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Waterjet and vacuum equipment at the live demonstrations in Houston, Texas, at the 2009 American WJTA Conference and Expo, August 18-20, 2009.

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August 17-19, 2010

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On the inside

Electrostatic Charge Generation In Waterjet Systems

By: Paul L. Miller, Gradient Technology, Elk River, Minnesota

ABSTRACT

The use of waterjets can generate electrostatic charges that are potentially hazardous to personnel and harmful to equipment and product. Several serious fires have been attributed to static discharge during waterjet cleaning operations, and static electric arc discharge has been known to damage composite materials. The waterjet industry's trend toward using higher velocity liquid jets and higher purity water increases the risk of electric spark generation as shown by theoretical analysis and empirical testing. This paper identifies the mechanisms related to static electric charge generation during waterjet operations and the corrective measures necessary to control potentially hazardous electrostatic discharge.

1.0 INTRODUCTION

The presence of static electricity has been known since early Greece, and most likely long before. The modern word "electron" is derived from the Greek word for the material known to us as amber, as it was commonly used for developing a static electric charge. For most technologies throughout time the build-up of static electricity was little more than a nuisance. A century ago the worst effects a person could expect from static electricity was a jolt when touching a doorknob on a winter's day. It was not until combustible dusts and flammable liquids became more prevalent that the more serious hazards of electrostatic discharge (ESD) became well known. Modern fluid jet equipment has the potential of generating thousands of volts of electricity and has caused several spectacular fires from undesired ESD generation around flammable materials.

1.1 Static Electricity Fundamentals

Static electricity is caused by the buildup of an electrical charge imbalance, with one item's having an excess of electrons and another item's having a deficiency of electrons. The transfer of electrons to balance out the systems is called an electrostatic discharge. Since the speed of electricity is functionally the same as the speed of light, or about $3.0 \times 10^8 m•s^{-1}$, when using a good conductor the transfer rate can be extremely fast. Nonconductive materials can substantially slow down the rate of electron transfer and can effectively prevent electrons from flowing.

When two different uncharged materials are in contact, an "electrical double layer" forms where electrons transfer back and forth with a "contact potential" of between 1.0×10^{-3} to 1.0×10^{-1} volts. When two conductive materials are used, the electrons can quickly transfer back and correct any differences in electron balance. However, when a nonconductive (or insulating) material is used, some of the electrons can be "trapped" on its surface and the imbalance in electron quantities can create an electrical potential. The length of time required for the electrical charges to dissipate from a given material is known as the "relaxation time." The relaxation time for hydrocarbons of different conductivities is shown in Table1.

1.2 Electrostatic Discharge Damage

Many common modern materials and equipment can be damaged by electrostatic discharge. These items can include computer components, photographic film, electrical equipment, and composite laminates. In some extreme cases, workers can be injured or even metallic structures damaged from ESD.

In most of the cases the ESD damage is from a localized melting of an item due to the extreme levels of heat generated by a miniscule electric arc. Integrated circuit components are especially vulnerable to such discharge and can even be damaged by the amount of electricity accumulated when people walk across a floor. The ESD sensitivity standards for electrical components is shown in Table 2

Even more important is the potential for ESD to ignite flammable liquids and combustible dusts. As shown in Table 3, the amount of energy required to ignite common flammable materials is rather low. A more unusual concern is in locations where ESD can ignite explosive materials at very low electrical energy levels as shown in Table 4. Explosive materials usually receive extreme attention in such situations, but flammable liquids and gases actually require substantially

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Table 1. Relaxation Time for Hydrocarbons of Differing Conductivities (Eichel, 1967)

Conductivity ($mho•m^{-1}$)	Relaxation Time seconds	Material
10^{-20}	2.196×10^5	hexane
10^{-19}	2.196×10^4	benzene
10^{-18}	2.196×10^3	
10^{-17}	2.196×10^2	xylene
10^{-16}	2.196×10^1	toluene
10^{-15}	2.196×10^0	

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Swedish Dam Relies On Hydrodemolition Techniques Throughout Refurbishment

Hydrodemolition techniques are being used for the refurbishment contract on Sweden's Jäpströmmen hydropower station dam wall and three spillway gates using Aquajet's Aqua Cutter robotic hydrodemolition equipment. Working conditions included underwater operations and night-time temperatures of -25ºC.

Swedish hydrodemolition specialist E-Schakt has started work on the major refurbishment contract for the concrete dam and three spillways, some 80 km west of Ostersund, mid-Sweden, to meet increased water volumes.

Built in 1944 and located on Lake Kallsjön, the dam walls and concrete structures of the three spillway gates have badly deteriorated as a result of poor initial construction methods and materials and subsequent maintenance.

The region experiences severe sub-zero temperatures throughout the winter creating considerable frost and ice damage across the concrete faces with extensive cracking. Major moss growth on the concrete walls in the summer months has further aggravated the situation resulting in water seepage into the concrete fissures.

