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**WJTA** WaterJet Technology Association

# Jet News

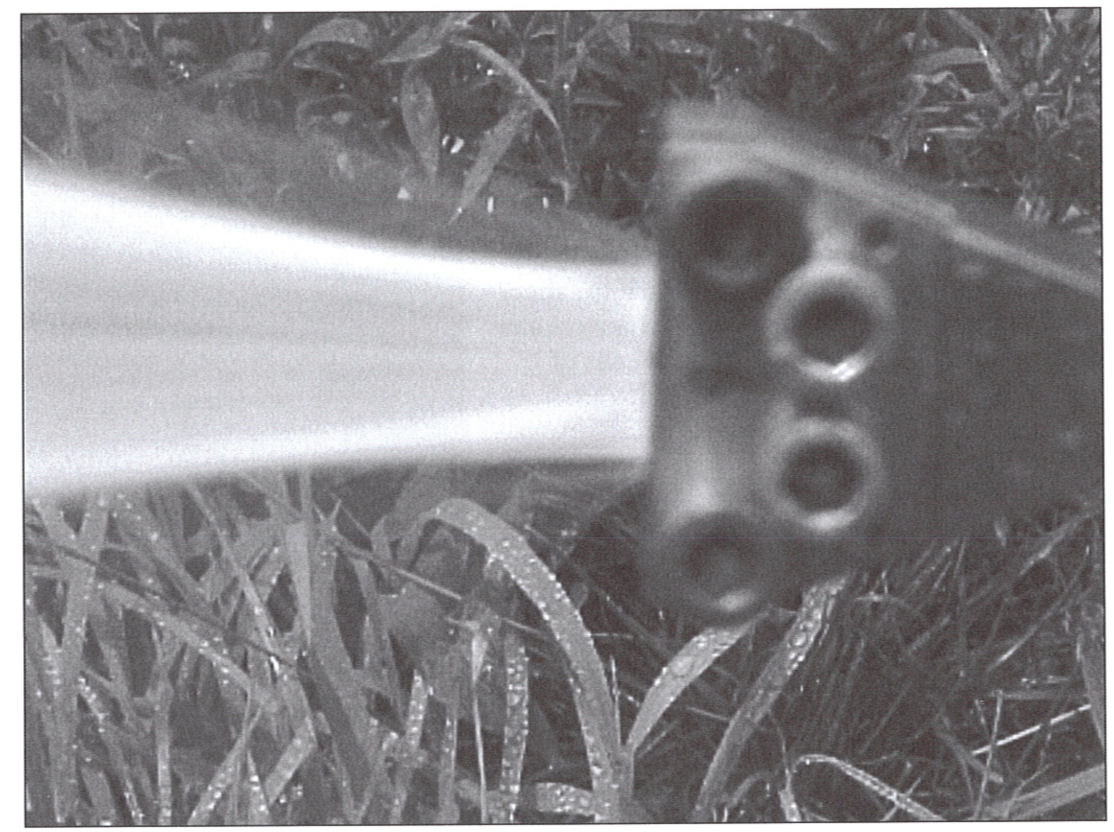
NOVEMBER 2004

*Published by the WaterJet Technology Association for the benefit of its members*

906 Olive Street, Suite 1200 • St. Louis, MO 63101-1434, USA • Telephone: (314)241-1445, Fax: (314)241-1449

## Formation And Application Of A Rectangular Jet

E.S. Geskin and B. Goldenberg
New Jersey Institute of Technology (NJIT), Newark, New Jersey, USA



**A rectangular jet generated by NJIT nozzle at a pressure of 140 MPa (20,300 psi) and a flow rate of 17.01/min. (4.49 gpm), scale 1:1**

ABSTRACT

Depending on the kind of application, a water stream should operate either as a knife or saw (cutting) or as a scraper or brush (milling, cleaning, decoating, etc.). The use of a rectangular jet with a precisely controlled aspect ratio enables us to attain both these goals. Several versions of the slot nozzle used in generating a rectangular jet were constructed and tested at the NJIT's Waterjet laboratory. The experiments performed showed the effectiveness of this nozzle even at an early stage of its engineering. In particular, the specific water consumption by the slot nozzle was significantly reduced and the

**(continued on page 3)**

### On the inside

# Granite Cornerstone For New York City's Freedom Tower Supplied By Barton Mines

Photographs courtesy of Barton Mines Company

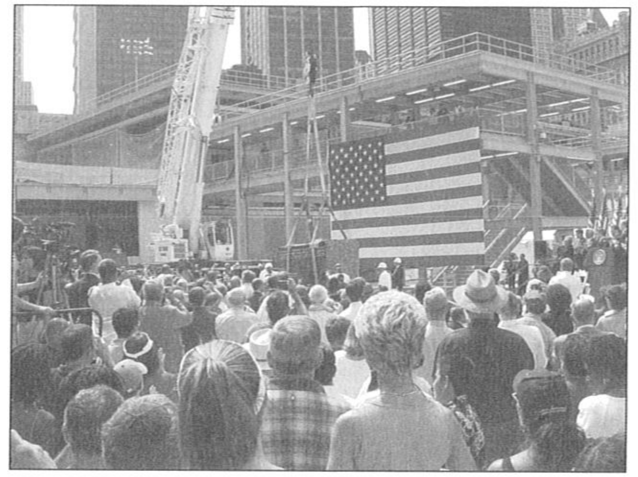
The cornerstone for the Freedom Tower to be built at the World Trade Center site in New York City is a 24-ton garnet-flecked granite block quarried in North River by Barton Mines Company, a subsidiary of The Barton Group. Barton Mines is a 14-year WJTA corporate member.

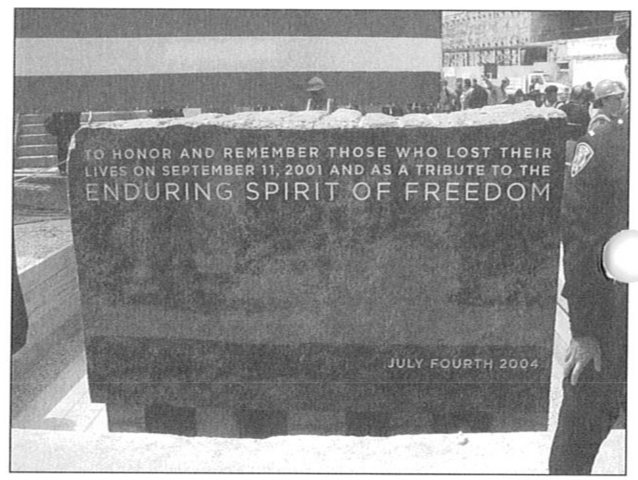
New York Governor George E. Pataki, New Jersey Governor James E. McGreevey, and New York City Mayor Michael R. Bloomberg laid the cornerstone for the Freedom Tower during a July 4, 2004, ceremony held at the site where the World Trade Center once stood. The massive stone is inscribed with the words, "To honor and remember those who lost their lives on September 11, 2001, and as a tribute to the enduring spirit of freedom. – July 4, 2004."

