434, phone: (314)241-1445, fax: (314)241-1449, e-mail: wjta@wjta.org, web site: www.wjta.org.

Recent Development Of Pulsed Waterjet Technology Opens New Markets And Expands Applications

Wenzhuo Yan, PhD, VP Engineering ● VLN Advanced Technologies Inc. ● Ottawa, Canada

1 INTRODUCTION

Since its first introduction about 15 years ago, VLN's forced pulsed waterjet (FPWJ) technology has made significant advances. New developments include manufacture of 20 kpsi RFM (pulsed waterjet generator), handheld multiple orifice nozzles and the TURN (Twin Ultrasonic Rotating Nozzle). These new developments have made the FPWJ technology highly attractive for many challenging industrial applications, which are briefly described below.

2 FORCED PULSED WATERJET: A BRIEF BACKGROUND

The underlying principles that make the FPWJ advantageous over conventional continuous waterjets (CWJ) are: (i) waterhammer pressure it produces and (ii) high frequency impacts on the target. When a CWJ impinges normally on any surface to be cut or cleaned with a speed of V_0, the maximum pressure at the point of impact, called the stagnation pressure, is given by $P_s = \frac{1}{2}\rho V_0^2$. However, if a drop or a slug of water strikes the same surface, the initial impact pressure will be much higher. This is the waterhammer pressure given by $P_i = \rho V_0 C_0$, where C_0 is the velocity of sound in water (5,000 ft/s). Thus, amplification of pressure, $M = \frac{P_i}{P_s} = \frac{2C_0}{V_0}$. For example, at an operating pressure of 10 kpsi, the amplification is about 8.2. However, at an operating pressure of 40 kpsi, the amplification is only 4.1. This is the reason why FPWJ works better at lower pressures.

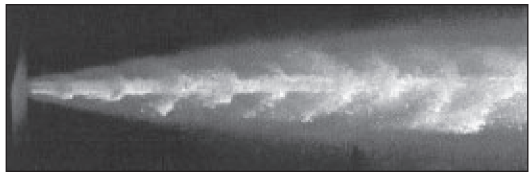


Figure 1. Photograph of the well-defined and fully developed FPWJ taken with an Nd-Yag Laser.

Figure 2. Pulsed waterjet produced with a dual-orifice nozzle.

Figure 3. Six-orifice nozzle.

VLN's unique technique generates powerful high-frequency (20 kHz) well-shaped pulses by modulating a stream of water [1]. Figure 1 and 2 show photographs of fully developed FPWJ waterjets issuing from single-orifice and dual-orifice rotating nozzles (stationary when the photograph was taken).

3 NEW DEVELOPMENTS

As a unique waterjet technique, FPWJ has become increasingly attractive for many industrial applications, such as aerospace, automobile, marine, to name only a few. This is, in addition to its exceptional performance, due to its low capital and maintenance costs.

As described in great detail by Vijay [2], FPWJ has been employed in several contractual applications using mainly single-orifice non-rotating and dual-orifice rotating nozzles. Single FPWJ is a very powerful tool, which has been proven to be the only viable green technique for the efficient removal of several types of hard metallic coatings used in the aerospace industry [3]. Dual-orifice rotating nozzles have also been found to be quite effective for the removal of hard epoxy coatings, hard deposits of chemicals on the inner wall of reactor vessels, and surface preparation of granite slabs in the mining industry [4]. Both the single and dual-orifice rotating nozzles are suitable for handheld operations or, for incorporation into automated systems, employed for instance, in aircraft engine maintenance, overhaul and repair centers. Significant improvement in performance achieved by increasing the pressure from 10 kpsi to 20 kpsi would no doubt make FPWJ technique even more attractive for these applications. There are, however, many applications which require a waterjet system to remove a

(continued on page 7)

Burst Pressure Of High Pressure Tubing

In water blasting market, tubing is not readily available and often requires special mill runs to user's specification. Therefore it is necessary to predict the burst pressure for tubing with a certain length, size, and material. The maximum allowable working pressure can be determined thereafter. Thrash and Britton* did some analytical and experimental work in this regard. The tubing used in the water blasting is considered as thick-walled cylinder because the ratio of wall thickness to inner radius is greater than 0.1. The maximum stress is at the inner diameter of the tubing and consists of these three components: longitudinal stress S1, tangential stress (or hoop stress) S2, and radial stress S3, calculated as follows:

$$S1 = F1 \cdot P \qquad S2 = F2 \cdot P \qquad S3 = F3 \cdot P$$

where $$F1 = \frac{R_{in}^2}{R_{out}^2 - R_{in}^2} \qquad F2 = \frac{R_{out}^2 + R_{in}^2}{R_{out}^2 - R_{in}^2} \qquad F3 = -1$$

The yield pressure P_y and isotropic (fully plastic) yield pressure P_{iy} are thus related to the material yield strength σ_y by:

$$P_y = \frac{\sigma_y}{\sqrt{\frac{(F2-F3)^2 + (F1-F3)^2 + (F2-F1)^2}{2}}}$$

$$P_{iy} = \frac{2 \cdot \sigma_y \cdot \ln(\frac{R_{in}}{R_{out}})}{\sqrt{3}}$$

The burst pressure was predicted by: $$P_b = (2 - \frac{\sigma_y}{\sigma_u}) \cdot P_{iy}$$

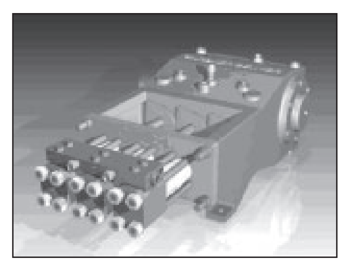
Tests were done on seven different types of tubing. The actual burst pressure was compared to the calculated data. The working pressures was determined (see below).

