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WATERJET TECHNOLOGY ASSOCIATION

INDUSTRY BEST PRACTICES FOR THE USE OF HIGH PRESSURE WATERJETTING EQUIPMENT

(SECOND EDITION, JANUARY 2021)

Published by the **WaterJet Technology Association**

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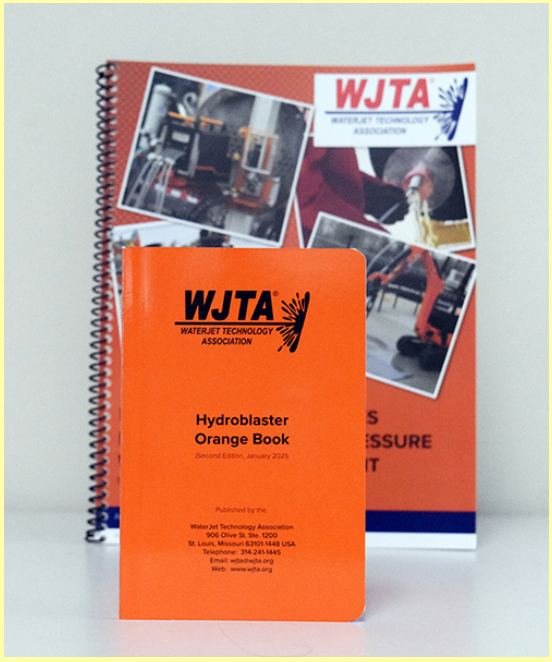
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Industry Best Practices for the Use of High Pressure Waterjetting Equipment

PREPARED BY THE WATERJET TECHNOLOGY ASSOCIATION (WJTA®)

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PREFACE

This is the second version of the Industry Best Practices put together by the Safety Committee of the WJTA. From the beginning this group has sought to bring together the views of government, academia and industry in order to make a workable and effective document.

The work of the original committee has been enhanced by numerous suggestions and advice from industrial contractors who have helped develop the cleaning industry that now exists. It is a pleasure to recognize the debt that the industry owes to these individuals and to their employers who have provided the time for them to make this effort. In addition, Mark Birenbaum, Ken Carroll, LeAnn Hampton and Peter Wright, as part of the management company that helps guide the Association, have significantly contributed to the final appearance of the document, and this effort is recognized gratefully.

Because the industry continues to change, it is important that this document recognize and reflect these developments in the industry. Thus, we request that any suggestions for change in these Industry Best Practices or other consideration be sent to:

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This pamphlet, *Industry Best Practices For The Use Of High Pressure Waterjetting Equipment*, printed by the WaterJet Technology Association (WJTA), is a report of industry information prepared for WJTA members. The WJTA has not promulgated, tested or certified the information contained in this pamphlet. The best practices have been prepared from advice, opinions and recommendations offered by many persons with differing experiences and knowledge in the use of waterjet equipment. No representations are made by the WJTA concerning the safety or effectiveness of the practices described herein. The WJTA has no responsibility or liability in any way related to the information or recommendations contained in this pamphlet, including for any errors or omissions. The WJTA notes that in this Industry Best Practices report, the word “shall” is used to mandate certain best practices, but when these best practices cannot be followed, a variance by a competent authority shall be put in place (refer to section 14.46 for more information).

The user of this pamphlet and any waterjet equipment should not use such equipment without consulting all applicable standards, guidelines, or recommendations of the United States Occupational Safety and Health Administration (OSHA), the American Society of Testing Materials (ASTM), the American National Standards Institute (ANSI), and the instructions, recommendations and standards of the equipment manufacturer. The WJTA does not guarantee that the practices described and the recommendations contained in this pamphlet will prevent harm or injury, even when such equipment is properly used or used in conformity with the Industry Best Practices. In the event of bodily injury, nothing in this pamphlet should substitute for proper medical care. Injuries caused by waterjet equipment can be serious and even life-threatening and proper medical attention should be sought immediately.

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1.0 INTRODUCTION

1.1 These *Industry Best Practices* apply to the operation of all types of high pressure waterjets as normally used in construction, maintenance, repair, cleaning, cutting, hydro-excavation, and demolition work. This text describes different types of equipment and operating systems commonly employed in these industrial applications, and this is intended to establish recommendations for the safe and efficient operation of high pressure equipment. It is also intended this be used in the training of operators and new employees. Equipment operators should adhere to appropriate regulations and standards promulgated by regulatory entities, manufacturer recommendations, and industry best practices as found in company safety and health policy including site specific guidelines. Additional sources of information include the U.S. Occupational Safety and Health Administration (OSHA), the American Society of Testing Materials (ASTM), the American National Standards Institute (ANSI), or local equivalents.

1.2 The development of new applications and technology associated with high pressure equipment is changing rapidly. Therefore, these *Industry Best Practices* will be reviewed and revised regularly. The date of this version is shown on page 1.

1.3 In this document the term “high pressure,” unless another description is given, refers to all waterjetting done at an operating pressure of 5,000 psi (340 bar) or greater. Following best practices at pressures below 5,000 psi may still be recommended due to hazards presented by high flow rates or jobsite considerations such as impaired footing or confined space entry.

2.0 GENERAL

2.1 These *Industry Best Practices* are designed to describe the basic practices for using high pressure waterjets when cleaning, cutting, or excavating materials.

2.2 These *Industry Best Practices* do **NOT** replace the training necessary to safely operate and maintain high pressure waterjet systems; these guidelines, or comparable best practices, should be part of the overall training and qualification program for waterjet equipment operators.

2.3 Every job and work site has special conditions that must be reviewed by the contractor’s and owner’s representatives before work begins. As part of this process, a set of written procedures is typically needed to accompany a hazard assessment or job safety analysis (JSA). The procedures and JSA can and should be adjusted to account for specific conditions, then communicated to and signed by workers for every job. This *Industry Best Practices* is intended to serve as a resource for the development of these written procedures.

2.4 Waterjet systems are used over a wide range of operating pressures and flow rates, and can include mixtures of fluids, gases, and solids besides pure water. Regardless of pressure, waterjet systems can be potentially hazardous and cause injury if improperly used. As such, these *Industry Best Practices* should be referred to whenever waterjets are used.

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2.5 When using different systems at different sites, procedures may need to be changed. However, certain steps are recommended for all operations. In these *Industry Best Practices*, where "**shall**" is used rather than "should," the procedure described must be followed to comply with these Industry Best Practices.

2.6 Since the vocabulary often used to describe waterjet equipment and processes varies by industrial application and geographic location, a standardized set of definitions is provided in a glossary at the back of this booklet. These definitions apply to terms used in these *Industry Best Practices* and are recommended for general use.

2.7 **Deviations or Variances** from the practices contained in this document are acceptable only after all other measures have been exhausted, and both senior management and the customer have approved. This approval **shall** be contingent on using any one or a combination of the following: engineering controls, enhanced PPE, specialized training, and/or a written, detailed job procedure deemed adequate to mitigate any risk that could occur because of the deviation or variance.

2.8 Wherever possible, automated or robotic systems should be considered over the use of manually operated waterjet systems.