A two-year contract has been awarded to Skanska for the complete refurbishment of the dam walls, gate structures and three spillway gates, by Fortum, the private company operator of the power station supplying power into the country's national grid.

Phases 1-3

E-Schakt was awarded a three-phase sub-contract with work on Phase 1 starting in September 2009 for the concrete removal on the top slab and down-side wall of the dam, plus the gate 3 structure, all demanding hydrodemolition techniques. Skanska will then replace the treated areas with new concrete and where necessary, new rebar.

Phase 2 is scheduled to start in May 2010, again using hydrodemolition on the lake-side dam wall, including underwater operations and gateway 2.

The third 12-week contract is planned for November 2010 and will include gate 1 plus the removal of a small fourth gate and replaced by a new dam wall structure.

Use of hydrodemolition techniques ensures no rebar damage, minimized risk of good concrete removal, eliminates

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Vertical operation on the dam wall.

The Aqua Frame on the inclined dam abutment.

Mark Your Calendar For The 2010 WJTA-IMCA Expo

WJTA and IMCA will host the inaugural **WJTA – IMCA Expo, August 17-19, 2010, at the George R. Brown (GRB) Convention Center in Houston, Texas.**

The WJTA – IMCA Expo will feature an expanded exhibit hall and boot camp sessions for individuals and companies in the waterjet and industrial vacuuming industries, including applications in precision waterjet cutting, industrial cleaning, and other applications in the manufacturing, mining, construction, and process industries.

Exhibit displays will include equipment, products and services relating to precision waterjet cutting, industrial cleaning, waterblasting, hydrodemolition, surface preparation, and industrial vacuum equipment/trucks. There will be live table top precision waterjet cutting in the exhibit hall.

To reserve exhibit space, contact Ken Carroll by phone: 314-241-1445, fax: 314-241-1449, or email: wjta-imca@wjta.org. The exhibit hall floor plan and an application for exhibit space are available online at www.wjta.org.

2010 WJTA-IMCA Expo

August 17-19, 2010
George R. Brown Convention Center
Houston, Texas

Preliminary Schedule of Events

Tuesday, August 17

6:30-8:30 P.M.
Welcoming Reception

Wednesday, August 18

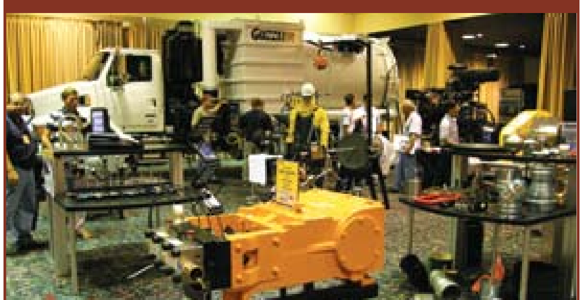
9:00 A.M.-5:00 P.M.
Exhibit Hall Open

9:30 A.M.-5:00 P.M.
Boot Camp Sessions

Thursday, August 19

9:00 A.M.-3:00 P.M.
Exhibit Hall Open

9:30 A.M.-3:00 P.M.
Boot Camp Sessions



Reserve Your Exhibit Space

Make plans now to exhibit at the 2010 WJTA-IMCA Expo. To reserve exhibit space, contact Ken Carroll by phone: 314-241-1445, fax: 314-241-1449, or email: wjta-imca@wjta.org. The exhibit hall floor plan and an application for exhibit space are available online at www.wjta.org.

Opportunities To Win $$$

- **Attendance Prizes -** Expo registrants are eligible to win one of eight $250 cash prizes. Attendance prizes sponsored by High Pressure Equipment Company.
- **Exhibit Passport -** Complete your Exhibit Passport for a chance to win one of four $50 cash prizes.
- **Expo Survey -** Complete your Expo survey and enter to win one of two $50 cash prizes.

dust and crystalline silica pollution and leaves a superior bonding surface. It is also substantially faster than mechanical removal methods and is also considerably less labor intensive.

Hydrodemolition

E-Schakt is using hydrodemolition equipment from Sweden's Aquajet Systems and includes an HVD Evolution Aqua Cutter robot, an Aqua Frame for underwater operations and a PP-700 Ecosilence power pack.

Dam Wall

Featuring a total length of 41.8 m, the all-concrete dam structure has a maximum height of 14 m, a 2.5 m wide top slab and 6 m wide base.

In Phase 1, E-Schakt has removed 500 mm depth of concrete from the top slab and within a five-week period virtually completed the hydrodemolition of the dam's dam-side wall to a depth of 200 mm using both the Aqua Cutter robot and Aqua Frame for the angled face.

A key feature of the Aquajet robot has been the ability to undertake geometric triangular cuts, according to E-Schakt's site foreman, Andreas Nordström. With three triangular sections of the wall face each measuring 4 m x 2 m, the system eliminated the need for time consuming alternative methods.