The cornerstone, which measured 119 by 67 by 47 inches when quarried, was placed on a concrete and steel foundation at the base of the Freedom Tower. "It is fitting that this 24-ton block of granite quarried in the Adirondack Mountains becomes a symbol of strength, unity and freedom for our state and the Nation. May this stone be a lasting tribute to the birth of our nation on Independence Day and our rebirth following the tragic events of September 11, 2001," said Charles H. Bracken Jr., chairman of The Barton Group.

Barton Mines is headquartered in Lake George and has grown to become a leading producer of high-quality industrial garnet abrasive products. "The dedication of the Freedom Stone will provide another chapter in the rich history of the company my Great Great Grandfather started the year of our country's first centennial in 1876," said Bracken.

Bracken added, "Barton Mines Company, throughout its long history, has been committed to the patriotic needs of our nation. Our garnet powder has been used to polish the sights on World War II aircraft, the windows of the space shuttle and the lens on the Hubble space telescope. Our products are used to cut the armor plating for Humvees and to finish the hulls of U.S. Navy aircraft carriers."






Barton's stone was selected as the "Freedom Stone" partly because garnet is the official gem of New York State. The block was quarried in May and supplied to Innovative Stone of Hauppauge in early June. Innovative Stone cut, honed, polished and inscribed the block and is preparing it for placement in the Independence Day ceremony.

## WJTA New Address!

Effective September 18, 2004, WJTA relocated to a new office at the following address:

**WJTA**
**906 Olive Street, Suite 1200**
**Saint Louis, MO 63101-1434**

Only our street address changed. The telephone and fax numbers and email and web addresses remain unchanged as follows: Telephone: (314) 241-1445, Fax: (314)241-1449, Email: wjta@wjta.org, Web: www.wjta.org



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productivity greater than that of the commercial round nozzles under comparable operational conditions. It was demonstrated that the rectangular jets constitute an effective machining and cleaning tool.

## 1. INTRODUCTION

A high speed fluid stream has a potential of becoming a major tool for material removal. This potential, however, is still yet to be utilized. One of impediments to the expansion of the jet in applications for material separation is the low energy efficiency of the process. An improvement in jet geometry will increase this efficiency.

Practically speaking, all existing nozzles have a round orifice, as it is much easier to generate a round opening than an opening of any other geometry. Further, a round jet has a minimal surface-to-volume ratio that gives the minimal head loss per a unit of mass. The cost of the nozzle fabrication and the stability of the streams generated assure the competitiveness of the round nozzles. The round jet geometry has, however, significant shortcomings. The principal shortcoming is a limited energy delivery to the substrate and a poor energy efficiency. Several avenues have been adopted by industry in order to address these shortcomings. The energy delivery to the impingement zone might be dramatically increased by high speed nozzle rotation (Summers, 1995). This technique is widely used in jet based surface processing. A rotating nozzle increases the productivity and energy efficiency of jet cleaning; however, it involves the use of rather complicated facilities. More important, in this case the impact zone is still circular, although the diameter of the circle by far exceeds the nozzle diameter. Nevertheless, the rotational nozzle has been adopted by industry. Another approach to the improvement of the jet-substrate interaction is the use of a fan jet (Summers, 1995). This nozzle changes the geometry of the impact zone and thus enhances process productivity. However it negatively affects the momentum of the stream. Finally, non-round nozzle geometries have been designed and commercialized by nozzle manufacturers (Aqua-Dyne, 2003).

(continued on page 4)

## Formation And Application Of A Rectangular Jet, from page 3

Practice had found the optimal shape of a conduit for energy transfer during material processing. A typical surface processing (cleaning, decoating, etc.) tool is a brush or its modifications, such as a scraper or rake. The typical material separation (cutting, sawing, drilling, etc.) tool is a knife or its modification, such as found in machining tools. The principal geometric feature of all these tools is a rectangular tool-workpiece interface with the maximal possible aspect ratio. While the geometry of the high energy beams (laser, waterjet, plasma, etc.) is determined by the physics of the beam formation, the geometry of the solid tool is mostly determined by the conditions of the energy exchange between the source and the workpiece. Thus, it is reasonable to suggest that a rectangle with a large aspect ration is an optimal geometry for the water nozzle.

A rectangular nozzle with a variable aspect ratio was developed at the NJIT Waterjet Laboratory. The nozzle forms a high-speed jet with a controllable geometry by expelling a fluid from the high-pressure chamber through a specially designed rectangular port [Geskin and Goldenberg, 2002)]. These nozzles were successfully used for metal depainting, derusting and graffiti removal. Special experiments were carried out in order to compare the performance of this invented nozzle and a commercial nozzle. The tests showed the effectiveness of the NJIT nozzle even at an early stage of its engineering. Particularly, the specific water consumption of the newly developed nozzle was significantly below that using a comparable commercial nozzle.

This paper presents the results of the preliminary testing of a rectangular nozzle with a high aspect ratio (a slot nozzle) designed by the Waterjet Laboratory of NJIT. Firstly, a simplified analysis of the energy utilization by the round and rectangular impact zones is given. Then the results of the experiments demonstrating stability and relative effectiveness of the slot jet are given and a possible direction for an improvement in the nozzle design is suggested.

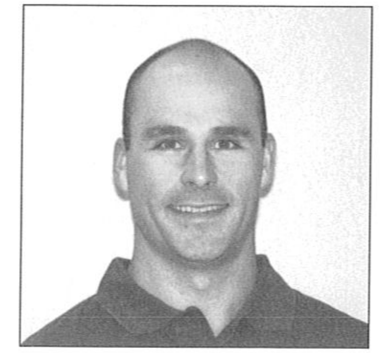
### 2. DEFICIENCY OF ROUND JETS

Figure 1 illustrates the interaction between a round jet and the substrate. Although this figure as well as the analysis below is concerned with a traversing jet, it is equally applicable to rotational jets. As it is shown in Figure 1, the substrate A is subject to

(continued on page 6)



## Federal Signal Names New Western Regional Sales Manager



Mike Kohn

Federal Signal Environmental Products Group announces Mike Kohn as the new Western Regional Sales Manager. He will be responsible for direct sales of Guzzler and Jetstream products in California, Nevada, Arizona, New Mexico, Alaska and Hawaii.

Kohn holds a B.S. degree in Natural Resources from Ohio State University and has 10 years of technical sales experience.

The Federal Signal Environmental Products Group includes Jetstream, Elgin Sweeper, Vactor Manufacturing, Guzzler Manufacturing, and Leach.

For more information, visit Federal Signal at www.federalsignal.com

# Pat DeBusk Joins DeBusk Industrial Services Company

Pat DeBusk has joined Debusk Industrial Services Co. (DISC) and will serve on the board of directors and direct the company. Mr. DeBusk has 40 years of experience in the industrial cleaning business. He was the vice president of Hydro Services for 20 years and the president of Hydro Services for seven years. In the 1960s Mr. DeBusk played an integral role in creating the tools and components that would become the foundation of the industrial waterblasting business.

Mr. DeBusk has been active in the WaterJet Technology Association (WJTA) for many years, and he has served on the board of directors for six years. In 2003, the WJTA recognized Mr. DeBusk's achievements and contributions to the industry by presenting him with the association's most prestigious honor – the Pioneer Award.