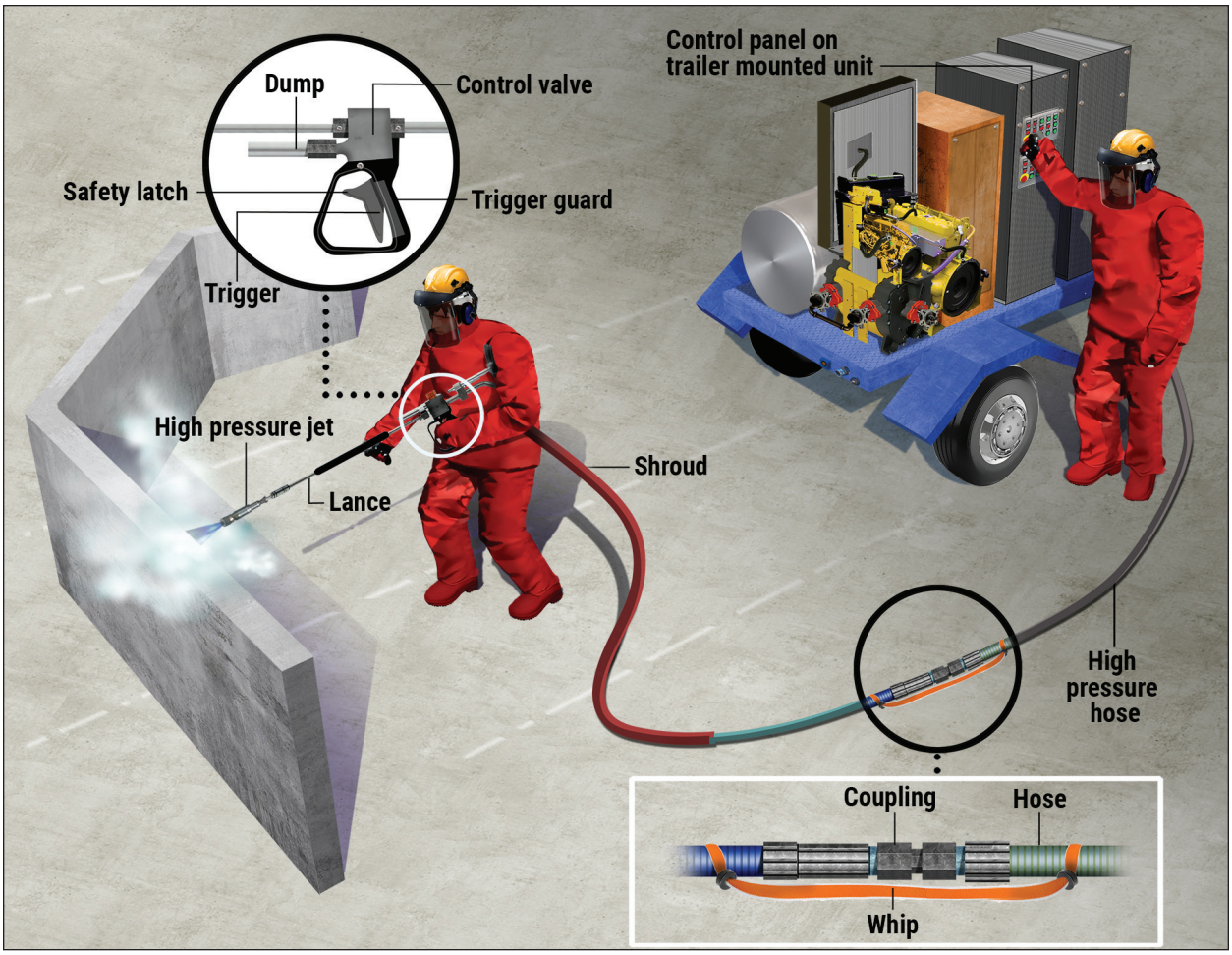


Figure 1. Waterjet Cleaning Operation Showing System Components. The pump can be fixed or mobile and powered by hydraulic, gasoline, diesel, or electric motors.

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3.0 RESPONSIBILITY

3.1 **Purpose** – To serve as a reference guide to assist with the safe and proper use of waterjet equipment.

During any waterjet activity the correct operation and application of the waterjet equipment is the responsibility of the operator, who should be familiar with the identification of high pressure pumps, metal fittings, hoses, guns, and accessories (Figure 1).

The modification of waterjet equipment or accessories is not recommended without the prior written approval of the manufacturer of the equipment.

Serious harm or injury may result from the misuse of waterjet equipment or the use of improper fittings, hoses, or attachments. The WaterJet Technology Association (WJTA) does not guarantee that the practices described and the recommendations contained in these *Industry Best Practices* will prevent harm or injury.

4.0 HAZARDS

4.1 **Personal Injury** – In the event of a waterjet injury or if a waterjet injury is suspected, immediately provide first aid and take the injured person to a medical facility equipped and staffed to handle this type of wound. Be sure to inform the medical staff of the cause of the injury. Medical attention **shall** be sought for all suspected waterjet injuries regardless of external appearance.

A person injured by a waterjet will not necessarily see the full extent of the injury, particularly the internal damage and depth of penetration. Even though the surface wound may be small and may not even bleed, it is quite possible that large quantities of water have punctured the skin, flesh, and internal organs through a very small hole (Figure 2). The spread of micro-organisms and infection through a wound of this type is a very real concern; the injury should, therefore, be carefully monitored for several days.

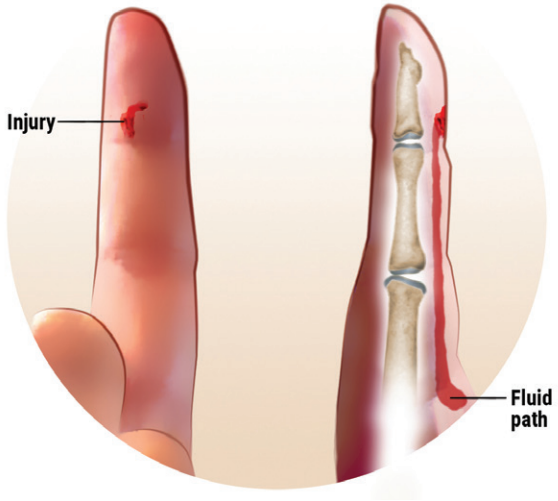


Figure 2.

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4.1.1 Operator Identification – To ensure the medical staff knows and understands the cause of injury, all waterjet operators **shall** carry an easily accessible waterproof card that outlines the possible nature of the injury. The wording on the card might be as follows:

MEDICAL ALERT: NOTE TO PHYSICIAN

This patient may be suffering from a waterjet injury. Evaluation and management should parallel that of a gunshot injury. The external manifestations of the injury cannot be used to predict the extent of internal damage. Initial management should include stabilization and a thorough neurovascular examination. X-rays can be used to assess subcutaneous air and foreign bodies distant from the site of injury. Injuries to the extremities can involve extensive nerve, muscle, vessel damage, as well as cause a distal compartment syndrome. Injuries to the torso can involve internal organ damage. Surgical consultation should be obtained. Aggressive irrigation and debridement is recommended. Surgical decompression and exploration may also be necessary. Angiographic studies are recommended preoperatively if arterial injury is suspected. Bandages with a hygroscopic solution ($MgSO_4$) and hyperbaric oxygen treatment have been used as adjunctive therapy to decrease pain, edema and subcutaneous emphysema. Unusual infections with uncommon organisms in immunocompetent patients have been seen; the source of the water is important in deciding on initial, empiric antibiotic treatment, and broad-spectrum intravenous antibiotics should be administered. Cultures should be obtained.

4.1.2 All team members should know how to activate emergency services, know the appropriate telephone numbers to call, know how to immediately contact a person capable of administering first aid and CPR, and know the address and specific location within the jobsite where the team is located.

4.1.3 Reporting Injuries – appropriate medical attention is the first priority after a waterjet injury, but a first report of incident (FROI) should be made soon after the incident. Following the FROI, a responsible party for the employer should be assigned to investigate to establish basic facts, as well as: incident investigation findings, root cause analysis, corrective actions, and the securement of affected waterjet equipment and accessories for analysis as needed. External reporting to customers or government entities may also be required.

4.2 Other Hazards

4.2.1 Corrosive Materials – Where the jetting operation involves, or the operator may be exposed to, corrosive or toxic material, the owner or the owner's representative **shall** be requested to inform the contractor or the contractor's representative of the special precautions that may be necessary in working around the material, in protecting personnel, and in the collection and disposal of waste materials. Personnel should be made aware of any chemical reactions which may occur during the waterjetting which may release toxic gases or fumes.

4.2.2 Gases, Vapors and Biologic Agents – The act of cleaning removes material from surfaces, possibly creating or releasing gases, vapors, and/or biologic agents that could be harmful to health or even life-threatening in some cases. Waterjet operators

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shall be made aware of any possible chemical reactions which may release toxic gases, vapors, or biologic agents. Confined or poorly ventilated spaces pose additional hazards that **shall** be accounted for in job planning.

There is a chance of being exposed to biologic agents during waterjetting activities. Proper procedures should include a thorough flush of all lines and, if necessary, sanitation of the water source.

4.2.3 Confined Spaces – When jetting must be carried out in a confined area or space, a specific written set of procedures and precautions **shall** be prepared by the owner and contractor or their representatives. These procedures **shall** include written certification that the space has been properly cleared. OSHA or other regulatory agencies' regulations for confined space entry **shall** be followed. All persons involved in a confined space entry **shall** be trained and qualified in confined space entry procedures.

4.2.4 Energy Control (Lockout/Tagout) – Follow lockout/tagout procedures to ensure that potential energy sources, such as agitators, heat sources, electrical, piping and valves, are deenergized and protected from accidental opening, closing, movement and/or activation prior to entering any work area or confined space.

4.2.5 Work Area – Where practical, items that are to be jetted should be taken to an area that has been set aside for high pressure waterjetting. Where this is not practical, the item can be jetted where it is installed or close to it, provided that the necessary permission and procedures have been obtained and agreed upon with the owner or the owner's representative.

4.2.6 Electrical Equipment – Any electrical equipment in the immediate area of the waterjetting operation that presents a hazard **shall** be de-energized, shielded, or otherwise made safe, for example, by using proper lockout-tagout procedures.