"Another advantage has been the 12 m high mast, which has allowed us to work at the maximum height," says Nordström.

A 1 m deep channel excavated along the dam face will provide access for the Aqua Cutter robot to continue removing deteriorated concrete below the ground level.

During the second phase contract, E-Schakt will remove 5.5 m of concrete on the vertical element of the upstream side of the dam to a depth of 200 mm, including at least 1 m underwater.

For this operation, the Aqua Frame robot will be positioned on the vertical upstream dam wall and be secured to the wall by divers. Then, in close collaboration with the Skanska divers, the E-Schakt operator can continue the underwater hydrodemolition operation remotely from above the surface.

The Aqua Frame includes 8 meter side rails with a 4 meter traverse rail to support the oscillating lance in the traversing power head with its nozzle to continue operating at 1000 bar at a rate of 260 l/min – 330 l/min depending on the removal depth.

Spillway Gates

The Järpströmmen installation features three steel spillway gates, one with a gate well and two without a well, featuring concrete slab spillways. The three gates provide a total length of almost 60 m and a maximum height of 16 m.

Throughout each of the three phases of refurbishment, a single gate will be removed in turn for blasting and retreatment. Hydrodemolition techniques on all concrete structures to the gates will follow removal of the gate.

Vertical removal.

Evolution robot removing a triangle part of the cracked concrete.

10 meter high vertical removal from the dam.

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KMT Aqua-Dyne Relocates Administrative Offices, Production To Baxter Springs, Kansas

KMT Aqua-Dyne, a leading global manufacturer of water blasting pumps, custom equipment, and high pressure components moved its administrative offices and production facilities from Houston, TX to Baxter Springs, KS on November 10, 2009. Service and sales staff will remain in Houston, Texas

This move will allow KMT Aqua-Dyne to take advantage of a state-of-the-art production facility along with improving customer service not only to its North America customers, but also customers around the world. The proximity to KMT Waterjet will allow KMT Aqua-Dyne to incorporate advanced technology into its current and future products. KMT Waterjet is a world leader in waterjet technology for quality, reliability, and service. KMT Waterjet has over 40 years of experience in the ultra high pressure waterjet industry.

For more information, visit www.aqua-dyne.com or contact Clayton Burleson by telephone: (620)856 6274, email: clayton.burleson@aqua-dyne.com, or mail: KMT Aqua-Dyne, 635 West 12th St. Baxter Springs, KS 66713.

Comments Solicited On Improvements To Recommended Practices

Comments are solicited regarding improvements to the WJTA publications, *Recommended Practices for the Use of Manually Operated High Pressure Waterjetting Equipment* and *Recommended Practices for the Use of Industrial Vacuum Equipment*. While both publications are reviewed periodically at the biennial WJTA conferences and throughout the year, your comments and suggestions for improving the publications are invited and welcome anytime.

The *Recommended Practices for the Use of Manually Operated High Pressure Waterjetting Equipment* is currently under review and being revised.

Please address your comments and suggestions to: WJTA, 906 Olive Street, Suite 1200, st. Louis, MO 63101-1448, phone: (314)241-1445, fax: (314) 241-1449, email: wjta@wjta.org. Please specify which publication you are commenting on.

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This aspect would normally provide problems for contractors with the numerous angles to be treated. "It is the trickiest element, but we are confident that the Aquajet's unique control system will help us to remain on schedule," says Nordström.

In total, the contract calls for the removal of more than 162 m^3 of concrete from the dam and 439 m^3 for all three spillways.

Freezing Temperatures

The probability of night-time temperatures plummeting to below -20ºC is the principal concern for the sub-contractor throughout operations during the winter months.

"Currently, in mid-October, we are experiencing daytime temperatures of -9ºC," confirmed Nordström. "With the downstream river already frozen for the winter, the project could become a giant ice cube. Today it is only -7ºC, but by the night it is getting much colder."

To prevent the hoses from freezing overnight, E-Schakt has resorted to continually passing water through the high pressure hoses throughout the night and disconnecting the power pack, pass the water into the downstream river. A heated circuit is also maintained in the water pumps 24/7 operation and antifreeze is also applied to the hoses.

"It's about preparing for the night-time temperature drop, otherwise we will have a real problem next morning," Nordström added.

First thing each morning, high pressure air is flushed through the hoses to clear the antifreeze before reconnecting them to the power pack. Similarly during daytime breaks for meals and meetings, equipment is kept in 'idle' rather than shutting down.

Throughout each 12-week contract, E-Schakt has a team of three operators working a 12-hour shift, 7 days a week on a 7-day changeover cycle.

The downstream damside ready for new concrete.

Järpströmmen Hydropower Station

The power station was built in 1944 and features three 118 MW turbines providing 415 GWh/year of electricity for the national grid.