												0.33
	O.D.	I.D.	YIELD	TENSILE				P YIELD	P YIE ISO	P BURST CALC	P BURST ACTUAL	P WORK
DESC.	(in)	(in)	(psi)	(psi)	HOOP	LONG	EQUIV	(psi)	(psi)	(psi)	(psi)	(psi)
1/4" Sch.40 BLACK	0.540	0.088	35,000	60,000	2.6667	0.8333	3.1754	11,026	15,940	22,582	26,500	7452
1/4" Sch.40 GALV.	0.540	0.088	35,000	60,000	2.6667	0.8333	3.1754	11,026	15,940	22,582	29,000	7452
1/8" Sch. 80 4130	0.405	0.095	110,000	121,500	1.7838	0.3919	2.4108	45,611	80,433	88,046	80,000	29,055
1/4" Sch. 80 4130	0.540	0.119	110,000	121,500	1.9092	0.4546	2.5194	43,645	73,815	80,802	80,000	26,665
1/4" Sch. 80 SS	0.540	0.119	35,000	85,000	1.9092	0.4546	2.5194	13,887	23,487	37,302	44,000	12,310
1/2" Sch. 160 SS	0.840	0.187	35,000	85,000	1.8895	0.4447	2.5024	13,988	23,813	37,820	41,000	12,481
9/16" Tube SS	0.562	0.125	35,000	85,000	1.8903	0.4452	2.5031	13,979	23,784	37,774	44,000	12,466

* Thrash, Thomas and Britton, Charles (1999) Mathematical modeling of thick wall tubing, in Mohamed Hashish (ed.), Proceedings of the 10th American Waterjet Conference, August 14-17, Houston, Texas, Paper 74.

New 40K-psi Direct Drive Pumps

QualJet, the worldwide distributor of OH Precision (Taiwan), is pleased to introduce the latest member of its 40K-psi triplex direct drive pumps, UH-300, for water blasting, surface preparation, and concrete demolition application. With this addition, QualJet now carries direct drive pumps in 100, 160, 300, and 450 hp. OHP pumps are built on the same technology that has been use for the UHP water cutting industry. The same high-pressure seals that endures 55K psi are now "soothed" with 40K psi pressure. The lifetime of the seal set averages more than 500 hours and other key components lasts over 2000 hours. UH-300 pump operates at 300hp and with a flow rate of 11.8 gpm at a pump speed of 515 rpm. The bare pump weight 1,760 lbs.



For more information, please contact Qualjet at (866)782-5538 or info@qualjet.com.

larger swath of material per pass. Well-known examples are surface preparation of hull and deck of large ships or, cleaning of airport runways, which require removal of large swaths (12 to 20 in) per pass. In such cases, as back-thrust is not a major concern, manipulators can be used to control the movement of the nozzle. Thus, new multiple-orifice nozzles and the TURN, which can handle large amount of water, were developed to meet the needs of these applications.

3.1 Multiple-orifice nozzle

As shown in Figure 3, a 6-orifice rotating nozzle (Model 6-RV) was designed and manufactured based on energy balance theory. The theory simply takes into account the equal distribution of energy for each orifice in the nozzle. The nozzle was designed to remove approximately 3.5 in wide path of material per pass. The operating pressure ranges from 8 to 15 kpsi. The diameters of the orifices can range from 0.025 to 0.067 in, depending on a specific application. With the use of smaller orifices, the nozzle can be mounted on a handheld gun.

3.2 Model RFM -2020

The Model RFM-2020, illustrated in Figure 4, is a new pulsed waterjet generator, which can be operated at pressures up to 20 kpsi and more than 30 usgpm of water. It has been manufactured to meet the requirements of many challenging applications. All one needs to do is to connect it to a high pressure pump to produce 20 kHz FPWJ.

3.3 TURN

A general view of the TURN is shown in Figure 5 [**5**]. Enclosed within the stainless steel drum are two independent single-orifice ultrasonic nozzle assemblies mounted on a rotating steel plate, rotated by an electric motor. For manual operation, the drum is mounted on four rubber castors and is fitted with a rugged handle. It can be mounted on a robotic arm by simply removing the handle and casters. Furthermore, as the transducer of each nozzle assembly requires its own ultrasonic generator,

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A New Version Of Aquajet Hydrodemolition Crawler

Aquajet Systems AB, the Swedish specialist manufacturer of hydrodemolition technology, has launched a new version of its Aqua Cutter HVD/HVE crawler-mounted hydrodemolition robot, designed for greater ease of use and enhanced productivity in demolition work. The HVD/HVE is one of the most versatile robots available performing horizontal, vertical and up to 6 m overhead operations as standard.

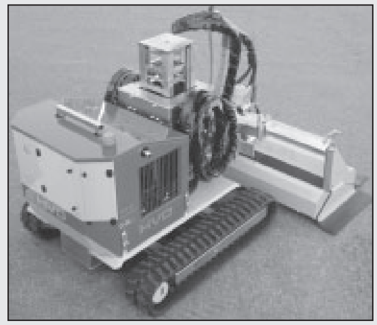
The Aqua Cutter now comes equipped with a new cutting head that has 50 percent more angling ability than the previous standard model. It introduces a new oscillation system providing an adjustable oscillation angle, an easy-to-set lance angle and an improved and extended EDS lance control. This in effect speeds the demolition operation allowing the robot to get into awkward areas, such as under rebar with more ease.

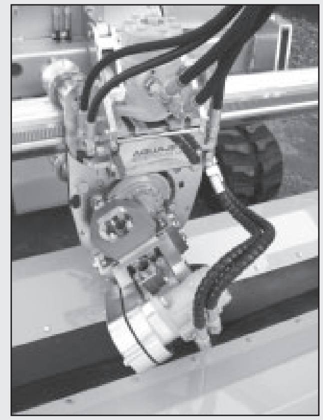
One of the most important new features is the removal of all sensors and electric cables from the front of the machine, out of the way of water, grease and dust, utilizing a new patented Intelligent Sensing Control (ISC).