4.2.7 Environmental Protection – Consideration must be given to protecting the worksite. Contamination from both the cleaning operation and the waterjetting equipment **shall** be controlled in compliance with the customer's environmental policy. The contractor should have materials on site to contain any fluid leaks coming from waterjetting equipment.

5.0 PERSONAL PROTECTIVE EQUIPMENT

Careful and prudent Personal Protective Equipment (PPE) selection and use must be implemented to protect workers from waterjet hazards while not creating new hazards.

5.1 Compliance (for work subject to the rules of government entities) – All personnel **shall** follow applicable government regulations for personal protective equipment.

5.2 Head Protection – All operators **shall** be issued suitable head protection which **shall** be worn at all times while at the worksite (Figure 3). Where possible, head protection should include a full face shield.

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5.3 **Eye Protection** – Eye protection must provide the protection needed and must be properly fitted to the worker. Eye protection **shall** be worn by all high pressure waterjet equipment operators and all visitors in the barricaded working area. Minimum eye protection **shall** include a full face shield and safety glasses (some states and countries have their own eye protection rules that **shall** be followed.) All eye protection **shall** meet appropriate ANSI requirements for that type of eye protection. Dark tinted safety glasses may not be worn: indoors, during vessel entry, during times of limited visibility, or at night time.



Figure 3.

Note: In some cases, liquids may be in use that can cause eye damage. In those cases a combination face shield and goggles (in lieu of safety glasses) or a full hood with shield **shall** be used. A face shield **shall** be worn by any worker whenever there is a possibility for exposure to chemicals or flying debris. At least one component **shall** meet the ANSI Z87.1 standard.

5.4 **Hearing Protection** – Waterjets generate considerable noise, both in air and under water. Therefore, all workers within a work area where the noise exposure is greater than 85 dBA **shall** wear hearing protection. In certain circumstances double hearing protection may be required (refer to OSHA standard 29CFR1910.95 for additional guidance). Hearing protection devices should be regularly inspected, properly maintained, and comply with appropriate federal and/or state regulatory standards. Noise levels should be measured to determine the level of hearing protection required.

All personnel in the vicinity of waterjet equipment should be taught how to properly fit and use hearing protection prior to beginning any work activity. In specific situations, regulatory standards may require that dual-hearing protection (earplugs and muffs) be used and that the company implement a formal hearing conservation program. For example, the pump operator is generally required to have dual-hearing protection (refer to OSHA standard 29CFR1910.95 or similar regulatory guidance for additional details).



Figure 4. Hearing protection.

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Figure 5. Types of body protection.

5.5 **Body Protection** – All operators **shall** use adequate means to protect their body, and this Personal Protective Equipment (PPE) **shall** be worn. PPE should also provide some protection from the impact of rebounding debris from the jet impact point where this may be a hazard to the operator.

Everyone working around a waterjet operation should wear sufficient waterproof clothing to provide protection from the type of exposure to water and debris that the work might create. Garments should completely cover the operator, including his/her arms. Pressure-rated garments may be required.

Liquid or chemical-resistant suits **shall** be worn when there is a reasonable chance that an injury can be prevented by using such PPE.

5.6 **Hand Protection** – All operators **shall** use adequate means to protect their arms and hands, and this PPE **shall** be worn.

5.7 **Foot Protection** – All operators and workers inside the barricaded area of a jetting operation **shall** wear waterproof boots that are resistant to the hazards present in the operation being performed. A metatarsal guard, gaiter, or a combination shin/metatarsal guard **shall** also be worn by manual waterjet operators or workers



Figure 6.



Figure 7.

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operating equipment that poses a significant hazard to the lower extremities unless the boot alone provides sufficient internal protection (e.g., the boot used is designed to protect the operator from water under pressure and/or compression at the same or higher level as a guard, gaiter, or combination shin/metatarsal guard).

5.8 **Respiratory Protection** – A respiratory program **shall** be implemented when required; respiratory protection should be used when there is a reasonable chance that an injury can be prevented.

5.9 **Equipment Limitations** – Proper PPE may not prevent injuries to operators and other workers. Engineering and administrative controls are preferred to mitigate or remove hazards, like those caused by the direct impact of high pressure waterjets or debris that may be thrown by the impact of the jet.

6.0 OPERATIONAL AND TRAINING REQUIREMENTS

6.1 **Qualified Operators** – Only personnel who have undergone a proper training program, and who have demonstrated the required knowledge and skill, and gained the experience to perform all likely assigned tasks **shall** operate high pressure waterjet equipment.

6.2 **Training** – Before being assigned to their first high pressure waterjet job, employees **shall** receive proper training. This training **shall** include, at a minimum, coverage of all items listed in these *Industry Best Practices*. A proper training program will be formally organized and aimed at imparting information and instructions to improve the students' performance and ensure the required level of knowledge and skill. It should include specific objectives and be approved by the employer.

6.3 **Cutting Action** – The cutting action of a high pressure waterjet and the potential hazard it poses to the human body **shall** be demonstrated through the use of audiovisual aids or actual use of equipment (by cutting through a concrete block, a piece of meat, a piece of lumber, etc.).

6.4 **Personal Protective Equipment** – The minimum personal protective equipment **shall** be explained. Instructions **shall** be given as to when and how specific clothing and other types of protective devices **shall** be worn according to the type of work performed, locations, etc.

6.5 **System Operation** – The operation of high pressure waterjet systems **shall** be explained by pointing out potential problems and proper corrective actions.

6.6 **Operating Pressure** – It **shall** be made clear not to operate equipment above the manufacturer's recommended working pressure of the lowest rated component.

6.7 **Control Devices** – The operation of all control devices **shall** be explained and demonstrated. The importance of not tampering with any control devices, as well as the importance of keeping them in proper working order, **shall** be stressed.

6.8 **Equipment Maintenance** – The importance of the proper and timely care and maintenance of high pressure waterjet equipment **shall** be presented. Instructions

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shall be provided on the procedures to follow in maintaining equipment and when the equipment must be returned for care by more qualified employees.

Stress that equipment **shall not** be repaired, or connections tightened, when the unit is in operation or the pump is running.

6.9 **Hose** – The proper method of identifying and connecting hoses, including avoiding kinks, tying off on vertical runs, protecting hoses from excessive wear, identifying worn or unsafe hoses, and proper tools to use on couplings and fittings, **shall** be explained.

Stress that fittings and couplings on hoses should not be tightened or tampered with while the hose is pressurized and that whip checks **shall** be used across hose connections.

6.10 **Stance** – The proper stance for sound footing and how to use the various devices for lancing, shotgunning, and moleing **shall** be demonstrated. The trainee, under close supervision, **shall** be trained to use the various devices while the unit is slowly pressurized until it is operating at its normal working capacity. It **shall** be stressed that waterjetting off a ladder is never acceptable.



Figure 8. Demonstrating appropriate stance.

6.11 **Proficiency** – Proficiency should be evidenced through written evaluation, documented training, on-the-job skills training, or any other dependable means of validating and recording knowledge and skill.

6.12 **Refresher Training** - Operator retraining should take place at minimum every three (3) years. Retraining should be more frequent if a waterjet operator or team member is involved in an incident, deficiencies are noted in performance, or if the operator/team member requests training.

6.13 **Additional Training** – Additional regulatory or customer-mandated training may be required.

7.0 PRE-OPERATING PROCEDURES

7.1 **Planning** – Each job **shall** be planned prior to work beginning. Personnel familiar with the equipment, structure, area/items to be waterjetted, material to be cut and the

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work environment **shall** meet with the personnel who will be doing the work and **shall** outline potential hazards of the work area, environmental problems, safety standards, and emergency procedures. Hazards **shall** be mitigated or removed in the planning phase.

7.2 **Operating Pressure and Flow** – The contractor **shall** inform the owner of the anticipated pressures, flow rates, and hazards associate with the work to be carried out.

7.3 **Checklist** – A checklist **shall** be used to verify proper procedures and equipment selections. (See Appendix C)

7.3.1 **Reporting Equipment Damage** – If waterjet equipment is damaged or malfunctioning, remove from service, mark "out-of-service" and follow proper lockout/tagout procedures, if applicable. Notification **shall** be made to a responsible party of the employer or equipment owner.

7.4 **Dump Valve** – High pressure waterjet systems **shall** include at least one valve that will allow the operator to rapidly shut down the equipment or dump the water to atmosphere, rapidly reducing the pressure within the system to a low level. The Nozzle Operator **shall** have control of the dump valve that will stop the jet action. This valve should be of the type that will automatically activate if the operator releases the control handle, whether the control handle is operated by hand or foot. The valve **shall** have a guard to prevent accidental activation of the system. This valve **shall** be checked at the beginning of a jetting operation and, should it be defective, work **shall** not begin until this valve is replaced or repaired.