Featuring a fall height of 66 m to the underground plant, the turbines are fed by a waterflow of 220 m^3/sec from the 156 km^2 lake Kallsjön, Sweden's sixth largest lake with a depth of 134 km. ■

Jet Edge Acquires Calypso Waterjet Systems

Waterjet manufacturer Jet Edge, Inc. has acquired Calypso Waterjet Systems of Dallas, Texas.

Founded in 1992, Calypso Waterjet Systems had been a world-leading manufacturer of waterjet cutting systems prior to its departure from the waterjet industry in early 2009. Calypso products include waterjet cutting machines; abrasive removal, closed loop water, and automatic height sensing systems; nesting software; plastic waterjet cutting bricks; bulk abrasive feeder tanks; and replacement parts for waterjet intensifier pumps, cutting heads, and waterjet tables.

Jet Edge President Jude Lague says he plans to reintroduce many of Calypso's products under Calypso's brand names.

"Calypso waterjets provide an excellent entry-level waterjet solution for price-conscious buyers," Lague noted. "Through our acquisition of Calypso, we will be able to make precision waterjet cutting capabilities available to a much broader range of customers in the growing entry-level market."

For information about Jet Edge, visit www.jetedge.com or call 1-800-JET-EDGE (538-3343). For information about Calypso, visit www.calypsowaterjets.com or call 1-800-JET-EDGE (538-3343).

Typhoon™ 10 Nozzles Clean Small Pipes With Less Leakage

Two new Typhoon™ 10 rotating waterjet nozzles from NLB Corp. clean pipes as small as 5/8-inch (1.6 cm) in diameter and use water more efficiently than other rotating nozzles. The Typhoon™ 24-10 is for applications requiring water pressure of up to 24,000 psi (1,680 bar), while the Typhoon™ 15-10 is for pressures up to 15,000 psi (1,035 bar). These self-propelling nozzles rotate at up to 7,000 rpm with a maximum flow of 10 gpm (38 lpm).

Both new nozzles feature several improvements to traditional rotating nozzle designs. The rotating action comes from the nozzle instead of the barrel, to focus the force of the high-pressure water up front where it can be most effective. While some leakage is desirable (as lubrication against metal-to-metal friction), an innovative new seal limits it to about half the industry norm. This leakage is distributed at both ends to equalize nozzle wear.

NLB has two other rotating nozzles for pipe cleaning, both with variable rotation, speed control and field repair-ability. The Typhoon™ 20 is designed for pipe diameters from 6 to 10 inches (15.2 – 25.4 cm) and operates at flows up to 20 gpm (76 lpm). The Typhoon™ 60 is a high-flow nozzle for large pipes (up to 50 inches in diameter, or 127 cm) and rotates at up to 500 rpm.

For more information, visit www.nlbcorp.com, call (248) 624-5555, or email vandamja@nlbusa.com.

Tube Bundle Cleaning Is Automated And Self-Contained

The ATL-5000, a new, fully automated waterjet system from NLB Corp., cleans tube bundles three times faster than manual methods and sets new standards for operator comfort and protection. An adjustable lance stroke allows the system to be configured for bundles of various lengths up to 30 feet (98.4m).

The system has five rigid lances, each with a specially-designed nozzle to deliver high-pressure water (up to 20,000 psi, or 1,400 bar) to clear the tubes of hardened debris. A powerful hydraulic drive inserts the five lances at a rate of 39" (1m) per second, then withdraws them so they can be positioned to clean the next five tubes. All movements (in/out, up/down and left/right) are controlled by the operator from a convenient overhead station, which provides excellent visibility at a safe distance from the action. The operator can even rotate the bundles with the optional bundle roller control package.

The diesel-powered ATL-5000 is completely self-contained. It requires no external power or air supply and can be taken by trailer to jobsites. Exclusive features include a lockout to prevent accidental actuation and an optional HVAC package to keep the operator station cool and comfortable.

For more information, visit www.nlbcorp.com, call (248) 624-5555, or email vandamja@nlbusa.com.

less energy to ignite, as shown in Tables 3 and 4.

2.0 ANALYZING AND CONTROLLING ESD HAZARDS

2.1 Creation of a Hazard

Before any accident can occur many intermediate steps must take place to properly set the scene. The first step in creating a hazard is usually that there must be hazardous or sensitive material present in order to cause a problem. The second step is often that certain environmental conditions must be favorable for an event to take place. The third step is that a source of energy is present, while the fourth step is the factor of probability and may take the form of "luck" or of "Murphy's Law" depending on if it is working for you or against you.

2.2 Eliminating Hazards by Removing Hazardous or Sensitive Materials

The presence of hazardous or sensitive materials is simple to resolve in many cases. We can simply remove the flammable liquids or explosives from the area before we do any work or remove the work to a separate area where there is no exposure to the hazardous materials. For the sake of argument, we will include sensitive electronic equipment in this same group. However, there are certain operations where we might not be able to remove the hazardous or sensitive materials from the area in which we are working, often because we are working directly on these materials or trying to remove other material in close proximity to them.