The robot now operates with greater safety and reliability. In addition the machine's front end has a cleaner, more functional appearance, with new easy-to-open hose protection and support system for the hydraulic hoses.

All robots can be delivered with a radio remote control system, which can also be operated by wire connection if preferred. This allows the robot to operate in congested areas without risk of the cable becoming snagged.

At the same time, the LCD display panel uses clear and simple pictorial graphics combined with small multi language text making it very easy to program the robot. Previously, this information had been given only in text format. Graphical representation provides a far quicker assessment of the robot's programming. This feature will be of particular value in export markets in which English language usage is minimal.





All hydrodemolition robots are equipped with Aquajet's worldwide patented Equal Distance System (EDS) lance movement and nozzle system. As the waterjet rapidly loses power with distance from the nozzle, it is necessary to keep the jet as close to the surface of the concrete as possible. The EDS allows the latest robot to achieve a lance angle of attack of as much as 30 degrees to each side, without wasting energy from the jet, directing the power of the water where it is most needed.

The operation width of the new power head can easily be increased and the traverse beam can be extended for up to 4 m operation width. This feature is particularly advantageous for increased production on bridges and similar large surface projects.

Aquajet hydrodemolition robots are versatile machines that are ideal for working on bridges, tunnels, roads, harbors, pillars, walls, parking garages or overhead roofs. Working with a typically 1000 bar pressure and 250 l/min, the robot handles removal depths down to approximately 1000 mm of concrete if required.

The Aqua Cutter robot can be delivered with a diesel or electric motor.

Total length of the robot is 2480 mm with a minimum height of 1575 mm and a standard operating height of 6000 mm which can be extended up to a height of 15 m.

The variable-width chassis can be extended from 1030 mm to 1510 mm and provides maximum stability during set up and operation. Its low centre of gravity in the chassis further enhances the units stability. In its narrow version, access to the tightest passages, including, for example doorways, alleys and footbridges, is achieved.

The weight of the unit is 1900 kg for the HVE electrically driven version and 2000 kg for the HVD diesel driven version.

An HD/HE Aqua Cutter is also available for horizontal operations.

For further information please contact: Stefan Hilmersson, Aquajet Systems AB, Brunnsvägen 15, SE-570 15 Holsbybrunn, Sweden, Tel: int +46 (0)383 508 01, Fax: int +46 (0)383 507 30, email: aquajet@aquajet.se.

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the RFM-2020 (Figure 4) was slightly modified to house two ultrasonic generators.

4 APPLICATIONS

Although FPWJ has been used for many applications [**2**], the most recent challenges have been in removing the coatings which are harder than the substrate material. Many thermal spray coatings fall in this category. Thermal-spray coatings are heavily used in aerospace industry where components are subject to very high abrasion and thermal wear. Specifically, Tungsten Carbide - High Velocity Oxygen Fuel (HVOF) coating, which is a derivation of thermal-spray technology, is currently being tested on landing gear components. HVOF coatings can be easily applied and are highly resistant to abrasion wear. Moreover, this coating is believed to have the potential to replace apparently hazardous electrolytic hard chrome coatings [**6**]. However, HVOF coating's intrinsic durability also makes it difficult to be stripped for inspection and recoating. Current coating removal methods involve a multi-step process whereby the coating must undergo diamond wheel grinding, chemical dipping, grit blasting, UHP {ultra-high pressure (380 MPa, 55 kpsi)} water blasting, and possibly a repeated chemical dip, depending on the type and thickness of the coating. Some of the highly encouraging results obtained in recent trials are listed below.

4.1 Marine coatings Removed with TURN

Figure 6 shows the 16 in wide swath of non-skid coat removed with the TURN in a single pass at 10 kpsi. The surface finish of the panel is considered to be excellent (bare metal with no damage to the substrate). The rates of removal and the corresponding energy consumption have been respectively of the order of 240 ft^2/hr and 0.28 hp.hr/ft^2.

4.2 HVOF coatings

Figure 7 shows a close-up photograph of 300M steel coupon from which 0.007 in thick HVOF (WC-Co-Cr) coating was removed. The photograph clearly shows that FPWJ has removed the hard coating to bare metal finish. The surface profile is considered to be the same as the original grit-blasted profile, implying that FPWJ did not alter it [**3**].

Based on these highly promising results, a series of tests was conducted on landing gear pins provided by Messier-Dowty in Canada. Technical specifications of the pins were: Substrate material: Type 4330 C steel; Profile: 0.005 in - grit blast - 120-140 Ra or ìm surface roughness; Average thickness: 0.015 in. Figure 8 shows typical appearance of the pins from which the coating was effectively removed with the FPWJ at a pressure of 15 kpsi (hydraulic power = 84 hp). The time required to finish each pin was about 16 min, which is believed to be significantly lower than the multi-step process currently used. Messier-Dowty, among other aerospace companies, are quite satisfied with the results, and as FPWJ process uses only tap water, it is considered as a green viable technology [**3**].

4.3 Honeycomb – Aircraft Engine Component

Figure 9 shows an aircraft component with honeycomb provided by one of the aerospace companies. Test results obtained with the FPWJ at 10 kpsi (45 hp) are shown along with those obtained with the CWJ at 55 kpsi (300 hp). The traverse speeds of the FPWJ

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Figure 4. Model 2020-RFM FPWJ generator.

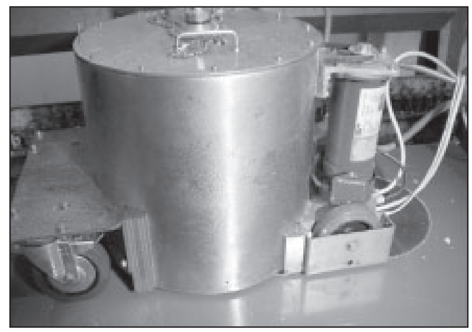

Figure 5. A general view of the TURN in the process of removing epoxy coating from a steel panel.