If a dump valve is not used with the system a variance process **shall** be followed and the safe distance **shall** be determined, unless the waterjet nozzle and attachments are entirely enclosed in a protective barrier.

7.5 **Area Limits** – The area around a work site that will be required for the jetting operation and for the protection of those not involved in the jetting operation **shall** be defined by the owner and contractor or their representative. The boundary of this area **shall** be clearly marked by the waterjet team, providing both a visible and a physical barrier to entry by unauthorized personnel. Notices that state: "DANGER - KEEP CLEAR, HIGH PRESSURE WATERJETS IN OPERATION" or other suitable wording should be posted. Barriers should be of either the warning type or the protective type, depending on the distance at which they are located from the jetting operation.



Figure 9.

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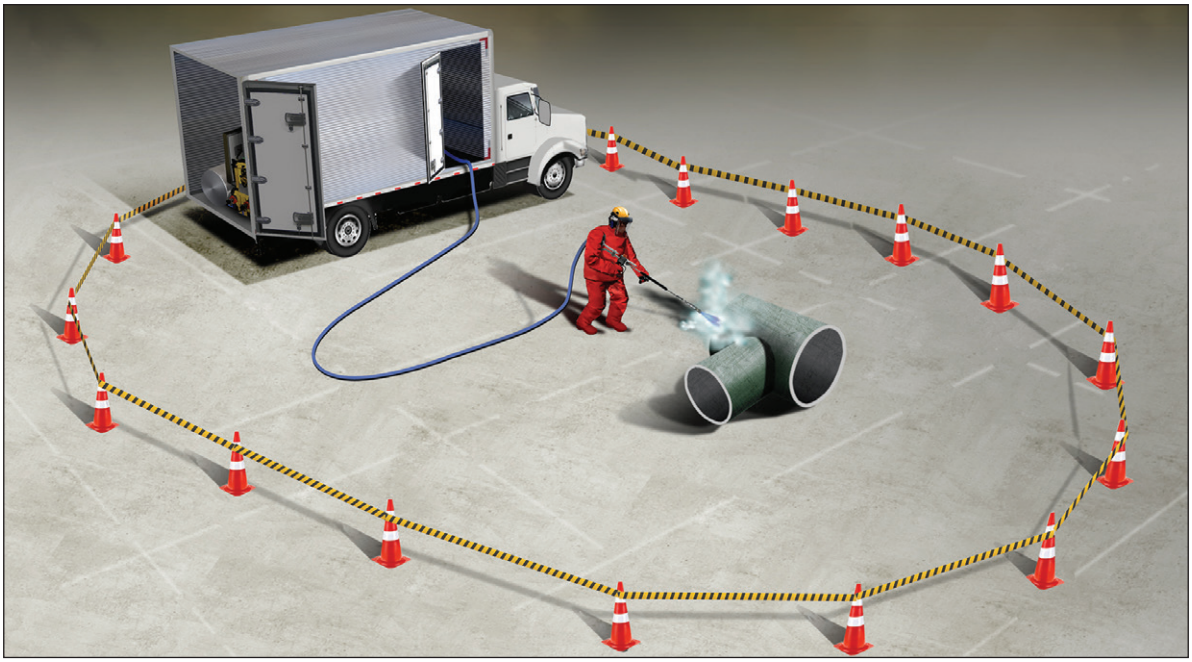


Figure 10. Open barricade.

7.6 **Warning Barricade** – Suitable barricades **shall** be erected to restrict access to the hazard area, including the waterjet pump, high pressure hoses, and the work area where the cleaning is being done. Temporary barricades are typically constructed using red barricade tape with lettering, of a contrasting color, indicating "DANGER," "DANGER WATERJETTING" or similar wording. Barricades **shall** extend to minimum distance of 15 feet, however the distance **shall** be such that water or debris leaving the barricaded area does not present a danger to life and health, in all directions, from the source of all hazards created by the waterjetting (Figure 10-11).

If a 15-foot distance cannot be achieved, a suitable barrier or hose shroud **shall** be used (refer to 14.21).



Figure 11. Warning sign, barricade.

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7.7 **Protective Barriers** – Protective physical barriers **shall** be erected anytime the waterjet or debris could pass beyond the barricaded area. Protective barriers **shall** be designed to prevent energized fluids and particles from going beyond the barriers. See Figure 12.

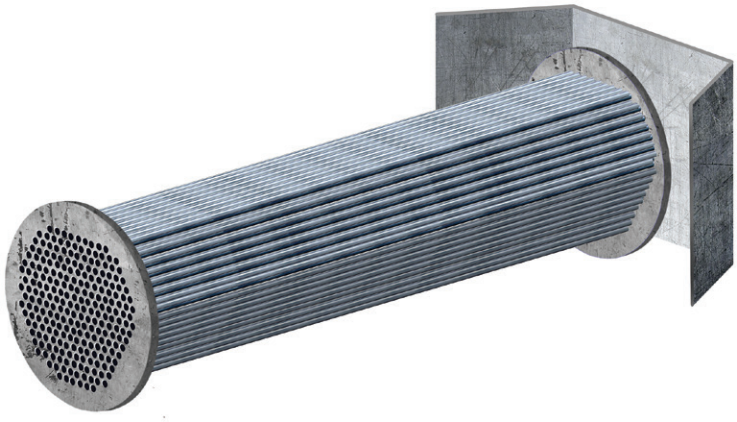


Figure 12. Tube bundle with protective barrier.

7.8 **Hose Layout and Support** – Hose **shall** be arranged to minimize tripping hazards. Hoses, pipes, and fittings **shall** be supported and laid out to avoid abrasive wear and prevent excessive sway and/or wear created by vibration or stress on the end connections. Personnel **shall** not be within 6 feet of pressurized, unshielded high pressure hose connections or weep holes.

7.9 **Hose Protection** –Hoses should be arranged to protect them from being run over by vehicles, such as forklift trucks. A hose **shall** not be operated at a pressure exceeding the working pressure. Hoses **shall** be routed and shielded in such manner as to prevent injury to pedestrian traffic.

7.10 **Fittings** – All fittings **shall** be cleaned, inspected, and Teflon taped or lubricated, as required, before installing in the system. Be sure all fittings are leak free and pressure rated for the purpose.

7.11 **Hose Condition** – All hoses **shall** be checked for evidence of damage, wear, or imperfections prior to use and periodically during the operation. As the system is being assembled for a job, the hose and connections **shall** be checked to ensure that they are rated for use at the pressures to be used. Any defective item **shall** be taken out of service. (See 14.7.1 for inspection details.) (For more information see the NAHAD reference in Appendix A.)

7.12 **Whip Checks** – **Shall** be used at all high pressure hose connections.

Exceptions, the following do not require a whip check:

- flex lance and line mole hose connections that will travel through the pipe being cleaned
- flex lance and line mole hose connections that will travel through a hose feeder
- hoses that rotate to facilitate the cleaning process

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7.13 **Pre-flushing** – Before installing the nozzle, the system **shall** be completely flushed with water to remove any contaminants.



Figure 13. Pre-flushing the system.

7.14 **Nozzles** – All orifices in nozzles **shall** be checked for any blockage, damage or imperfections before the nozzle is attached to the system. Defects **shall** be corrected before the nozzle is used, unless the defect results in the nozzle being removed from service. Pressurize the system slowly to make sure the nozzle is open and clear. Nozzles should also be checked to ensure that the orifices are properly sized and balanced for the flow and pressure to be used.

7.15 **Air Systems** – Steel-braided hoses should be used on air-operated fail-safe systems to prevent the system from being accidentally activated by someone stepping on or running over the hose.

7.16 **Work Surface** – Before beginning work, the operator **shall** ensure it is possible to jet all surfaces to be cleaned, and that a stable, secure working platform is available at all times from which to reach those surfaces. The operator should be able to maintain a sound and secure footing at all times. It **shall** be stressed that waterjetting off a ladder is never acceptable. The working area **shall** be checked before beginning work to ensure that hoses and other required equipment do not interfere with or pose hazards to the movement of the operator or others. All loose materials should be removed, or securely fastened, and the site checked to minimize the risk of slipping or tripping over an obstacle.

7.17 **Procedures for Entering the Barricaded Area** – The owner or the owner's representative **shall** be requested to tell all those who normally work at the site, and especially those who might need access to the barricaded area, that high pressure waterjetting will take place. Workers **shall** also be informed of the procedures to enter the barricaded area. Prior to an individual entering an area where high pressure waterjetting is in progress, the system should be depressurized and/or eye contact made with the operator.

7.18 **Rupture Disc** – All waterjetting pumps **shall** be equipped with a disc rated no greater than 1.2 times the maximum acceptable working pressure (MAWP) of the lowest rated component in the high pressure delivery system. The rupture disc or rupture disc assembly seal must be visually verified on a daily basis.