Flammable liquids and gases are considered hazardous when sufficient quantities are present to exceed their lower flammability limit (LFL) and be below the upper flammability limit (UFL). The LFL and UFL levels for flammable liquids and gases are published in NFPA 325-M (1984) and Zabetakis (1965).

Table 2. Electrostatic Sensitivity Levels of Electrical Components – Human Body Model (ESD, 1998)

Class	Voltage Range
Class 0	<250 volts
Class 1A	250 volts to <500 volts
Class 1B	500 volts to < 1,000 volts
Class 1C	1000 volts to < 2,000 volts
Class 2	2000 volts to < 4,000 volts
Class 3A	4000 volts to < 8000 volts
Class 3B	>= 8000 volts

Table 3. Electrostatic Sensitivity Levels of Common Flammable Materials (NFPA 1993 and Crowl and Louvar 1984)

Material	Ignition Energy (J)
Methane	2.9×10^{-4}
Propane	2.5×10^{-4}
Cyclopropane	1.8×10^{-4}
Ethylene	8.0×10^{-5}
Acetylene	1.7×10^{-5}
Hydrogen	1.2×10^{-5}
Gasoline	1.0×10^{-3}

Table 4. Electrostatic Sensitivity Levels of Explosive Materials (Brown, et al 1953)

Material	Ignition Energy (J)
Lead Azide	7.0×10^{-3}
Mercury Fulminate	2.5×10^{-2}
TNT	6.2×10^{-2}
Tetryl	7.0×10^{-3}
PETN	6.2×10^{-2}
Smokeless Powder	1.2×10^{-2}
Black Powder	8.0×10^{-1}

2.3 Environmental Conditions

In order for many materials to become hazardous there must be certain environmental conditions present. The most important one is usually oxygen present in the atmosphere in order to support fire. This environmental condition does not affect explosives, which contain their own oxygen, or electrically sensitive components. In order to eliminate the oxygen in a space an inert gas purge is often used. Inert gas purging requires some special technical considerations depending on the hazardous material and can be extremely dangerous to personnel entering a confined space. Special precautions are required and a

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safety engineer should be consulted prior to using an inert gas purge in a work area.

Another common environmental factor is temperature. Materials that normally are safe to handle may become flammable if the temperature is substantially raised. The rise in temperature can come from situations such as metal surfaces exposed to sunlight or even from the hot water in a waterjet spray.

To recalculate the LFL of a flammable liquid or gas at an elevated temperature the following equation, shown in Crowl and Louvar (1984), is used [(1) (2)]:

$$LFL_{elevated} = LFL_{25} \bullet [1 - 0.75 \bullet (T\text{-}25) \bullet \Delta H_c^{-1}] \quad (1)$$

$$UFL_{elevated} = UFL_{25} \bullet [1 + 0.75 \bullet (T\text{-}25) \bullet \Delta H_c^{-1}] \quad (2)$$

where $LFL_{elevated}$ = lower flammability limit at elevated temperature
LFL_{25} = lower flammability limit at 25 degrees C
ΔH_c = net heat of combustion (kcal • $mole^{-1}$)
$UFL_{elevated}$ = upper flammability limit at elevated temperature
UFL_{25} = upper flammability limit at 25 degrees C.

Another common environmental factor is the presence of water vapor. Sufficient water vapor can act as a conductive material to drain off excess electrical charges and many operations handling explosives or sensitive electronic components are conducted in humidified areas to minimize ESD damage according to NFPA 77 (1993). However, the presence of humidity should not be depended on for reducing the hazard, as in some cases the presence of moisture actually increases the risk as shown in Roux et al., (1993) where HMX explosive is *most* sensitive to ESD at 60% humidity.

2.4 Electrostatic Charging of Liquids

The third factor in the generation of an ESD hazard is the creation of energy. For waterjet operations this is usually caused by the flowing of liquids but can also occur from the impact of crystals against hard targets.

It is a well known phenomenon in safety engineering that flowing liquids can generate large

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amounts of static electricity. This generation of static electricity from flowing liquids even occurs during the operation of items expected to be “safe.” A classic example is the generation of up to 5,000 volts during the discharge of a carbon dioxide fire extinguisher as described by Petrick (1968).

Usually the liquid must be a poor conductor in order to build a substantial electrical charge. Plain water used for waterjet cleaning is not normally considered a “poor conductor” of electricity, but it can be. As detailed in Reif and Hawk (1974), three very large crude oil carriers (VLCC) were destroyed in December 1969 from electrostatic discharge during washdown by waterjets. Tests performed as a result of these accidents led to the following observations:

- clean seawater sprayed on oil-contaminated walls produced a negative electrical charge
- clean seawater sprayed on clean walls produced a positive electrical charge
- water-containing detergents sprayed on either dirty or clean walls produced a negative electrical charge.