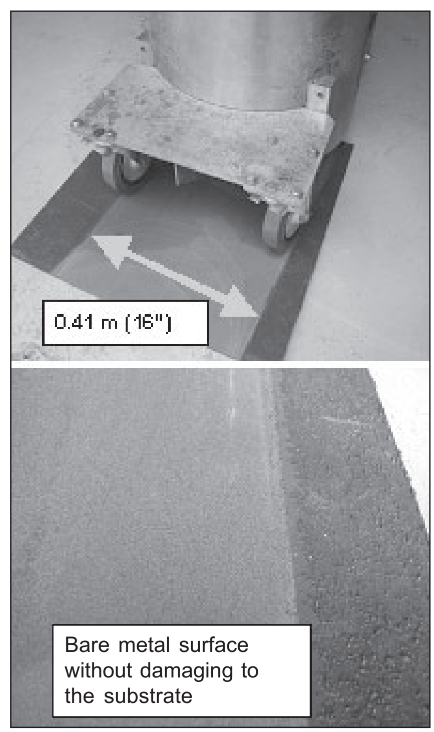

Figure 6. Removing non-skid coating with TURN at 10 kpsi.

KMT Divests KMT Ursviken And Streamlines Operations To Three Business Areas

KMT's Board of Directors has approved the divestment of subsidiary KMT Ursviken to the Finnish venture capital fund Sentica. The divestment of Ursviken follows on from earlier divestments of the subsidiaries Herber and Pullmax, and represents the final phase in the discontinuation of the KMT Sheet Metal Working business area.

The purchase consideration amounts to approximately SEK 100 M, which is expected to generate a capital gain of about SEK 50 M. The operation will be removed from the Group accounts as of June 25, 2007.

The buyer, Sentica, already owns companies within the field of sheet-metal working and intends to create a new corporate Group based on Pivatic, one of these companies, and Ursviken.

"For a long time, we have been streamlining the Group to include three business areas, namely, advanced equipment for waterjet cutting and robotic system solutions within this segment, and machines for precision grinding of ball bearings and other components requiring high precision. My assessment is that Ursviken's new ownership will provide a better possibility for the company to develop, while our operation will be concentrated further," says Lars Bergström, KMT's CEO.

KMT Ursviken produces and markets advanced sheet-metal working machines, such as press brakes and guillotine shears. In 2006, sales amounted to SEK 187 M. The number of employees amounts to slightly more than 80.

For further information, contact: Lars Bergström, President and CEO, KMT Group AB Tel: +46 (0)8-594 211 50 or by e-mail: lars.bergstrom@kmtgroup.se.

and CWJ nozzle were respectively of the order of 200 in/min and 6 in/min. This comparison clearly confirms the efficacy of the FPWJ.

5 FUTURE DEVELOPMENTS

Many developments to enhance the efficiency of the FPWJ are in progress. The developments currently in progress are: (1) to reduce the size of the TURN and (2) oscillating nozzles consisting of two or more orifices.

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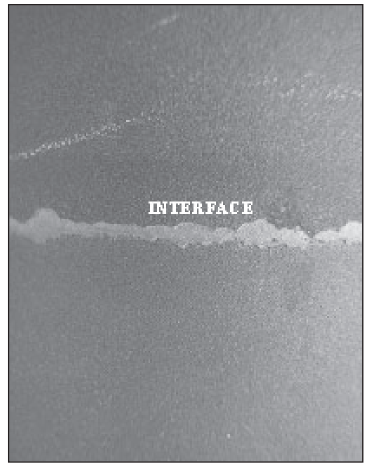
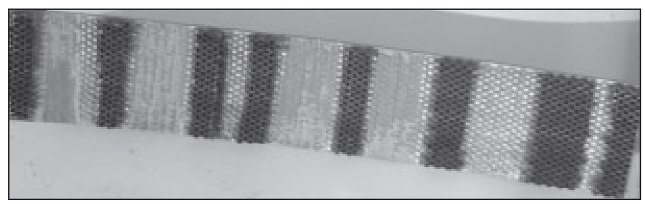


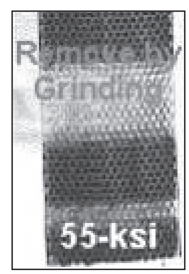
Figure 7. Close up view of the coating (left) and substrate (right) showing the clean finish achieved with FPWJ stripping.

Figure 8. HVOF coating removal on landing gear pins supplied by Messier-Dowty



(A)

Figure 9. Honeycomb removed with (A) FPWJ at 10 kpsi. (B) 55 kpsi (330 hp) CWJ followed by grinding (data provided by the client: Confidential).



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Flow International Appoints Charles Brown As Chief Executive Officer

Flow International Corp., a leader in the development and manufacture of ultrahigh-pressure water jet technology, today announced that the board of directors has named Charles "Charley" Brown as the Company's new chief executive officer, effective upon the retirement of Stephen Light, whose plan to retire was announced in February, 2007. Mr. Light will remain as CEO through the announcement of fiscal 2007 earnings and the earnings call, which is expected to take place July 12, 2007, and through the filing of the 2007 10-K. Mr. Brown's employment as CEO will begin immediately thereafter.

"I couldn't be more pleased that Charley will serve as Flow's next CEO. His demonstrated leadership and outstanding track record give us full confidence in his ability to drive growth within the Company. We look forward to working with Charley and are excited to welcome him to the Flow team," said Kathryn Munro, Flow's chairman of the board. "On behalf of the board, we would like to thank Stephen Light for his leadership in the successful turnaround of Flow. Under his guidance, Flow increased value for shareholders and helped position the Company for future growth. We wish him well in his future endeavors."

During Charley Brown's 23-year career he has held ever-increasing positions of responsibility and leadership at Johnson & Johnson, Black & Decker Corporation, Masco Corporation and at Pentair, Inc. Most recently Charley was the president and chief operating officer of the Pump, Pool and Spa Divisions at Pentair, Inc, a company with 2006 revenues of approximately $3.15 billion. In this position Mr. Brown had full P&L responsibility for two divisions with eight businesses and eleven factories representing $1.5 billion in annual sales. During his tenure, these divisions integrated the acquisition of a major competitor and many of the businesses achieved record sales and profits.