7.19 **Safety Shroud** – The point where the hose connects to the gun or to a manually controlled stiff lance **shall** be fitted with a hose shroud or other protective device, which will act to protect the operator if the hose, pipe, or fitting fails (Refer to section 14.21)

7.20 **Safety Data Sheets (SDSs)** – As required by the U.S. Occupational Safety and Health Administration (OSHA) or other regulatory agency, SDSs **shall** be available for any and all materials, chemicals, etc. that may be encountered in the course of the job.

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7.21 **Disabling of Moving Equipment** – All moving equipment, such as agitators, choppers, conveyors, etc. that are in proximity of the waterjet operation **shall** be disabled with an appropriate lockout-tagout procedure, except where the nature of the waterjetting operations require continuous movement.

7.22 **Grounding** – The waterjetting pump **shall** be grounded to a valid earth ground.

7.23 **Wheel Chocks** – At least one tire on a waterjet pump's trailer/vehicle **shall** be double chocked to prevent accidental movement, prior to uncoupling the trailer from the tow vehicle.



Figure 14. Waterjetting pump.

7.24 **Housekeeping** – During the job, it is the responsibility of the crew to maintain good housekeeping practices. This includes, but is not limited to, the elimination of slip, trip and fall hazards, hose placement, and proper disposal of trash, contaminated PPE and any other waste generated by the cleaning process, unless otherwise arranged. After the completion of the job, remove all barricades and barricade tape and return the job site to the same, or better, pre-work standards.

8.0 WATERJET TEAM

The number of operators required will vary, depending both on the size and nature of the work.

8.1 **Nozzle Operator** – The member of the team who holds a gun, lance, delivery hose or controls the equipment, includingthe motion and direction of the jet(s) is known as the Nozzle Operator. The Nozzle Operator **shall** control the jetting operation while waterjetting is taking place.

8.2 **Pump Operator** – The Pump Operator, monitors and controls the pressurizing pump during jetting operations. The Pump Operator **shall** maintain continuous communications with the Nozzle Operator, to react if a difficulty arises or if the Nozzle Operator begins to show signs of fatigue. The Pump Operator **shall** monitor the work area and its surroundings in case anyone tries to enter the area or in case a potentially

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hazardous condition should occur. In either of these circumstances, or as otherwise necessary, the Pump Operator **shall** depressurize the system until the condition is resolved. Caution **shall** be exercised when reducing pressure rapidly, because this can cause loss of footing by the Nozzle Operator. The Pump Operator **shall** be stationed close enough to the pump to immediately shut down the pump in case of an emergency. The Pump Operator may operate no more than two pumps and only when the pumps are located in the same barricaded area. The Pump Operator may leave the work area when replaced by another qualified operator or after shutting down the pump/pumps.

8.3 **Additional Personnel** – In addition to the Nozzle and Pump Operators, other personnel may be required on the team, depending on the site and nature of the work. For example, assistance may be required in handling a jetting gun if it is fitted with more than one jetting extension or if the hose must be fed forward into the workpiece. Alternately, if the pump is located at some distance, and out of the sight of the Nozzle Operator, an additional team member may be required to monitor the jetting action and the working area and to communicate between the Nozzle and Pump Operators. If direct line-of-site is not possible, radio communications, using a dedicated channel, is an option. In physically strenuous conditions, including elevated temperatures, additional Nozzle Operators may be required (see OSHA guidance document at https://www.osha.gov/SLTC/heatillness/heat_index/).

8.4 **Supervisor/Crew Leader** – The Supervisor/Crew Leader is tasked with ensuring that:

a. team members are trained and fit for duty;

b. team members work together and follow safety procedures;

c. the Pre-operating Procedures (Section 7) have been properly carried out;

d. the Operational Procedures (Section 9) are properly carried out;

e. the working area is properly prepared and maintained during waterjet operations; and

f. all necessary permits, permissions, procedures, and agreements have been obtained before work begins.

8.5 **Back Thrust** – The team **shall** understand how to calculate back thrust from a jet, using the following equation:

$$\text{Back thrust (lb)} = 0.052 \times \text{GPM} \times \sqrt{\text{PSI}}$$

As an example, an operator working with a jet flowing at 10,000 psi* at 10 gpm will experience a force equal to:

$$0.052 \times 10 \times \sqrt{10{,}000} = 0.052 \times 10 \times 100 = 52 \text{ lb}$$

It is not recommended that any one person be required to withstand a back thrust of more than one-third (1/3) of his/her body weight for an extended period of time. For the above example, this means that the operator should weigh at least 156 pounds in order to operate the nozzle. Under adverse conditions such as confined space or

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slippery conditions, a reduction in back thrust may be required. No one **shall** be directed to withstand a back thrust above his/her comfort level. In general, 60 pounds is the recommended maximum level of back thrust. Back thrust calculation is just one factor that employers must take into account.

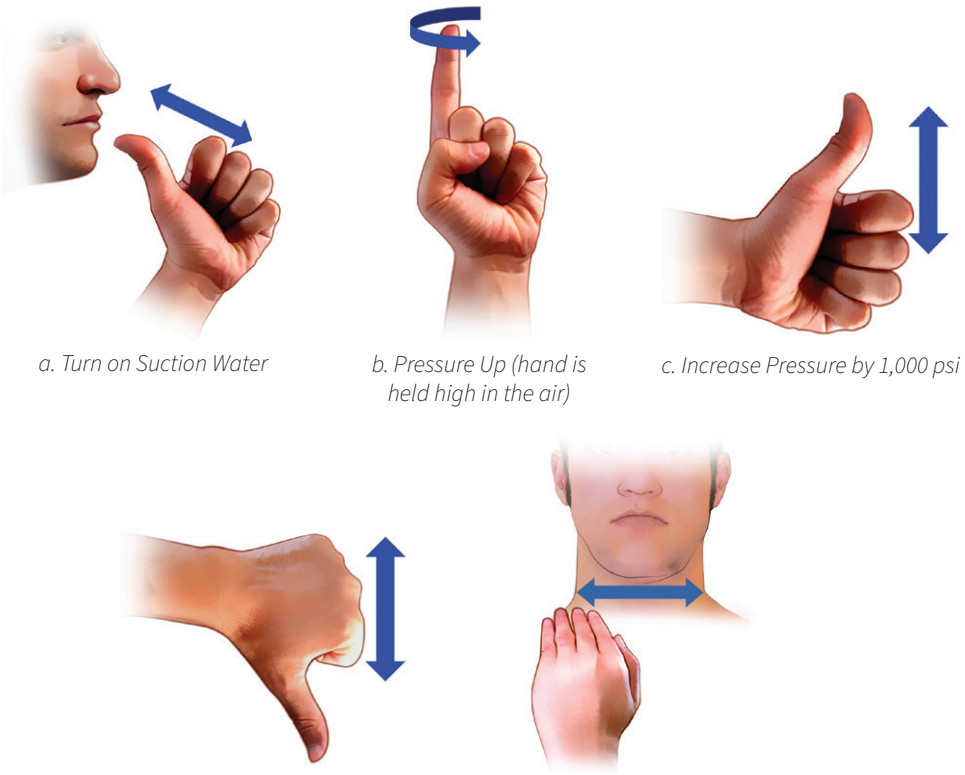
* Note that the pressure at the nozzle will be lower than the pressure at the pump due to pressure loss. The hose manufacturer can be contacted for an estimated pressure loss per length of hose.

8.6 **Rotation of Tasks** – The reaction force and the working environment (for example, spray) from the operation of a jetting gun can physically stress the Nozzle Operator. The Supervisor/Crew Leader should set up a schedule to regularly change the Nozzle Operator and to rotate qualified members of the team to perform different tasks of the jetting operation, as needed.

8.7 **Fitness** – The Nozzle Operator and other team members **shall** be fit for duty and physically capable of performing the required operations.

8.8 **Code of Signals** – The noise that waterjets make and the nature of the protective equipment may limit voice communication. Clear signals for each step in the operation of the equipment (e.g., start the pump; raise the pressure; lower the pressure; shut down the pump) **shall** be demonstrated and acknowledged by all team members before work begins. The Supervisor/Crew Leader is responsible for ensuring that each member of the team understands the meaning of each signal before work begins.

8.8.1 **Hand Signals** – **shall** be defined as follows for each operation (Figure 15 a-e):



a. Turn on Suction Water

b. Pressure Up (hand is held high in the air)

c. Increase Pressure by 1,000 psi

d. Decrease Pressure by 1,000 psi

e. Cut Pressure, Shut Down System

Figure 15 a-e. Recommended Hand SIgnals.