The investigators came to the conclusion that the water spray created a charged cloud of water droplets which was able to store sufficient energy to create an electrical discharge. The charged clouds were able to create between 2.2×10^4 and 1.0×10^6 V during the washing process.

All of these tests were performed with water that would be considered as being highly conductive. In several tests performed in this author’s presence, high pressure (350 MPa) waterjet systems also create substantial electrostatic charge buildup as purified water was being used. In these cases the electrostatic charge was sufficient to create a corona discharge, or ionization of the nitrogen in the atmosphere, identifiable by a distinctive pink glowing cloud around the nozzle. As water is purified, either by reverse osmosis (RO) or deionization (DI) technologies, the conductivity of water is substantially reduced. The lack of conductivity is actually used for determining the quality of the purified water.

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2.5 Electrostatic Charging Mechanisms

When liquids flow through any system they rapidly build up an electrical charge. If the liquid is conductive, the liquid just as rapidly gives up the electrical charge. For non-conductive liquids, the time to dissipate the electrical charge may be substantial. We refer to the ability of a given liquid to dissipate the electrical charge as the relative dielectric constant (ε) and the conductivity of the liquid as its specific conductivity (γ).

Eichel (1967) shows that the relaxation time for a liquid to dissipate the electrical charge built up in it would be [(3)]:

$$t_r = 8.85 \times 10^{-16} (\varepsilon \bullet \gamma^{-1}) \qquad (3)$$

where t_r = relaxation time (sec)
ε = relative dielectric constant (dimensionless)
γ = specific conductivity (mho • m^{-1})

The double thickness layer is described by Eichel (1967) as the equivalent distance between two plates of a condenser that would have the same capacitance as the interface layer of the fluid flowing through the pipe. The double thickness layer is calculated as [4]:

$$\delta = (D_m \bullet t_r)^{-0.5} \qquad (4)$$

where δ = double thickness layer (meter)
D_m = molecular diffusion constant (m^2•s^{-1})
t_r = relaxation time (sec)

The amount of electrons captured or lost by a liquid flowing through a hose or pipe is termed the streaming current. The streaming current for turbulent flow (R_e >2400) adapted from Crowl and Louvar (1984) is [(5)]:

$$I_s = (1.932 \times 10^{-13} \bullet \text{amp} \bullet (\text{m} \bullet \text{s}^{-1})^{-1} \bullet \text{volt}) \bullet ((d \bullet u \bullet \varepsilon \bullet \zeta) \bullet \delta^{-1}) \qquad (5)$$

where I_s = streaming current (amp)
d = pipe diameter (meter)
u = fluid velocity (m•s^{-1})
ε = relative dielectric constant (dimensionless)
ζ = contact potential (volt)
δ = double thickness layer (meter)

The specific parameters for common liquids can be found either in Dean (1985) or in Perry (1950).

The voltage that the liquid accumulates is then calculated by [(6)]:

$$V_a = I_s \bullet (L \bullet (\gamma \bullet A)^{-1} \qquad (6)$$

where V_a = accumulated voltage (volt)
I_s = streaming current (amp)
L = length of pipe or hose (meter)
γ = specific conductivity (mho • m^{-1})
A = area of pipe or hose (m^2)

Likewise, the accumulated charge received by a streaming fluid can be calculated as [(7)]:

$$Q_a = I_s \bullet t \qquad (7)$$

where Q_a = accumulated charge (coulomb)
I_s = streaming current (amp)
t = operation time (sec)

The amount of energy that can be stored in an object with an electrostatic charge is given as either [(8), (9), (10)]:

$$J_a = C_a \bullet V_a^2 \bullet 2^{-1} \qquad (8)$$
or
$$J_a = Q_a \bullet V_a \bullet 2^{-1} \qquad (9)$$
or
$$J_a = Q_a^2 \bullet (2 \bullet C_t)^{-1} \qquad (10)$$

where J_a = accumulated energy (joule)
C_t = target's capacitance (farad)
V_a = accumulated potential (volt)
Q_a = accumulated charge (coulomb)

Eichel (1967) states that the minimum sparking potential is about 350 volts and that this can easily be achieved by using low conductivity liquids with either high velocity or high volume flow. For high velocity waterjets, the presence of a corona indicates that the potential may be as high as 30,000 volts.

2.6 Control of Static Electricity

There are many ways to control static electricity that are quite effective:

1. Always bond all components together with a grounding cable and have a secure connection to ground.
2. Use conductive piping and hoses. Be careful that gaskets do not insulate the piping from the system.

(continued on page 16)

3. Minimize fluid velocity by using larger diameter piping or hoses. A rule of thumb given by ESCIS (1988) is 1 m• s^{-1} maximum fluid velocity.
4. Use humidity to minimize static buildup if it is appropriate for the hazardous material in the area.
5. Eichel (1967) suggests using ionization (either electrically or radioactively) to minimize static buildup.
6. The use of additives to the spray stream to increase the conductivity of the liquid may also be useful, according to Eichel (1967).