For more information, visit www.flowcorp.com.

Booth # 73, 74, 75
Gardner Denver Water Jetting Systems

times the orifice diameter; in the fastest rotation speed tests, the jet effectiveness showed rapid deterioration beyond 150 to 160 times the orifice diameter. Slower rotation speeds allowed effective removal out to 230 times the orifice diameter, which was the furthest standoff distance tested. No deterioration at the maximum distance was observed using the bent arms at the fastest rotation speed tested.

3.2 Rotation Speed

The purpose of these tests was to determine if there is a rotation speed where jets begin to lose power. The diameter of the jet path affects the velocity that the nozzle tip is moving; a jet path diameter of 91 mm (3.6 inches) rotating at 3000 rpm results in a velocity of 14.3 m/sec (47 ft/sec), while a jet path diameter of 366 mm (14.4 inches) rotating at 1800 rpm results in a velocity of 34.5 m/sec (113 ft/sec). Therefore, it is expected that as the jet path diameter increases, the rotation speed should be slowed to maintain an effective velocity. Equation 1 can be used to calculate the velocity of a head in m/sec, where the head diameter is in millimeters.

$$\text{(1)}\quad \text{Velocity} = \text{Pi}/60{,}000 \cdot \text{diameter} \cdot \text{rpm}$$

Four different parameters varied the effect of rotation speed on performance; these were standoff distance, orifice diameter, feed rate, and head design.

Increasing rotation speed with increasing standoff distance narrowed the effective standoff distance range as explained previously. The relation between rotation speed and the orifice diameter is shown in Figure 6; the jet performance with increasing rotation speed deteriorated faster with a smaller orifice diameter. The effects of rotation speed made a slight difference as the linear feed rate was increased; the relation is shown in Figure 7 for two different feed rates using the 366 mm bar head. The plot for the faster feed rate shows improvement with increasing rotation speed up to a point before performance begins to decrease.

Rotation speed was tested at three different jet path diameters. The 366 mm (14.4 in.) bar head was tested at 500, 1000, and 1800 rpm. The 213 mm (8.4 in.) head was tested at 1000, 1500, and 2000 rpm, and the 91 mm (3.6 in.) head was tested at 2000 and 3200 rpm. The feed rates were adjusted to produce the same rate of coverage; therefore the 91 mm head was advanced at a rate four times that of the 366 mm head. Figure 8 shows that for the head diameters and speeds tested, the results fall on approximately the same curve and deterioration in jet power begins to occur at a velocity greater than 20 m/sec (66 ft/sec).

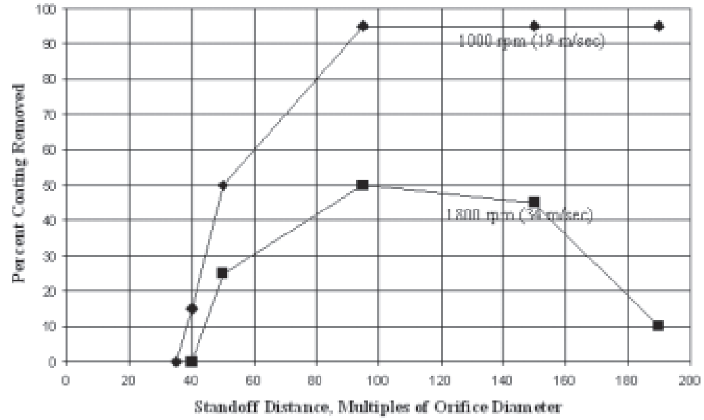

Figure 5. Effective Standoff Distance with 366 mm (14.4 in.) Bar Head at Two Rotation Speeds.

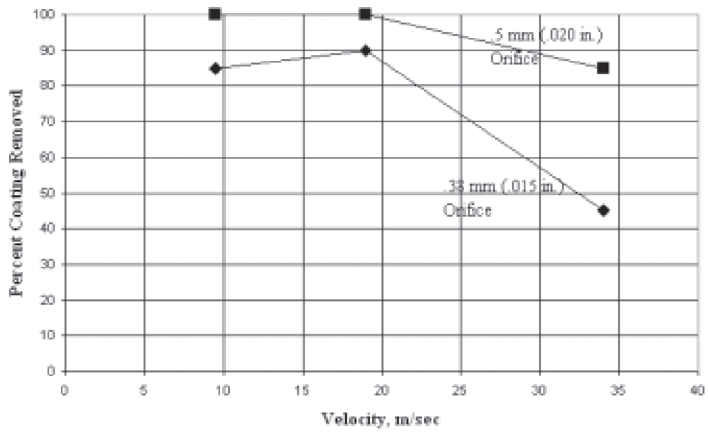

Figure 6. Relation Between Orifice Size and Rotation Speed Velocity with 366 mm Bar Head.

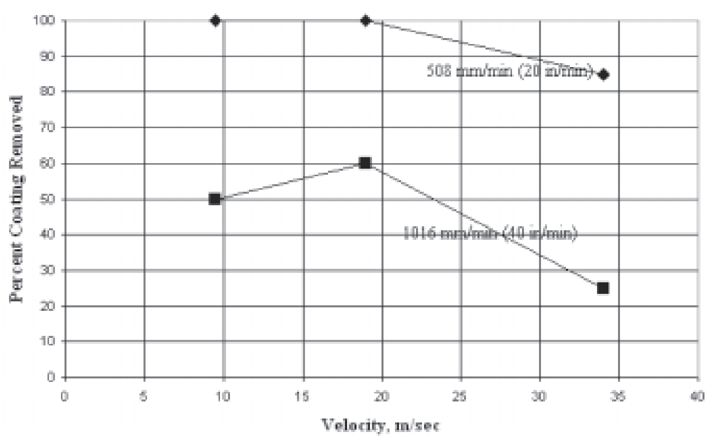

Figure 7. Relation Between Feed Rate and Rotation Speed Velocity with 366 mm Bar Head.