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9.0 OPERATIONAL PROCEDURES

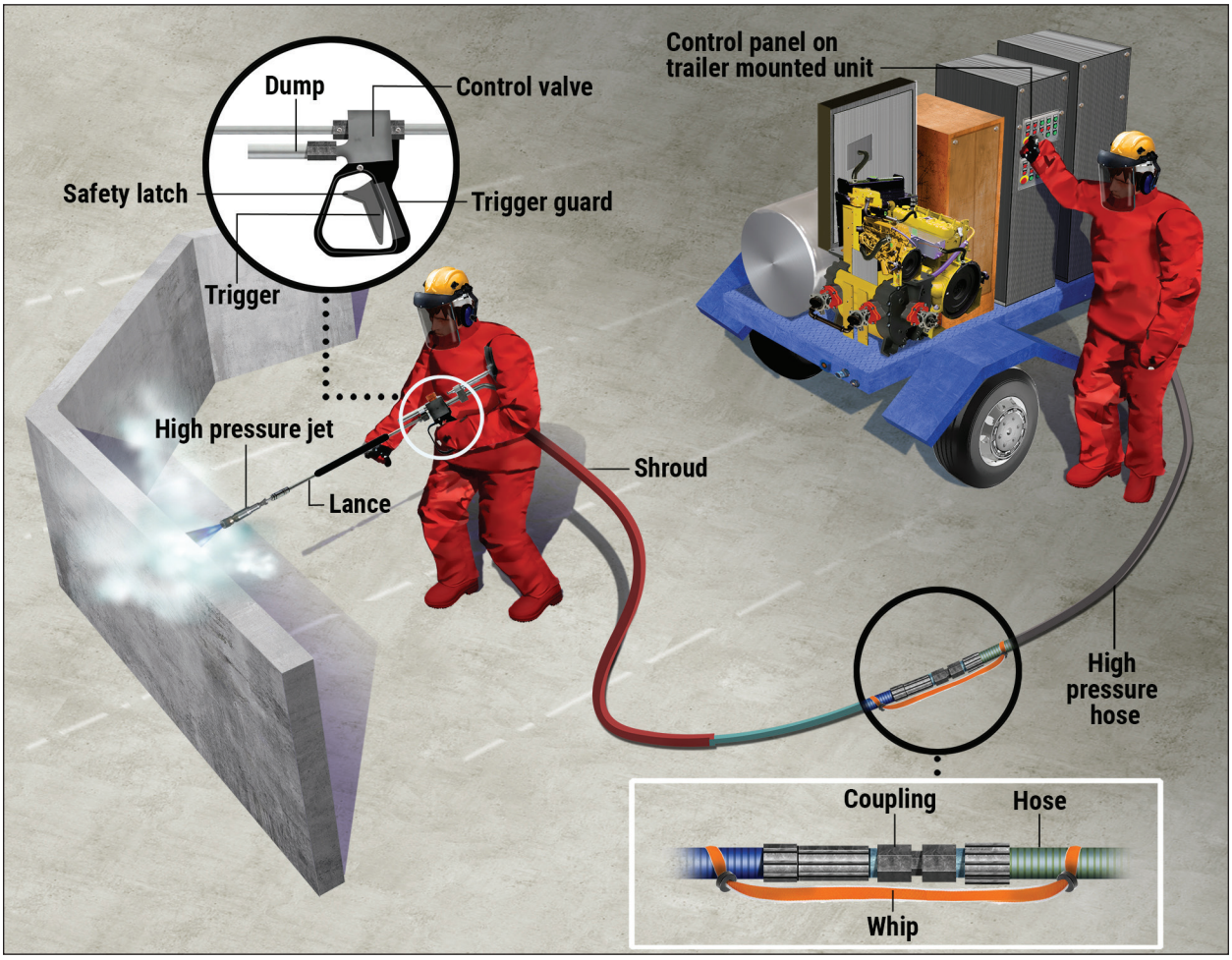


Figure 16. Basic Cleaning Layout. The pump can be fixed or mobile and powered by hydraulic, gasoline, diesel or electric motors.

9.1 Proper Operation

9.1.1 Start up – The Pump Operator **shall** not start the unit (Figure 16) until told to do so, by word or signal, by the Nozzle Operator. Before bringing the unit up to pressure, and on a second signal, the Pump Operator **shall** ensure that the jetting nozzle is either directed at or positioned within the workpiece; that the Nozzle Operator has a secure stance and control of the nozzle; and that each team member is in the proper position to perform their task.

9.1.2 Operational Check – Both before and after bringing the system up to pressure the Pump Operator **shall** visually examine the hose and connections to the jetting gun or nozzle assembly to detect any leaks in the system.

9.1.3 Tightening and Adjusting Components – Apart from the normal adjusting of valves and other components required in a standard jetting procedure, no attempt **shall** be made to tighten or otherwise adjust any nut, hose connection, or other fitting or component of a high pressure waterjet system while the system is under pressure. The pumps **shall** be stopped and any pressure in the line discharged before any repair

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or other adjustment is made. The manufacturer's recommended torque **shall** not be exceeded when tightening components.

9.1.4 Equipment Malfunction – If any dump valve or pressure relief valve does not work properly when tested at the beginning of an operation or if the valve fails during operation, the system **shall** be shut down. The component **shall** then be repaired or replaced by properly trained personnel before the system is restarted.

9.1.5 Reaction Force – The Pump Operator **shall** slowly raise the pressure of the system to allow the Nozzle Operator to adjust to the changing reaction force from the nozzle. Once the operating pressure has been reached, then the pressure **shall** not be further adjusted without the Nozzle Operator being aware that an adjustment is to occur. When the pressure is reduced at shutdown, the pressure should also be lowered slowly to prevent the sudden lack of force from causing the Nozzle Operator to lose his/her balance. The reaction force **shall** not exceed one third (1/3rd) of the Nozzle Operator's body weight. Caution: worksite conditions such as slippery footing may require that the backthrust be lower.

9.1.6 Operating Pressure and Orifice Selection – The Supervisor/Crew Leader **shall** determine the working pressure for the job to be undertaken. Pump and nozzle orifice sizes and configurations **shall** be selected to match these conditions.

9.1.7 Effect of Pressure Change – The reaction force experienced by the Nozzle Operator can suddenly change when the trigger on a gun activates a dry shutoff or dump valve. The Nozzle Operator should be familiar with this change in thrust at pressures up to the working pressure for the job, standing in such a way as to be able to withstand this change. The system may include devices that are designed to reduce this effect.

9.1.8 Operator Position – The Pump Operator **shall** monitor the positions of other team members while the system is in operation, and **shall** depressurize the system if any team member approaches a hazardous or potentially hazardous position.

9.1.9 Use of Balanced Nozzle Orifices – Particularly when cleaning internal surfaces, nozzle orifices may be used that have jets issuing at some angle to the body of the nozzle. These are often designed so that the reaction forces from opposing jets are equal, reducing the out-of-balance force on the Nozzle Operator. However, if one nozzle orifice should be damaged or blocked, then the flow from such opposing jets may no longer balance. This may throw a sudden and unexpected sideways force on the nozzle that may cause the Nozzle Operator to lose control. These nozzle orifices should, therefore, be checked in particular before operation, and they should only be brought up to pressure when they are located within the work piece.

Where balanced nozzle orifices are used in a shotgunning type of operation, the pressure to the gun should be raised slowly to ensure that the jets from the nozzle are providing equal thrust. The Nozzle Operator should also brace the gun to protect against sudden sideways loading from an instantaneous blockage or failure of a nozzle.

9.1.10 Work Stoppage – Waterjetting operations **shall** stop and the system **shall** be depressurized:

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a. if any unauthorized person enters the working area;

b. if a hazardous or potentially hazardous condition is detected;

c. if an alarm is sounded within the plant or works; or

d. if *Industry Best Practices* in this document are not being followed.

Additionally, the system **shall** be depressurized when not in use or when it is being repaired/serviced.

9.1.11 Shutdown – Care should be taken to release the pressure in the system, especially when a dry shutoff gun is in use. The Nozzle Operator **shall** ensure that no pressure remains in the line or gun after shutdown.

9.2 Improper Use – The hose or any other component of a high pressure waterjet system **shall** not be used as a means of support for the Nozzle Operator or to carry the operator's weight, particularly when going up or down into a confined space.

9.3 Access – During the time that waterjetting is in progress no unauthorized persons **shall** be allowed into the area closed off by the barriers. Warning notices restricting entry into the area **shall** be clearly posted outside the barriers.

9.3.1 Establishment of a Waterjetting Zone – A barricaded work area **shall** be established such that energized water or particles will not present a hazard. At minimum, the barricaded work zone should be fifteen (15) feet in all directions surrounding the waterjet pump and the general work area. If the pump and general work area are not enclosed in the same barricaded area, then both locations, plus the pathway for the high pressure hoses, should be barricaded. The barricade perimeter should be identified by tape, warning signs, or any other visible, restrictive means. When cleaning tubes, pipes, tanks, and other process equipment, ensure openings that may expose individuals to waterjets or debris are likewise secured.