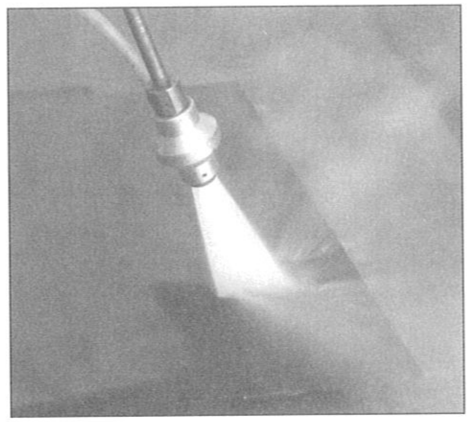
Customer satisfaction is the primary goal at DISC and service is the key to success, says Mr. DeBusk. DISC provides these services: hydroblasting, vacuuming, chemical cleaning, transportation, coke cutting, hydrocutting, specialty line cleaning, and specialty vessel cleaning.

DISC, a WJTA corporate member, has five operating offices: a home office in La Porte, Texas, and other offices in Groves, Texas; Sulfur, Louisiana; Memphis and Chattanooga, Tennessee. DISC offers a well-trained work force headed up by company President Andrew DeBusk.

For more information, visit www.debuskindustrialservices.com or call (281)842-8000.

## New NLB Products, from page 17

virtually eliminates the dust commonly generated by abrasive blasting, and the resulting health and environmental hazards.



The Profiler™

Designed for surface preparation on ships and other metal surfaces, the Profiler leaves an excellent bonding surface for new coatings. It profiles a 100mm (4-inch) path at rates of up to 5m (15 feet) per minute. Various abrasive media can be used to suit specific applications. These media are fed to the nozzle from an abrasive feed hopper through metering discs that restrict the flow to a predetermined rate. A typical flow is 0.9 kg (2 pounds) per minute.

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### Starjet™ Highway Stripe Removal System

NLB Corp.'s automated stripe removal system, the Starjet™, is now available with an optional vacuum recovery system to simplify clean-up. The Starjet removes highway stripes faster and more completely than abrasive methods, using ultra-high pressure water (up to 40,000 psi). It typically removes coatings, membranes and epoxies at rates of up to 7,000 feet per hour without damaging pavement. The vacuum recovery option allows water and debris to be contained so that the water can be filtered and reused.

The stripe removal is performed by NLB's patented rotating nozzle assembly, mounted on the front of a truck. The truck tows a water tank and a trailer with the vacuum unit and ultra-high pressure pump, providing contractors with a self-contained system. All controls are conveniently located by the driver's seat.

Starjet™ Highway Stripe Removal System

NLB, a leader in high pressure and ultra high pressure waterjet technology, manufactures a full line of quality waterjetting systems and accessories for many uses, including surface preparation, industrial cleaning, tank cleaning, descaling, paint and sludge removal, concrete demolition, concrete and pipe cutting, and more. For more information, visit www.nlbcorp.com or call (248)624-5555.

The *Jet News* is published by the WaterJet Technology Association (WJTA) and is a benefit of membership in the Association.

## Formation And Application Of A Rectangular Jet, from page 4

treatment (cleaning, decoating, etc.) by the jet B moving with speed V in the direction of the arrow. The treatment is due to the energy delivered to the substrate A by the jet B. The section " a" is a part of substrate A, while the section " b" is a part of the jet B. Because the widths w of the sections " a" and " b" are equal, the section " a" of the substrate is treated by section " b" of the jet only. The length of the sector " b" , λ determines the duration of the interaction between the jet B and the section " a" . Here $\lambda = \frac{F_b}{W}$ is the average length of the chord of the section " b" and $F_b$ is the area of the section " b" . The energy which the section " a" receives from the jet B, while the jet is impacting the substrate A, is delivered only by the section " b" . The energy of the rest of the jet does not affect the section " a" . The amount of energy delivered to section " a" by jet B is proportional to the duration of the ' a" -" b" interaction (residence time) i.e., the length λ of the section " b" .

Let us assume that the kinetic energy is evenly distributed across jet B and that the kinetic energy of the water is completely transferred to the substrate A in the course of the water impact on the substrate surface. Thus the energy E absorbed by the section " a" in the course of the jet-surface interaction is (Geskin et.al, 1998, Leu et al, 1998, Meng et al,1998)

$$E = \frac{\lambda F_a e}{V} \qquad (1)$$

where $F_a$ is the area of section " a" , e is the kinetic energy of the jet per unit of the jet cross sectional area and per unit of time, V is the traverse rate of the nozzle. Because, for a given set of operational conditions, the values of $F_a$, e and V can be assumed constant, the amount of energy delivered to the substrate is

$$E = k\lambda \qquad (2)$$

where k is a constant. Thus, for given jet characteristics and traverse rates the amount of energy delivered to a substrate is a function of λ. The energy required for the surface treatment $E_0$ is given by the equation:

$$E_0 = k\lambda_0 \qquad (3)$$

Here $\lambda_0$ is the length of the section that delivers the required amount of energy to section " a" under given process conditions.

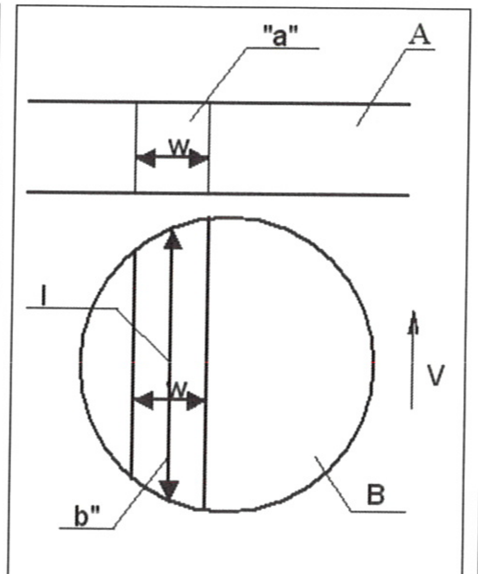


**Figure 1. Schematic of cleaning substrate " *A*" by jet " *B*" moving with a speed *V.* Section" b" is a part of jet B impacting section " a" of the substrate A.**

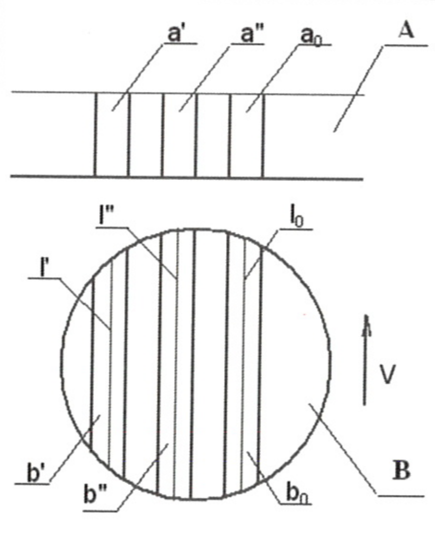


**Figure 2. Schematic of cleaning a', a" and $a_0$ of the substrate A by moving jet B. Notice different durations of cleaning section a' , a" and $a_0$**