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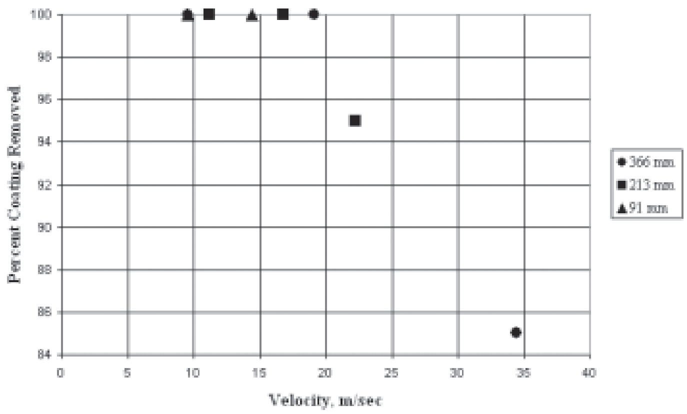


Figure 8. Rotation Speed Velocity with Three Bar Head Diameters.

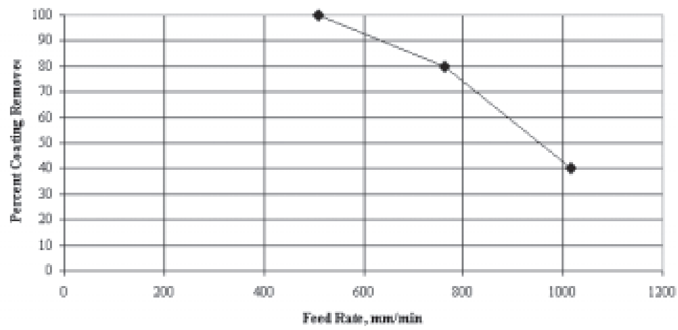


Figure 9. Coating Removal as Function of Feed Rate, for 366 mm Bar Head.

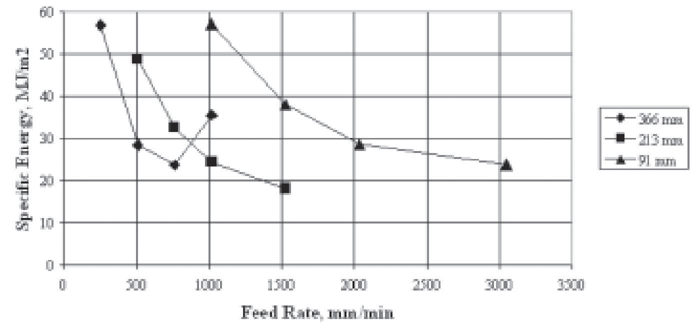


Figure 10. Coating Removal Efficiency as a Function of Feed Rate for Three Bar Heads.

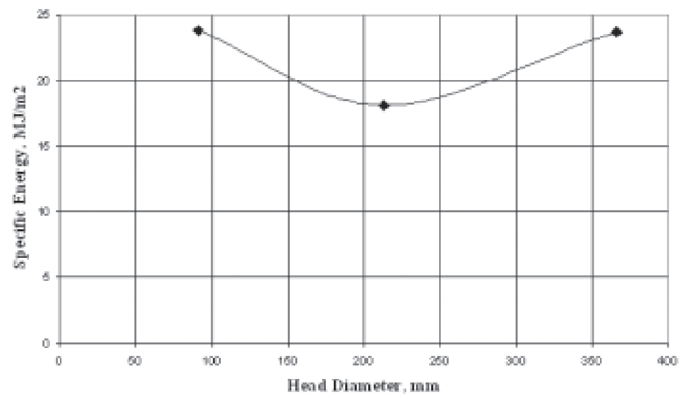


Figure 11. Efficiency of Coating Removal with Bar Head Jet Path Diameter.

(continued on page 16)

3.3 Feed Rate

These tests showed the feed rate to have the greatest effect of all the parameters on percentage of coating removal. The 366 mm (14.4 in.) bar head was tested with rotation speeds of 500, 1000, and 1800 rpm at feed rates of 508, 762, and 1016 mm/min (20, 30, and 40 in./min), with the optimum efficiency occurring at 1000 rpm and 762 mm/min. The 213 mm (8.4 in.) bar head was tested with rotation speeds of 1000, 1500, and 2000 rpm at feed rates of 1016 and 1524 mm/min (40 and 60 in./min), with the best performance at 2000 rpm and 1524 mm/min. The 91 mm (3.6 in.) bar head was tested with 2000 and 3000 rpm at 2032 and 3048 mm/min (80 and 120 in./min), with the best performance occurring at 2000 rpm and 3048 mm/min. Figure 9 shows the percentage of coating removed as a function of feed rate for the 366 mm bar head. The efficiency relative to feed rate is shown in Figure 10; the curve for the larger bar head is much more sensitive than the smallest diameter head.

3.4 Jet Path Diameter

The efficiency of jet path diameter based on the bar heads tested is shown in Figure 11. For the three to be equal in efficiency, the 91 mm (3.6 in.) diameter head had to have an effective feed rate of three times that of the 366 mm (14.4 in.) head, which held to be true. The greatest efficiency appeared with the 213 mm (8.4 in.) head; it did produce a cleaner pass than either of the two other heads, at a feed rate of twice that of the 366 mm head. Referring back to the curves in Figure 10, the sensitivity of the larger head diameter curve may be another contributing factor in head diameter selection. The efficiencies of these heads are not too far apart, but if the trend continues beyond the diameters tested, one would expect a further loss of efficiency.