The waterjetting zone may be reduced from the 15 foot perimeter, provided that hard engineering controls (such as physical barriers) have been implemented and their purpose communicated to personnel in the area of work. Finally, the variance procedure should be followed in advance of the planned operation.



Figure 17. Waterjetting zone.

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9.4 **Procedures for Entering the Working Area** – Access procedures should be agreed upon before work begins, and should include steps to ensure that no person enters the working area while waterjetting is in progress and until the operators are aware that entry is required. Those who wish to enter the area, or to have operations stopped, should first gain the attention of a team member other than the Nozzle Operator. The Nozzle Operator **shall** not be distracted while operating the gun until the jet has been shut down.

9.5 **Additional Protection** – Where it is necessary to shield personnel or to protect equipment from water and solid materials removed from, rebounding from, or passing through the workpiece, additional protective barriers or shields **shall** be set up within the working area. Protective barriers should be arranged so as not to interfere with the access of the Nozzle Operator to the working surface.

9.6 **Personal Protective Equipment (PPE)** – All personnel working in or entering the barricaded area while waterjetting is in progress **shall** wear the required protective equipment.

9.7 **Pressurizing the System** – Pressure **shall** be increased slowly while the system is being inspected for leaks and/or faulty components. All leaks or faulty components **shall** be repaired or replaced immediately. The system **shall** be depressurized for repairs.

9.8 **Additives** – Any water additive (chemical, detergent, or solid particle) **shall** be used in accordance with the manufacturer's recommendations.

9.9 **Shotgunning**



Figure 18. Manual shotgunning operation.

9.9.1 **Controls** – The jetting gun **shall** be fitted with either a dump system or dry shutoff control valve and equipped with a trigger guard and safety interlock. The person operating the gun, lance, or nozzle assembly **shall** have direct control of the dump system. The trigger mechanism **shall** never be locked, wedged, or blocked in the "on" position.

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9.9.2 **Hose Safety Shroud** – All shotgun whip hoses **shall** be fitted with a shroud to protect the operator in the event of a hose failure. Refer to section 14.21 for a definition of the hose safety shroud.

9.9.3 **Attendance** – The system **shall** never be left unattended when pressurized.

9.9.4 **Multiple Operation** – When more than one shotgunning operation is being performed within the same area, a physical barrier **shall** be installed or adequate spacing between operators **shall** be maintained to prevent the possibility of injury from the high pressure water.

9.9.5 **Holding the Target** – Objects to be cleaned **shall** never be held manually.

9.9.6 **Standard Shotgun Barrel Length** – Shotguns **shall** have a minimum barrel of length of 48 inches, measured from the nozzle to the pivot point of the rear-most trigger, and an overall length of 66 inches, measured from the nozzle to the shoulder rest.

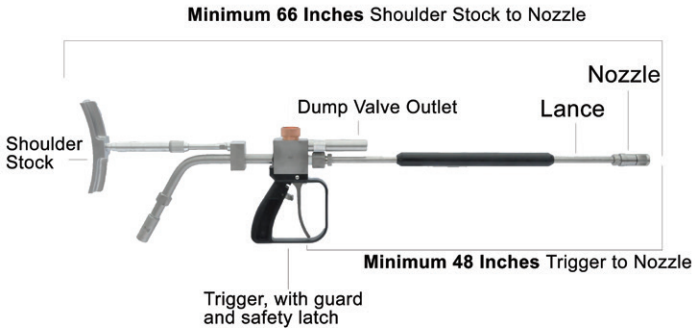


Figure 19. Standard shotgun barrel length.

9.9.7 **Powered Rotating Barrel Shotgun** – A handheld rotating gun, typically an air motor driven swivel that drives a nozzle assembly whereby the rotational speed can be varied. Recommended practice is a minimum barrel of length of 48 inches, measured from the end of the nozzle to the rear-most trigger.

9.9.8 **Handheld Surface Removal Tools** – Handheld tools generally used for coating removal and surface cleaning are exempt from the shotgun barrel length recommendation. They are designed to be held with both hands against the surface to be cleaned, sometimes incorporating the use of a tool balancer as well as vacuum recovery. The device **shall** have a method to stop the high pressure water flow either by using a dual trigger assembly or a contact sensor with the surface whereby high pressure water will dump or stop discharging from the tool. The thrust generated by the waterjets should not exceed 40 pounds.

9.9.9 **Thrust** – The thrust produced by the reaction to the waterjet **shall** not exceed 1/3 of the body weight of the operator. In no case **shall** the shotgun operator be required to manage any thrust level that exceeds the operator's comfort level.

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9.10 Line Moleing or Pipe Cleaning



Figure 20. Manual line moleing operation.

9.10.1 **Line Moleing** – Line moleing is generally defined as internal line cleaning in process pipes, drains, and sewers using a nozzle on the end of a flexible hose or lance.

9.10.2 **Control** – The feed assembly to the flexible lance or hose **shall** be fitted with either a dump system or a dry shutoff control valve. The operator inserting the nozzle **shall** maintain control of the system. The control system **shall** be foot operated and shielded in such manner as to prevent accidental activation.

9.10.3 **Reversing** – There **shall** be an anti-reversal device of sufficient length to ensure that the rigid length measurement from the tip of the nozzle to the back end of the hose crimp is 1-1/2 times the internal diameter of any pipe that can be accessed in the cleaning operation This is done to prevent the nozzle from turning around 180° and doubling back toward the operator. This may require a stinger; for lines with intersecting lines, a longer stinger length may be required. If a 1-1/2 time rigid diameter is unable to traverse the pipe being cleaned, the variance process **shall** be followed. If the line diameters and intersections have not been verified prior to starting the job, a smash plate **shall** be installed.

9.10.4 **Pre-Cleaning** – The first two feet of a line **shall** be cleaned prior to line moleing, unless a shielding device has been installed to prevent operator contact with jets or debris.



Figure 21. Demonstration of pre-cleaning the line entrance.

9.10.5 **Pressurization** – During manual operations, the nozzle **shall** be inserted into the line before pressurizing. The nozzle should be far enough into the line so that any backward facing jets do not pose a hazard to the operator. Conversely, the system **shall** be depressurized

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before removing the nozzle from the line. The operator's foot should be removed completely from the foot pedal and planted firmly on the ground prior to removing the nozzle from the line.

9.10.6 **End Identification** – Hoses should be conspicuously marked at two, four, and six foot intervals from the nozzle to warn the operator when the nozzle is getting close to the line entry point.

9.10.7 **Anti-Withdrawal Device (AWD)** – An anti-withdrawal device **shall** be installed on the line entrance. This will prevent the mole from being pulled out of the line under pressure. Preferably, the anti-withdrawal device is of a plate type that is capable of deflecting backward facing jets, water and debris away from the operator. The plate type anti-withdrawal device should be installed as close to the line entrance as sufficient to still allow debris and water to flow out of the line. Any slots or openings in the plate should be smaller than the nozzle assembly diameter for protection in the event of a reversing nozzle. The moleing hose **shall** be fitted with a positive stop that prevents the nozzle from going beyond the desired length of travel into the line that is being cleaned. If the nozzle diameter is less than or equal to the diameter of the hose crimp, a non-adjustable AWD **shall** be used.

9.10.8 **Pull Test** – Validate that the AWD is functioning correctly by pulling back on the moleing hose to insure that the nozzle cannot pass through the AWD.

9.11 Flex Lancing

9.11.1 **Flex Lancing** – Flex Lancing is generally defined as internal tube cleaning in tube bundles as found in heat exchangers, evaporators, coolers, and boilers using a nozzle on the end of a flexible lance.

9.11.2 **Pre-Cleaning** – The first six inches of a tube **shall** be cleaned prior to flex lancing, unless a shielding device has been installed to prevent operator contact with jets or debris.

9.11.3 **Control** – The feed assembly to the flexible lance **shall** be fitted with either a dump system or a dry shutoff control valve. The operator inserting the nozzle **shall** maintain control of the dump system. The control system **shall** be foot operated and shielded to prevent accidental activation.



Figure 22. Manual flex lancing operation.

9.11.4 **Pressurization** – In manual flex lancing operations, the system **shall** be depressurized before removing the nozzle from the tube. The operator's foot should be removed completely from the foot pedal and planted firmly on the ground prior to removing the nozzle from the tube.

9.11.5 **Clearance** – The clearance between the outside diameter of the flex lance, end fittings, and nozzle assembly to the inside wall of the tubes being cleaned **shall** be

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sufficient to allow adequate washout of water and debris. This reduces the potential that the nozzle will hydraulic backwards out of the tube.