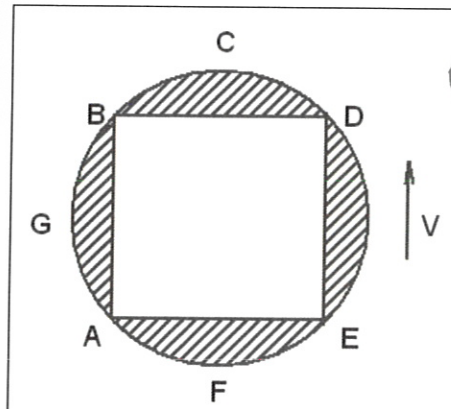


**Figure 3. Schematic of water utilization in the course of cleaning by a round jet moving with a speed V. A part of the stream energy proportional to the area ABDE (AB=$l_0$) is utilized. The part of the stream energy proportional to the shaded area is lost.**

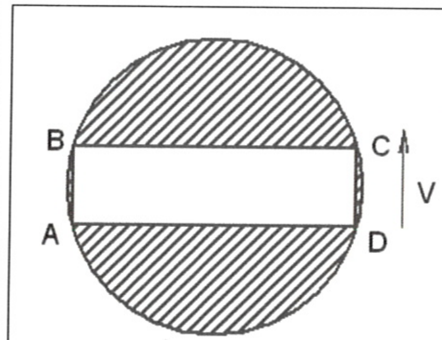


**Figure 4. Utilization of the energy of the rectangular and round jets Notice *AB=$l_0$* the part of the energy of the round jet proportional shaded area is lost.**

**(continued on page 7)**



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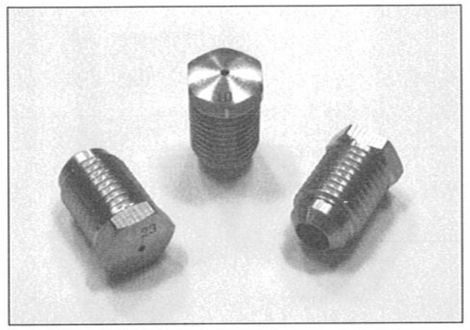
**(continued on page 22)**

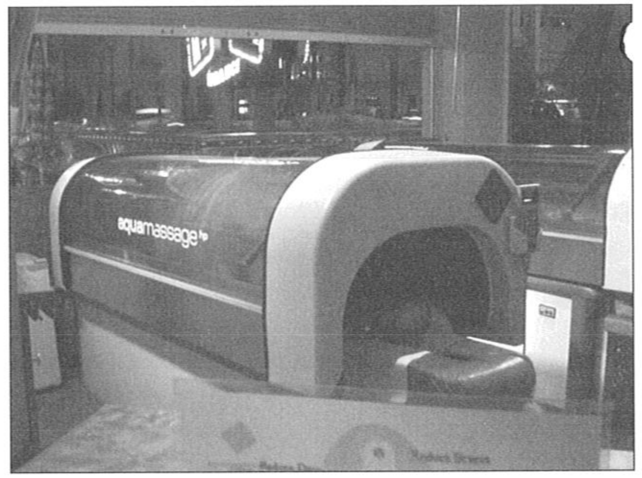
# H2O Jet Inc. Offers Orifice Mounts To The Cleaning Industry



After more than a decade of experience producing orifice mounts and waterjet parts to the 55,000 psi precision cutting industry, H2O Jet Inc. (www.h20jetcorp.com) is now offering its high quality mounts to the cleaning industry. H2O Jet Inc. is utilizing the same proven production process using only the highest quality components and quality control to produce it new line of "Blast I" and "Blast II" mounts. Sapphire, ruby and diamond mounts are available in a 3/8-inch, 24 thread, hex head style configuration in addition to a metric thread, hex head style. Low profile two-piece style mounts are also available.

The new cleaning product line will be sold exclusively through Tek Supply Ltd. in St. Paul, Minnesota. Contact Brian Gleeson by phone: 651-755-7089, fax: 651-755-7089 or e-mail bgleeson@mmwaterjet.com.

# Waterjet Massage




The Aqua Massage is a machine in which a person lying on his/her stomach receives a massage over three sides of the body from an array of 36 pulsating waterjets. The client's body conforms to a waterproof barrier so the user remains clothed and dry. The waterjets issue from a V-shaped spray bar contained under an acrylic canopy. The canopy opens and allows access for the client to lie down on a cushion. The spray bar travels back and forth moving the full length of the body or it may be programmed to concentrate on a specific area.

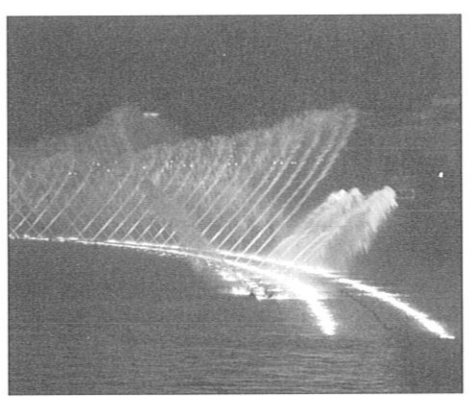
The waterjets impact force can be adjusted from two to ten pounds (similar to pressing the body with fingertips) to suit the sensitivity of the client.

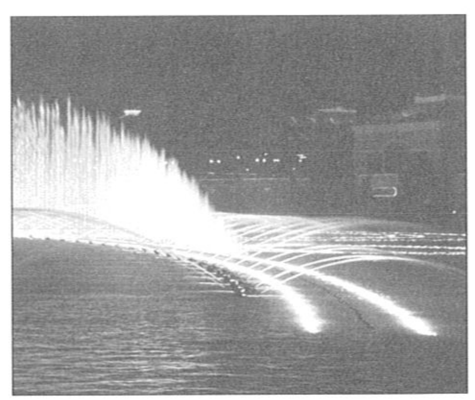
The waterjets pulsate at a rate adjustable from two cycles per second to ten cycles per second. The pulsation rate can be controlled independently from the water pressure. The water temperature is adjustable from 90ºF to 104ºF.

The Aqua Massage is self contained. No plumbing is required. No post-session clean-up or water disposal is necessary.

For more information, contact by phone: (905) 804-0594, email: info@aquickmassage.com, or visit www.aquickmassage.com

## The Dancing Fountains Of Bellagio, from page 8





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**2005 WJTA American Waterjet Conference**

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## Formation And Application Of A Rectangular Jet, from page 6

In treating substrate A by moving jet B (Figure 2) sections $a'$, $a_0$ and $a''$ are subjected to the impacts of sections $b'$, $b_0$ and $b''$ characterized by the lengths $\lambda'$, $\lambda_0$ and $\lambda''$ where $\lambda' < \lambda_0 < \lambda''$. Thus section $b_0$ delivers the required amount of energy to section $a_0$. On the other hand, section $a'$ does not acquire sufficient energy and should be treated again, while section $a''$ gains an excessive amount of energy. The insufficient and excessive energy supplies not only result in energy loss but also reduce the resulting surface quality. Section $a''$ might be damaged by the extra energy delivered in the course of treatment. Section $a'$ also might gain extra energy and be damaged during additional treatment.