The theoretical feed rate can be calculated (Equation 2) based on the number of jets traveling in the same path, the orifice diameter of the jets and the rotation speed; it does not take into account the head diameter. The ratio of the actual feed rate to the theoretical feed rate for the optimum efficiency varied from 1.5 times for the largest bar head to 3 times for the smallest. This means that this theoretical feed rate calculation is missing a variable to account for this, but it is still useful for providing an estimated starting point.

$$\text{(2)}\quad \text{Feed Rate} = \text{Orifice Diameter} \bullet \text{Number of Jets} \bullet \text{rpm}$$

3.5 Jet Angle

A 366 mm bar head with 5 degree outward angled ports was compared to a 366 mm bar head with straight downward facing ports. The angled ports removed an estimated 15 to 20 percent more coating than the straight ports in this test.

3.5 Bent Arm Head Design

The head design shown in Figure 4 was tested and compared to the bar head design. Figure 12 shows the side by side comparison of the two tests; the greatest effect occurred with standoff distance. The bent arm head showed less deterioration due to rotation speed rate as well, and the efficiency of coating removal compared to the bar head improved by 25 to 30 percent. Nearly the same removal was achieved with the .38 mm orifice size in the bent arms as that achieved by the .51 mm orifice size in the bar head. Further testing would be required to determine if this improved efficiency of the bent arm design could be translated directly into increased production rates.

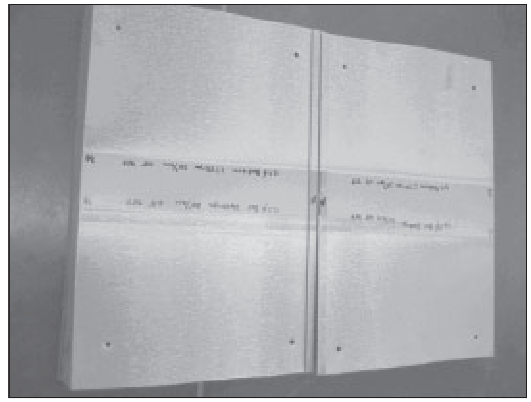


Figure 12. Bent Arm Head (Top) Compared to Bar Head (Bottom) Moving from Left to Right is Standoff Distance Change from 9 mm to 89 mm.

4.0 CONCLUSIONS

The relative effects of standoff distance, rotation speed, feed rate, and head design were measured and compared in these tests. Overall, the parameter having the greatest effect on performance was the feed rate, which also directly effects efficiency. The next strongest parameter was the head design; the bent arm head performance was 25 percent better than the bar head design, and jet angle improved performance by 15 percent. Jet path diameter appeared to reach an optimum around the 210 mm size range, although this was not a strong influence. Rotation speed effected performance in several ways, but was not shown to be very influential either. These tests showed that increasing rotation speed is not necessarily a direct path to allowing a faster feed rate; it should be kept within a range to produce a velocity between 10 and 25 m/sec (33 and 82 ft/sec) for optimum performance.

5.0 REFERENCES

Wright, D., Wolgamott, J., Zink, G., "A Study of Rotary Jets For Material Removal," *Proceedings of the 9th American Waterjet Conference*, M. Hashish (ed.), pp. 525-539, Waterjet Technology Association, St. Louis, Missouri, 1997.

Federal Signal Announces New Name For Retail Locations, First Rental Store

Federal Signal, which earlier this year announced the formation of its Environmental Solutions Group and the opening of four strategically located retail outlets, including a rental outlet in Toledo, is now calling those outlets FS Solutions centers.

"Federal Signal Environmental Solutions Group is unique in offering the breadth of product lines and trusted brands to provide solutions for waterblasting, vacuum loading, sewer cleaning and vacuum excavating," said Tony Fuller, director, Industrial Sales for Federal Signal's Environmental Solutions Group. "Calling our Federal Signal retail outlets FS Solutions centers provides a concise description of what we're offering."

Fuller said, "It also aligns with our corporate goals of providing, not just equipment, but total solutions. We're providing solutions for the contractor who is looking for faster, more cost-effective ways to perform cleaning operations. We're providing solutions for contractors who need the right equipment, parts and service and need it now. And we're providing solutions for businesses that can benefit from training, equipment evaluations or application expertise."

According to Fuller, all FS Solutions locations provide access to factory-trained, certified technicians and genuine OEM parts. "The businesses represented by the Guzzler, Jetstream and Vactor brands are specialized in nature. Customers look to our sales staff and service training technicians for recommendations and solutions to the unique challenges of their particular applications," he said.

FS Solutions locations in Birmingham, Ala.; Streator, Ill., and Houston repair, refurbish and sell used Guzzler industrial vacuum loaders, Vactor sewer cleaners and vacuum excavation equipment, and Jetstream waterblasters. They also repair and refurbish competitive equipment, offer OEM parts and accessories, and in some cases, equipment rentals.

Toledo Location Dedicated to Jetstream Rentals

The FS Solutions center in Toledo is currently devoted to rentals of Jetstream waterblasters. It also stocks a wide range of Jetstream parts and accessories and offers service and training.

"This is the first of a series of FS Solutions rental locations we plan to open around the country," Fuller said.

Contractors are able to rent equipment when they need it, based on seasonal peaks. "Our customers who help maintain power plants, for instance, tend to be busiest in the spring and fall, when utilities take shutdowns before power demand ramps up with hot or cold weather," said Fuller. Some firms work with manufacturing plants that schedule shutdowns in slow seasons. Others may receive contracts that have only limited duration.

"Lots of people have short-term contractual obligations, and it may not make sense for them to invest in new waterblasters to meet them," he added. "Just as important, renting can give you the equipment you need to get a job you otherwise couldn't go after." Fuller also noted that FS Solutions rental centers offer rent-to-own solutions for those qualifying customers who need to add a unit to their fleet but may not be prepared to meet the down payment requirements of traditional financing.