2.7 Risk Analysis

The fourth factor mentioned above is the probability of an event's happening. Statistics show that the risk of an undesirable event's happening is based on the amount of energy applied and the number of times the stimulus is applied. Many situations have occurred in which the exact same process was used repeatedly without an accident until the one event occurred during which the accident happened. The most common method for minimizing risk is to minimize exposure to hazardous materials when operating by removing them from the operating area. The next best method, if the materials cannot be removed, is to remove all sources of ignition from the process. It is only through thoughtful planning, rather than "lady luck," that safe operations can be provided.

3.0 CONCLUSIONS

Those individuals who need to work with waterjets near sensitive or hazardous material should be very familiar with the potential for serious electrostatic charge generation, even in seemingly innocent operations. For this reason any operations in proximity to sensitive or hazardous materials should be evaluated by trained personnel to make sure that the operation cannot generate sufficient energy to cause an ignition of hazardous materials or damage to sensitive components.

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Michael Gracey Retires

Veteran waterjetting expert Michael T. Gracey has retired from the industry.

Michael T. Gracey

A longtime WJTA member, Gracey has been participating in WJTA conferences and presenting papers since 1986. Gracey received a Bachelor of Science Degree from Lamar University in 1971 and began work at Levingston Shipyard in Orange, Texas. After working at Marathon Letourneu in Brownsville, Texas, he and his family moved to the Houston area where he took a job as a principal research scientist at the Maritime Research Center in Galveston. In 1975, Gracey received his professional engineering license with the state of Texas. He worked for Hempel Marine Paints and Partek Corp. before taking a job with Aqua-Dyne in 1977. His experience in design, research, product development, marketing, plant engineering, project management, and technical writing served well during his employment with numerous waterjet-related companies from 1977 until his retirement in 2009.

"I was in the waterjetting business over 30 years (started in 1973), but retirement is much more fun," says Gracey.

Gracey, taking his writing expertise in a whole new direction, has written the newly released non-waterjet related fiction novel, *The Timeshift*. (www.tatepublishing.com)

Gracey lives with his wife Beverly in Cypress, Texas.

Jet Edge Names Allegheny Machine Tool Systems Distributor for Western Pennsylvania

Jet Edge, Inc., a leading manufacturer of ultra-high pressure waterjet and abrasivejet systems for precision cutting, coating removal and surface preparation, has announced that Allegheny Machine Tool Systems Inc. (AMTSI) is distributing Jet Edge waterjets in Western Pennsylvania.

Located in McMurray, Pennsylvania, AMTSI has been distributing and supporting machine tools in Western Pennsylvania, Western Maryland and West Virginia since 1992. In addition to Jet Edge waterjets, the company carries EDM machines, lathes, mills, CAD-CAM systems and grinders. AMTSI also provides applications engineering expertise, training, technical support, parts and service. AMTSI's technicians are authorized to provide local service on Jet Edge waterjet systems.

For more information about Allegheny Machine Tool Systems Inc., visit www.allegmach.com or call 724-942-4451.

Flow Introduces Dynamic Waterjet® XD Technology

Flow International Corporation, a leading developer and manufacturer of ultra high-pressure (UHP) waterjet technology, has introduced the next groundbreaking waterjet advancement, Dynamic Waterjet XD.

Dynamic Waterjet XD introduces the first high-precision 3D cutting technology of its kind. This technology improves part cycle time and accuracy of two to four times that of standard non Dynamic systems, and is 30% faster than Flow's industry leading original Dynamic technology.

Manufacturers now can realize greater opportunity to capitalize on the demand for production of multi-dimensional parts. Dynamic Waterjet XD's versatility enables manufacturers to cut a wider variety of intricate designs, which gives them the capabilities to tap new markets. With 3D cutting and complex beveling, users can cut elaborate parts previously unattainable using standard non-Dynamic waterjets. These new 3D advancements have been integrated with the core benefits of Flow's original Dynamic Waterjet technology, which eliminates taper and other errors found on waterjet cut parts.

Available on Flow's Mach 4 series line of waterjet machines, Flow's easy-to-use software models enable users to simply point and click to program the waterjet to cut any intricate shape, including 3D or bevel edge.

"Now more than ever, the manufacturing industry demands cost-effective methods for parts production," said Chip Burnham, vice president of marketing. "Customers need to be able to handle complex geometries, and even faster, more accurate cutting from their waterjet. Dynamic XD gives Flow the opportunity to meet our customers' needs in producing complex, high-precision parts."

Flow customers already have realized benefits of Dynamic Waterjet XD. "The Dynamic XD is awesome, it is saving me time and money, and the part quality is excellent," said Brad Davidson, owner, Electro Mechanical Solutions. "I'm realizing a huge labor savings – for example, to produce one part in the past took 2 guys 1 ½ weeks to complete. Using Dynamic XD, that same part takes one guy 2 days to complete which is a huge labor savings and translates to tremendous cost savings. Plus, the part requires no secondary finishing."