Let us now discuss total energy use during surface treatment by a moving jet. Let us assume that under a given set of operational conditions the length of chord AB is equal to $l_0$. Then the part of the substrate impacted by the segment ABCDEF (Figure 3) will receive excessive energy, while areas treated by the segments AGB and EHD will receive insufficient amounts of energy. The amount of excessive energy delivered to the surface of the substrate is proportional to the areas of segments BCD and AFE and this energy is lost. The energy delivered to the substrate by the AGB and EHD segments is also lost, because the substrate surface subjected to treatment by these parts of the jet must be treated a second time. The useful energy, i.e., the energy necessary and sufficient for the surface treatment is proportional to the area of the rectangle ABDE. An optimal energy utilization is attained if the ratio of the area ABDE to the cross-sectional area of the jet is maximal. This is attained if $\lambda = \frac{d}{\sqrt{2}}$

where λ is the length of the chords AB and BD and d is the jet diameter. With this condition, the area of the square ABDE occupies 64% of the cross-sectional area of the jet. Because the energy delivered by the jet's segments AGB, BCD, EHD and EFA is lost, the minimum energy loss experienced during this use of a round jet will make up 36% of the energy supplied.

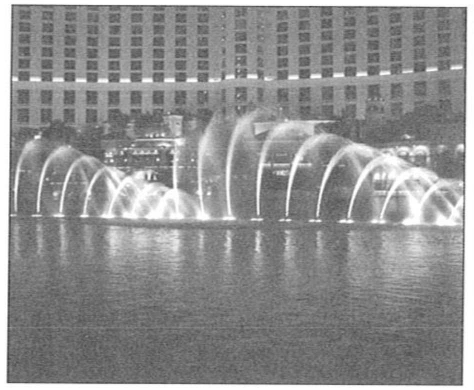
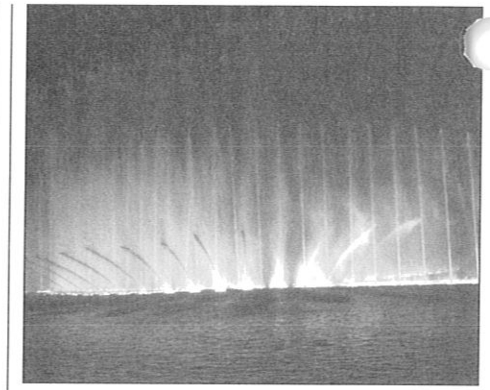
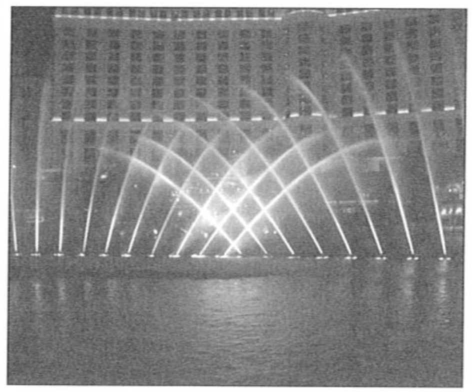
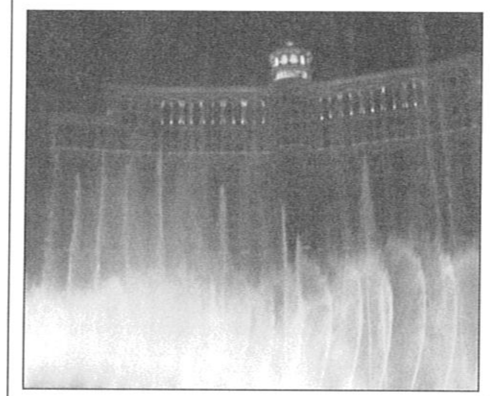
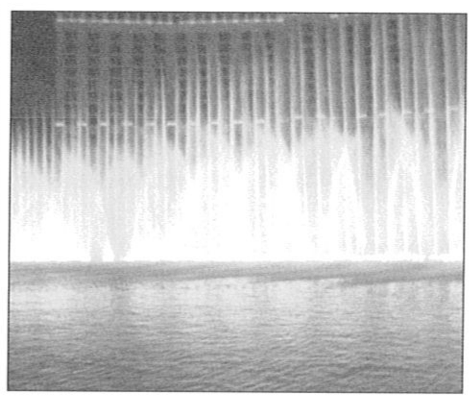
**(continued on page 10)**

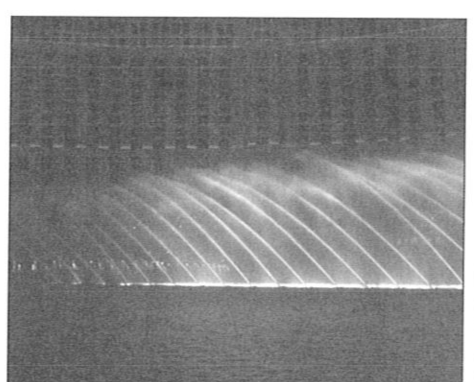
# The Dancing Fountains Of Bellagio, Las Vegas, Nevada

Beautiful displays of illuminated fountains and synchronized music welcome visitors to the Bellagio Hotel in Las Vegas. The Fountains of Bellagio are the result of a collaboration between Steve Wynn, chairman of Mirage Resorts, and WET Design of Universal City, California. Over 1,000 water expressions and over 4,000 individually programmed lights are located within the eight-acre lake in front of the Bellagio Hotel. WET Design created and manufactured a variety of technological devices for the Bellagio Fountains to ensure the intricate movements of water to music. The jets reach a maximum height of 240 feet.

Photographs are courtesy of Grzegorz J. Galecki, Ph.D., University of Missouri Rolla, Rolla, Missouri.






(continued on page 18)

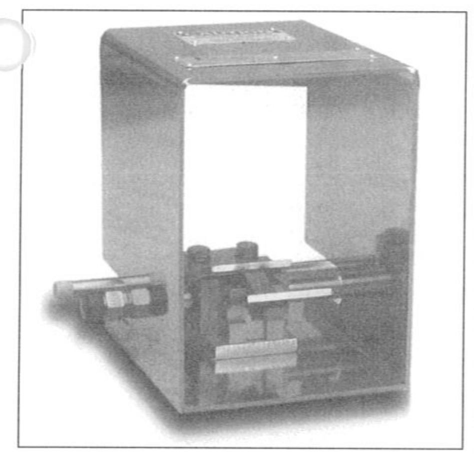


# New NLB Products

## NLB FC24-286 Foot Control

The latest waterjet foot control valve from NLB Corp. is suitable for more jobs than ever before, as it can be used at any pressure between 10,000 psi and 24,000 psi (700-1,700 bar). The FC24-286 also handles flows of up to 35 gpm (133 lpm) and drastically reduces downtime with a quick-change cartridge valve that can be replaced in the field in less than 60 seconds.

The new foot control is an ideal accessory for NLB's convertible waterjet pump units and most others. It features a patented pedal design (U.S. patent no. 5,636,789) that lets the operator dump pressure immediately, and dual dump ports that maintain valve stability during use.