Headquartered in Illinois, Federal Signal Corporation's Environmental Solutions Group is the corporate resource behind the Vactor, Guzzler and Jetstream brands. For more information about products and services available from FS Solutions centers, or to find a location near you, call 800/627-3171 ext. 298.

StoneAge Introduces Banshee BN24 Tube Cleaning Nozzle

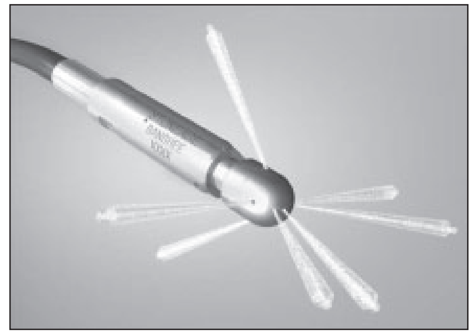
The Banshee BN24 Tube Cleaning Nozzle is the latest addition to the StoneAge tube cleaning family. It provides superior cleaning with an operating range of 2-20k psi and 11 - 24 gpm. The **BN24** is designed to clean 1.1" to 2" tubes.

Like the **Banshee BN13** and **BN18** the new **BN24** offers high quality jetting power without the need for regular maintenance or repair parts.

StoneAge has combined the Polisher and Unplugger head designs into one Universal Head capable of handling all your tube cleaning applications.

The **Banshee BN24** is in stock now, but a few days will be needed to make the new Universal Style heads to match your pump specifications.

For more information regarding all of the Banshee tools visit www.stoneagetools.com or call 970-259-2869.



KMT Waterjet Systems Inc. Announces New U.S. Based Marketing Manager And New Regional Sales Manager In Mexico

KMT Waterjet Systems Inc. has appointed Robert Pedrazas as marketing manager for the Americas in their global headquarters located in Baxter Springs, Kansas, and Antonio Diaz as regional sales manager – Mexico.

Most recently, Pedrazas was vice president of marketing, National Partitions in Knoxville, Tennessee, and has a total of 31 years of marketing, communications and media experience. He has master of arts, bachelor of science and associate of arts degrees in communications. He will be responsible for developing brand marketing and strategies to build the business.

Mr. Diaz was a regional sales manager for ELE Internacional Inc. in their Mexico and Central America regions, and has a total of 15 years of experience in sales and business management. Diaz has a bachelors degree in marketing and business administration and will be responsible for KMT sales in Mexico and Central America.

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Jet Edge Announces Mexican Distributor

Jet Edge, Inc., a leading manufacturer of ultra-high pressure waterjet and abrasivejet systems for precision cutting, coating removal and surface preparation, is pleased to announce that Rosber, S.A. de C.V. has been selected as its new distributor for Mexico and Central America.

Founded in 1952, Rosber is a leading provider of industrial equipment and abrasives in the Mexican and Central American markets. The company has offices and warehouses in Monterrey and Mexico City and distributors in all the Mexican Republic.

With its extensive knowledge of Jet Edge waterjet products, Rosber is capable of helping customers select the correct product for their precision cutting, cleaning or surface preparation applications. The company provides sample test cuts and product demonstrations through Jet Edge, and is qualified to provide ongoing customer training and technical support. It maintains an inventory of Jet Edge parts and prides itself on providing 24-hour parts delivery.

"Jet Edge is extremely proud of our new association with Rosber," said Thomas MacGibbon, Jet Edge vice president of sales and marketing. "Rosber's excellent reputation and commitment to its customers reflect the same core principles Jet Edge has built our business upon. Like Jet Edge, Rosber's commitment to its customers does not end at the sale. They follow through with ongoing training and technical support as well as timely parts delivery to make sure their customers achieve optimal performance out of their waterjet systems."

Rosber's Industrial Engineer Rubén Carreón Beraza said his company is dedicated to helping its customers find the best solution for their specific applications.

"By analyzing customers' processes, we search our products for the best solution," Beraza said. "We offer trials of our processes and products in our lab or at our supplier's labs. We also give the production cost by part or process. After sales, we offer constant training and new products research to support and improve the customer's processes. Through 57 years of experience and constant growth, supported in our quality system, we are able to support our customers in making the correct purchase decisions."

For more information about Rosber, visit www.rosber.com or e-mail ventas@rosber.com. In Mexico, call (55) 53 58 97 11. In Monterrey, call (81) 81 05 02 42. For more information about Jet Edge, visit www.jetedge.com, e-mail sales@jetedge.com or call 1-800-JET-EDGE (538-3343).

New Release - *Recommended Practices For The Use Of Industrial Vacuum Equipment*

The *Recommended Practices for the Use of Industrial Vacuum Equipment,* first edition, was prepared by the WJTA Committee to Develop Recommended Practices for the Use of Industrial Vacuum Equipment. Topics in the *Recommended Practices for Industrial Vacuum Equipment* include Injury Potential, Seeking Medical Attention, Damage, Explosion, Types of Trucks, Getting Started, Pre-Job Preparations, Working Safely, Job Completion, Loading/Off-Loading, Equipment Maintenance, and Regulations and Certifications.

To purchase your copy, see the enclosed WJTA order form for publications/products.

Kerry Petranek Joins StoneAge Staff

StoneAge has announced the appointment of Kerry Petranek as operations manager. Ms. Petranek will be responsible for heading up all of StoneAge's departments as well as leading the StoneAge team into the next phase of growth.

Kerry Petranek

Ms. Petranek comes to StoneAge with a broad background in operations and business development. She successfully led the operations for Eaton Corporation's electrical engineering service group in central Texas. Her focus is organizational development, improved communication, and strategic planning.

StoneAge has been manufacturing high-pressure waterblast tools for nearly three decades and strives to develop products that meet their customers' specific requirements. StoneAge is committed to manufacturing innovative tools and to providing superior customer service.

To ensure quality, StoneAge's Research & Development Center in Durango, Colorado US thoroughly engineers, tests, and validates performance for their complete line of tools. For more information, please visit www.stoneagetools.com.

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