For more information, visit www.flowcorp.com.

Barton Introduces The TRIDENT2 Integrated Diamond Cutting Head

Barton Mines Company, a leading supplier of waterjet abrasives and waterjet replacement parts has introduced the TRIDENT2 integrated diamond cutting head.

Taking advantage of breakthrough manufacturing technology, Barton has developed the next generation diamond cutting head. TRIDENT2 combines all the advantages of an integrated diamond design with the versatility of a replaceable orifice.

TRIDENT2 features even greater precision in the alignment between the diamond orifice and the nozzle than the highly successful first TRIDENT. Following extensive field trials including side by side testing against the original TRIDENT, customers report superior accuracy, reduced abrasive consumption and extended nozzle life with the new TRIDENT2.

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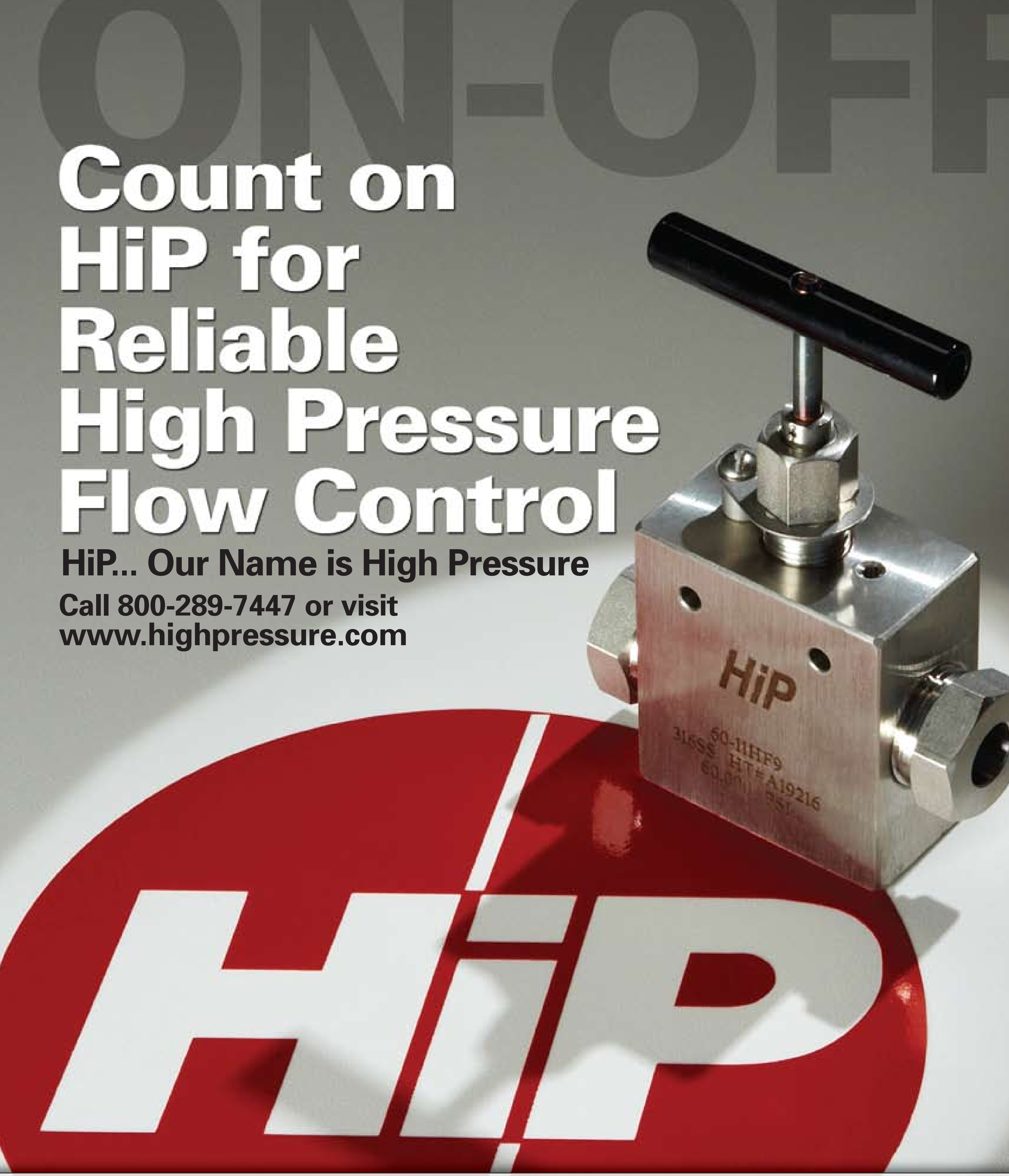

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