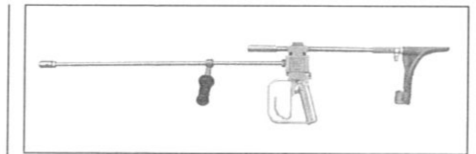


NLB FC24-286 Foot Control

The FC24-286 is rugged yet lightweight (just 31 pounds) and is made of non-corrosive materials for long service life. Each foot control valve is thoroughly tested before shipment.

## NLB NCG24-286

NLB has introduced the NCG24-286 waterjet lance that lets operators



NCG24-286 waterjet lance

work at all pressures between 10,000 psi and 24,000 psi (700-1,700 bar). The NCG24-286 lance handles flows as high as 35 gpm (133 lpm) and features a quick-change cartridge valve that practically eliminates downtime, since it can be replaced in the field in less than 60 seconds.

The pressure range of the new lance makes it an ideal accessory for NLB's convertible waterjet pump units. It is ergonomic and productive, with features to improve operator comfort and protection. A patented trigger (U.S. patent no. 5,636,789) lets the operator dump pressure immediately by simply pushing the trigger forward. The trigger can be operated with just 8 to 12 pounds of pressure, and a one-finger latch prevents accidental actuation.

The NCG24-286 lance weighs just 13.5 pounds, and the operator can adjust both the shoulder stock and handgrip to maximize personal comfort. Like all NLB accessories, the lance is made of top-quality materials and each is thoroughly tested before shipment.

## Profiler Waterjet Nozzle

The Profiler™, a new waterjet nozzle from NLB Corp., combines the force of ultra-high pressure waterjetting with the profiling action of abrasive media. The water

(continued on page 20)

## Guzzler NX Now Offers High-Dump Option

The Guzzler NX vacuum loader is now available with a High-Dump option. This addition to the industry-leading NX model allows for dumping debris directly into a roll-off container up to five feet (60 inches) in height.

A heavy duty, telescopic hydraulic cylinder at the rear of the Guzzler NX chassis lifts the debris body upward and slightly backward, allowing extra clearance from the rear of the truck for efficient dumping. With the option, an operator can choose to offloaddump material in either the normal- or high-dump mode.

"The unique high-dump on the NX feature is another customer-driven innovation," said Tony Fuller, Guzzler national sales manager. "Roll-off boxes are commonly used in debris cleanup and customers have been asking for the ability to dump into these containers."

The NX, unveiled in February 2003, is one of three models in the Guzzler line. Guzzler vacuum loaders tackle the toughest applications, from solids and dry bulk powders – like fly ash – to liquids, slurries and thick, heavy sludge. The NX offers very low sound levels, better fuel economy, increased loading capacity and the patent-pending VR (Vacuum Recovery) Technology for greater productivity.

Guzzler Manufacturing, Inc., based in Streator, Ill., is a leading manufacturer of industrial vacuum loaders. Guzzler is part of Federal Signal Corporation's (NYSE:FSS) Environmental Products Group, which includes Jetstream, Elgin Sweeper, Vactor Manufacturing, and Leach. Visit Guzzler on the Internet at www.guzzler.com.

Let us assume now that a section " a" is treated by a rectangular jet ABCD (Figure 4). Let us also assume that the length of the edge AB assures the delivery of energy to the substrate A required for surface treatment. The width of the jet that is equal to segment BC determines the width of the strip swept i.e. the rate of surface treatment. If the same rate of treatment is attained by a round jet, then the energy delivered by the shaded areas of the jet cross section is lost. Thus the use of a round nozzle for surface treatment necessarily results in energy losses which might constitute a significant part of the available jet energy.

## 3. INVESTIGATION OF THE STABILITY OF A RECTANGULAR JET

Several versions of the slot nozzle were constructed and tested in NJIT's Waterjet Laboratory. The first series of tests involved an evaluation of jet stability. A general view of the jet developed is shown in Figure 5. The figure shows that the slot nozzle generates a stable, coherent jet, which maintains its stability at L/b>2500, where L and b are the sizes of the rectangular stream. The stable, coherent jets can also be developed at large (Figure 6) and low (Figure 7) water flow rates. Figure 7 demonstrates the feasibility of generating micron sized streams using a slot nozzle. The stability of the rectangular jet is demonstrated by the behavior of the rebounding jet (Figure 8). Figure 9 demonstrates the peculiarities of the rectangular jet-substrate interaction. The nozzle shown on this picture is supported by the rebounding stream only. This stream, however, in addition to exerting a force compensating for the weight of the nozzle creates a vacuum that strongly attaches the nozzle to the

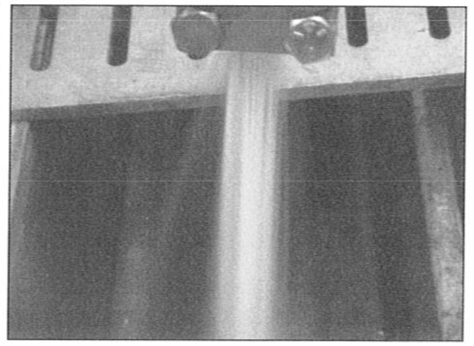


**Figure 5. A rectangular jet. Water pressure: 68 MPa, water flow rate: 6.5 l/min, slot: 12.5 x 0.0375 mm, scale: 1:1. The jet maintained its coherence at L/b>2500.**

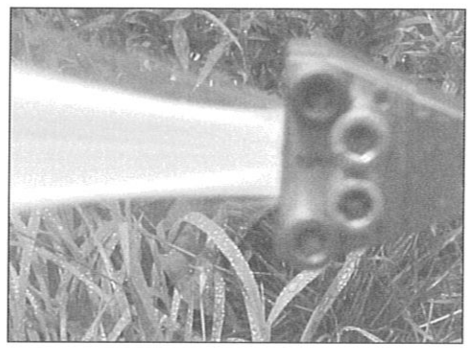


**Figure 6. A rectangular jet generated by NJIT nozzle at a pressure of 140 MPa and a flow rate of 17.0 l/min., scale 1:1.** (Also pictured on the cover.)

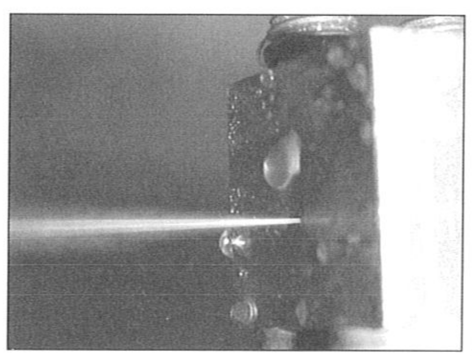


**Figure 7. A rectangular jet generated at a water pressure of 270 MPa, 0.1 l/min, and a flow rate of 0.1 l/min. Slot: 0.065 x 0.0025 mm, scale 2:1. A jet core is maintained at L/b=40,000.**

(continued on page 14)

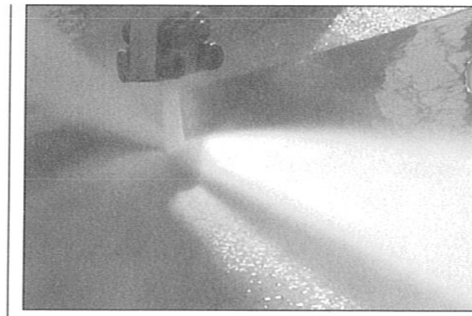


**Figure 8. A rectangular jet generated at a water pressure of 238 MPa, flow rate: 9 l/min, slot: 10 x 0.0315 mm, scale: 1:2. The rebounding jet maintains its coherence at L/b=800.**

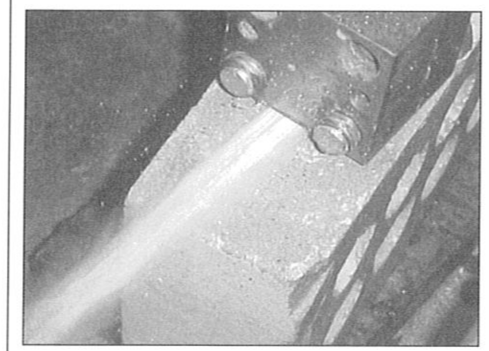
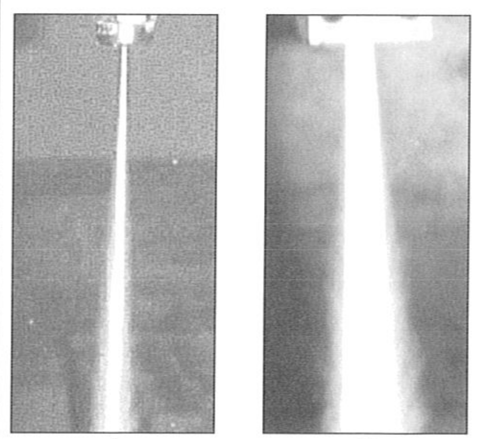


**Figure 9. A view of the rectangular stream normal to the nozzle axis and developed between the nozzle body and the substrate (brick). Water pressure: 68 MPa, water flow rate: 6.5 l/min. The slot: 12.5 x 0.0375 mm. Scale: 1:4. Notice the stream normal to the nozzle exit, maintained coherence at the distance of 15,000 L/b. brick.**



a) b)

**Figure 10. Water stream generated by a commercial and a NJIT nozzles**
**a) Commercial round nozzle, ID=0.7 mm, pressure P= 86 MPa, flow rate=1l/min.**
**b) NJIT nozzle, pressure P= 93 MPa, flow rate =2.9 l/min, scale 1:2.**





realistic immediate application of the nozzle developed is in the maintenance of civil infrastructure, for example in graffiti removal. The nozzle can also be used to improve cutting capabilities. Finally, two novel avenues for nozzle application might emerge. One might involve processing of large (roads, airports, beaches) surfaces and large volumes (waste management). Another one might bring about the development of such technologies as the fabrication of thin films, composites, etc.

## 6. ACKNOWLEDGEMENT

This study was partially supported by the NJ Center for Micro Fluidic Control and by NSF grant "Development of the Water Based Machining Technology", DMI 9900247.

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## 8. NOMENCLATURE

A - substrate
a - section of the substrate
B - jet
b - section of the jet
d - nozzle diameter
E - energy absorbed by the substrate
e - specific kinetic energy of the jet
$F_b$ - area of the section b
k - constant
L - stand off distance
$l_0$ - segment required for complete deposit removal
λ - length of the segment
V - traverse rarate
w - jet width

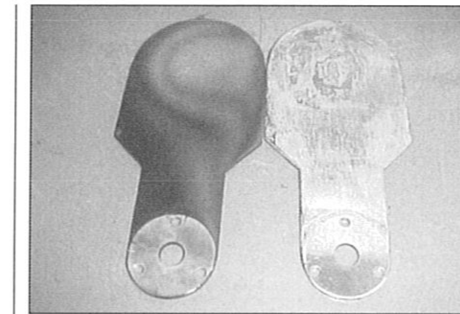

**Figure 15. The surface of an aluminum screen before and after removal of high temperature oxide deposit. Water pressure: 68 MPa, water flow rate: 6.5 l/min.**

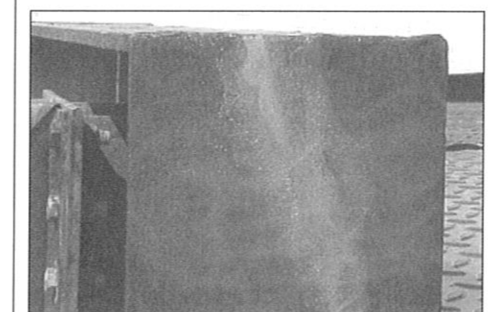

**Figure 16. Removal of heavy rust. Pressure: 240 MPa, water flow rate: 9 l/min slot: 0.4 x 0.0015", scale: 1:4.**

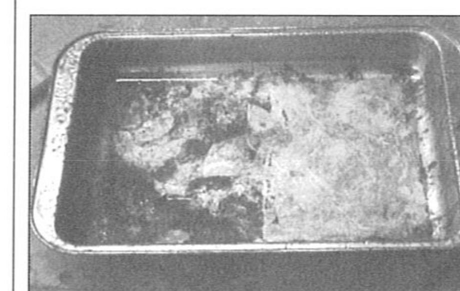

**Figure 17. Derusting of a heavily rusted pan. Water pressure: 65 MPa, water flow rate: 6.5 l/min. Slot: 12.5 x 0.0375.**

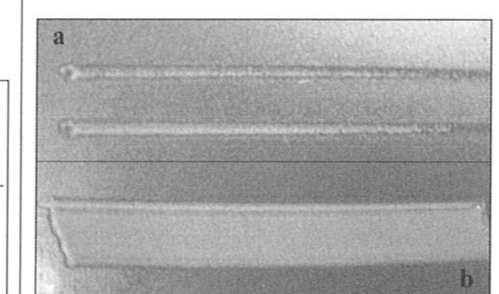


**Figure 18. Compare speed and quality cleaning a surface of the car body using commercial nozzle 0.1 mm (a) and a NJIT nozzle 0.4 x 0.0015 (b) scale 2:1.**
**a - Commercial nozzle, cleaning rate 3.2 cm²/min**
**b - NJIT nozzle, cleaning rate 58.0 cm²/min**

**Table 1. Comparison of the cleaning efficiency of the different nozzles**

| Kind of nozzle | Kind of deposit | S, $mm^2$ | P, MPa | F, L/min | D, mm | Rate of cleaning $cm^2/min$ |
|---|---|---|---|---|---|---|
| Commercial nozzle (Figure 6a) | Hard paint from a car body | 0.34 | 86 | 1.0 | 10.0 | 3.2 |
| NJIT nozzle (Figure 6b) | Hard paint from a car body | 0.48 | 93 | 0.8 | 10.0 | 58.0 |

Here

S - cross-sectional area of the nozzle opening, $mm^2$
P - water pressure, MPa
F - water flow rate, L/min
D - standoff distance, mm

substrate surface. As is shown in Figure 10 the streams generated by both round and rectangular nozzles are rather similar. Thus, the experiment performed shows that a slot nozzle generates a stable, coherent jet having an adequate stand off distance.

### 4. INVESTIGATION OF THE EFFICIENCY OF A RECTANGULAR JET

In order to determine the effectiveness of material removal by a slot nozzle, this nozzle was used for several surface processing operations. During this test the nozzle was guided manually (Figure 11). One of the experiments involved the removal of graffiti from a marble wall. (Figure 12). No damage to the substrate was observed in this operation. Figure 13 shows the removal of hard paint from a steel surface. Depainting a highly porous surface is depicted in Figure 14. Here the paint was completely removed from part of a brick subjected to cleaning. Figure 15 shows the removal of oxides from an aluminum shield used for substrate protection during vapor deposition. The jet practically completely removed these oxides. Removal of heavy rust from a steel surface is shown in Figure 16. Restoration of heavily rusted kitchen pan is depicted in Figure 17. The experiments described above show the feasibility of using slot nozzles for various surface processing operations. The effectiveness of the slot nozzle is demonstrated by Figure 18. As shown in this figure and Table 1, the productivity of a slot nozzle exceeds that of the conventional one by an order of magnitude.

In the experiments performed, the thickness of the jet was determined by the conditions set during nozzle fabrication and, in principle, can be reduced even further. The width of the stream was maximal and was determined by the available pump flow rate. The nozzle traverse rate was selected so that a desired level of surface cleanliness could be obtained.

### 5. CONCLUSION

The experiments performed in this work show that a rectangular jet has potential for improving surface processing techniques. The most

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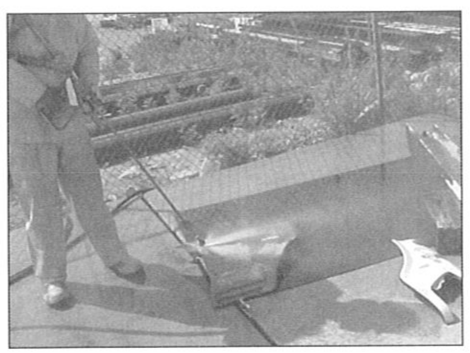

**Figure 11. Using the slot nozzle with manual guiding.**

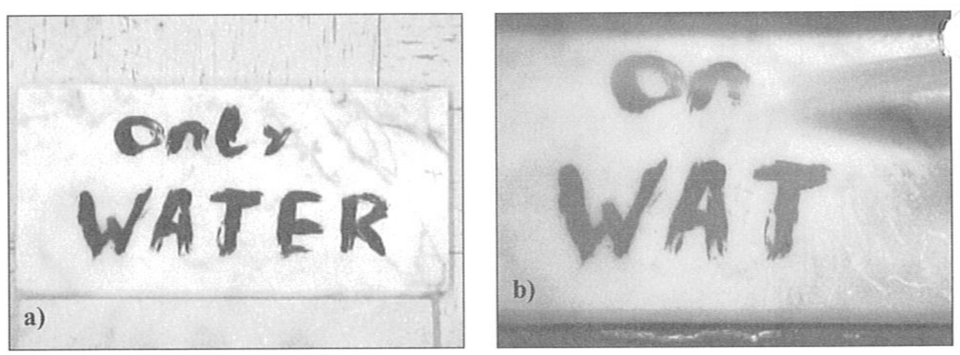


**Figure 12. Removal of graffiti using NJIT nozzle at a water pressure 68 MPa and a flow rate 6.5 l/min. a) prior to cleaning; b) in process. Scale: 1:4**

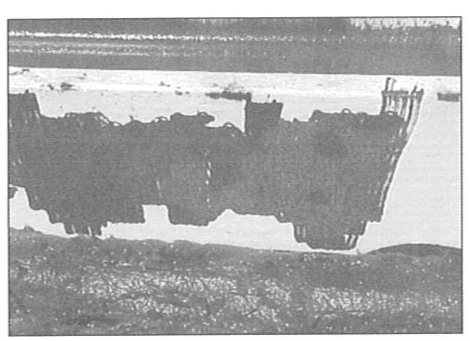

**Figure 13. Removal of hard paint. Water pressure: 240 MPa, 9 l/min, slot: 0.4 x 0.0015" Scale: 1:3, Rate of depainting: 55 $cm^2$/min.**

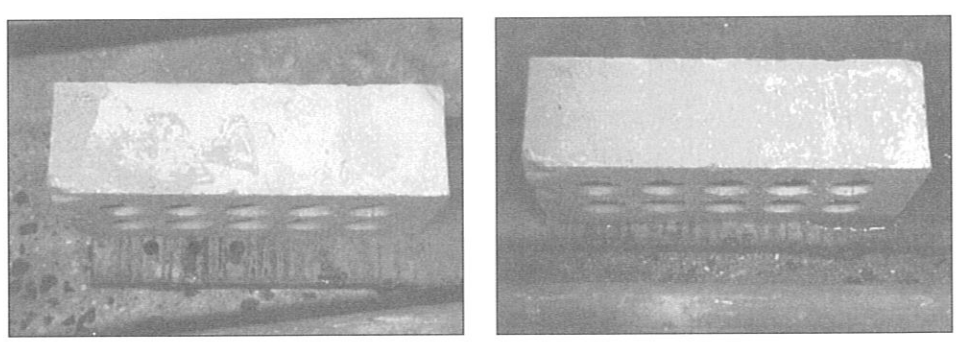

**Figure 14. Depainting of a porous brick. Water pressure: 68 MPa, water flow rate: 6.5 l/min. The slot: 12.5 x 0.0375 mm. Scale: 1:4. Notice: The jet was used to remove a paint (rustoleum, inc light marine grade, hard hat fast drive, industrial coating finish) from the left part of the upper edge of the brick. An area of 400 $cm^2$ was depainted in 50 sec.**



# 2005 WJTA American Waterjet Conference

August 21-23, 2005

Marriott Houston Westchase Hotel • Houston, Texas, USA

## Announcement and Call for Papers

Impressive progress and a fast-growing understanding of the diversified applications of waterjet technology are generating a growing excitement in the industry. New techniques and applications are being developed and current ones are being improved. Waterjet technology, now being used in nearly all types of industry — manufacturing, mining, construction, concrete, stone, aerospace, engineering, process, and medical industries — continues to expand at a rapid pace.

The **2005 WJTA American Waterjet Conference** will focus, from a practical and scientific viewpoint, on the most up-to-date advances in waterjetting equipment, techniques, and applications. The areas to be addressed include, but are not limited to:

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- **Advanced Industrial Applications**
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- **Components and Systems**
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- **Contractor Applications and Processes**
- **Demilitarization, including Removal of Land Mines (Demining)**
- **Drilling Applications**
- **Excavation, Tunneling, and Mining Applications**
- **High Pressure Equipment and Systems**
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- **Jet Mechanics**
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Commercial and academic authors are encouraged to submit titles and abstracts for consideration. To submit an abstract(s), please complete the abstract submission form on the back of this sheet, attach a copy of your abstract(s), and forward to the attention of the Conference Coordinator at the WaterJet Technology Association. **The deadline date for submission of abstracts is December 31, 2004.**

An Abstract Review Committee consisting of five referees will review the abstracts. Authors will be advised by **February 28, 2005**, regarding the decision of the Abstract Review Committee.

The 2005 WJTA American Waterjet Conference is organized by the **WaterJet Technology Association** and is endorsed by the **International Society of Water Jet Technology**. The WaterJet Technology Association looks forward to providing this forum and to your involvement and participation.

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