9.11.6 **Anti-Withdrawal Device (AWD)** – An anti-withdrawal device **shall** be used. This will prevent the nozzle from being pulled out of the tube under pressure and should be capable of deflecting backward facing jets, water and debris away from the operator. The anti-withdrawal device should be positioned within 1 inch of the tube face. The AWD **shall** be mechanically attached to the piece of equipment being cleaned and positioned so that its standoff distance is no greater than 1 inch from the entrance of the tube to be cleaned. The AWD **shall** have a restricting device constructed of stainless steel with a fixed diameter; adjustable AWDs with an adjustable point of restriction **shall** not be used.

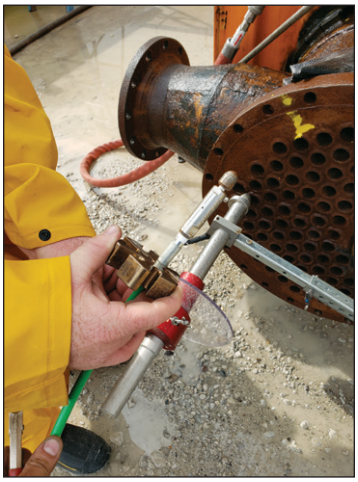


Figure 23. Non-adjustable point of restriction.

9.11.7 **Pull Test** – Validate that the AWD is functioning correctly by pulling back on the lance or hose to ensure the nozzle cannot pass through the AWD.

9.11.8 **Barrier** – When lancing vertical exchanger tubes from the top down, a physical barrier **shall** be installed to protect the operator's feet in the event that the nozzle is accidentally withdrawn under pressure from the tube.



Figure 24. Anti-withdrawal device.

9.11.9 **Cleaning from the Bottom of a Vertical Heat Exchanger** – Cleaning from the bottom of the tube **shall** not be performed unless using an automated tool.

9.11.10 **U Tube Heat Exchangers** – When cleaning U Tubes, the nozzle entry and exit are on the same tube sheet face. The lance should be marked or a physical stop used to identify when the nozzle has passed the center line of the U bend. The remainder of the tube is cleaned by inserting the cleaning nozzle into the opposite end of the tube and cleaning to the center line of the U bend. The Nozzle Operator **shall** not stand on the discharge side of the heat exchanger.

9.12 Rigid Lancing

Rigid Lancing should be performed with an automated tool. Manual rigid lancing **shall** not be performed without a properly executed variance and the following recommendations:

9.12.1 **Control** – The jetting extension or lance **shall** be fitted with either a dump system or a dry shutoff control valve that is shielded to prevent accidental activation. The operator inserting the nozzle **shall** have direct control of the system (Figure 25).

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Figure 25. Manual rigid lancing operation.

9.12.2 **Pre-Cleaning** – The first six inches of a tube **shall** be cleaned prior to rigid lancing, unless a shielding device has been installed to prevent operator contact with jets or debris.

9.12.3 **Pressurization** – In manual rigid lancing operations, the system **shall** be depressurized before removing the nozzle from the tube. The operator's foot should be removed completely from the foot pedal and planted firmly on the ground prior to removing the nozzle from the tube.

9.12.4 **Operators** – A rigid lance **shall** be controlled by a minimum of two operators, one inserting the nozzle and one supporting the lance at the point where it joins the hose, unless the lance is shorter than 6 feet. Use additional operators as necessary, to adequately support the lance.

9.12.5 **Lance Length** – The rigid lance should be longer than the tube being cleaned and should be one piece where possible.

9.12.6 **Lance-Hose Connection** – A lance and hose **shall** be connected by a fitting that is suitable to withstand the pressures and forces experienced at the connection point during rigid lancing operations. The lance-hose connection point should be covered with a minimum six foot safety shroud which will act to protect the operator if the hose – fitting connection point fails.

9.12.7 **Lance Stiffener** – The operator supporting the lance at the point where it joins the hose should use an external support device or cover that will prevent undue stress on the connection.



Figure 26. Lance stiffener.

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9.12.8 End Identification – The ground should be conspicuously marked to alert the operator(s) who are supporting the lance when the nozzle is approaching the entry / exit point.

9.12.9 Anti-Withdrawal Device – Use of an AWD is required when manually rigid lancing. The AWD **shall** be mechanically attached to the piece of equipment being cleaned and positioned so that its standoff distance is no greater than 1 inch from the entrance of the tube to be cleaned.



Figure 27. Anti-withdrawal device.



Figure 28. Demonstration of rigid lancing operation.

9.12.10 Clearance – The clearance between the outside diameter of the lance and nozzle and the inside wall of the item being cleaned **shall** be sufficient to allow adequate washout of water and debris. This reduces the potential that the lance will hydraulic backwards out of the pipe.

9.12.11 Shields – When lancing tubes with a rigid lance a safety shield should be installed, where practicable, to prevent debris from striking the operator.

9.12.12 Barrier – When lancing vertical exchanger tubes from the top down, a physical barrier **shall** be installed to protect the operator's feet in the event that the nozzle is accidentally withdrawn under pressure from the tube.

10.0 CARE AND MAINTENANCE OF EQUIPMENT

10.1 Maintenance, Servicing, and Repair – Three levels of maintenance **shall** be carried out on the components of high pressure waterjet systems. Always follow the equipment manufacturer's recommendations at minimum and perform maintenance with trained and competent personnel.

a. First is the daily preventive maintenance that **shall** be carried out by equipment operators. This includes a regular check that the components being used are correct for the job, that the connections and parts are in good condition, that the connections are properly made, and that no damage has occurred to the components of the system.

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b. Second is the regular checking of the external and internal parts of the valves, fittings, and gun components of the system.

c. Third is the servicing of the pump and major components of the system.



Figure 29.

10.2 Maintenance Scheduling – Equipment care and maintenance scheduling **shall** recognize that parts and equipment naturally wear out during jetting operations. Special care should be taken to examine the components of the jetting system to be sure that they are in fit condition to able to perform their necessary functions. This inspection **shall** be carried out while the system is being assembled before a jetting operation, and also when it is being taken apart. Both of these times allow for the examination of the threads and other internal parts that the operator could not otherwise see. All equipment **shall** be examined, and all necessary or scheduled maintenance performed, at a minimum, as recommended by the manufacturer of that component.

10.3 Drive Unit – Where an engine is used to drive the pump, the engine should be checked at least daily prior to and after use, and, at a minimum, at the intervals set by the manufacturer. Such checks **shall** ensure that all necessary fluids, including fuel, oil, hydraulic fluid and cooling water, are present, in good condition, and at the recommended levels. All belts should be checked for the correct tension and to be sure that they are in good shape and that they are not peeling, cracked, or otherwise damaged. All guards **shall** be checked to ensure that they are properly secured and undamaged. The control cables and engine controls should be inspected daily to ensure that they are working properly.

10.4 Pressurizing Pump – The pump **shall** be examined both when shut down and when operating. To ensure that there are no leaks or loose fittings, both visual and listening checks should be performed. The listening checks alert the operator to any unusual noises coming from the unit that might indicate an internal problem. Regular visual checks **shall** be made of the plungers and seals while the unit is not operating, and on a schedule at least as often as recommended by the manufacturer. In addition, all the maintenance specified by the manufacturer **shall** be performed on the schedule that has been specified.

10.5 Water Inlet, Reservoirs, and Booster Pump – Before the unit is started, a visual check **shall** be performed to determine the condition of the low pressure water line feeding into the pump, any booster pump required to assist in supplying water at the right pressure and flow to the pressurizing pump, and any containers used to store water during the jetting operation. This check **shall** ensure that there is sufficient water to supply the high pressure pump during the operation planned. Tanks should be free of rust and debris. All pump maintenance specified by the manufacturer **shall** be performed on the schedule that has been specified.

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10.6 Filters and Strainers – Regular checks **shall** be made of all fluid filters to ensure that they are not blocked or damaged. Care should be taken when examining, changing, or cleaning the filters to ensure that no solid particles escape into the supply lines to the pump and nozzle. These solid particles can damage valves and nozzles and make the pump run poorly. All fluid filters should be checked at regular intervals, especially where the supply of water is of poor quality. Filters should be examined when directed and in the manner specified by the manufacturer. Filters **shall** be adequately sized, per the manufacturer's recommendation.

10.7 Hose Assemblies – The condition of all hoses, high pressure tubing, and their connections is critical to the proper operation of the equipment. The outer covering of the hose **shall** be examined for any broken or exposed wires, obvious damage or places where ballooning of the hose has occurred as a result of internal failure. If any of these visual signs are noted or the hose has been driven over, it **shall** be removed from service. Refer to NAHAD Hose Safety Whitepaper for hose inspection referenced in Appendix A.

Where the hose is stored, care should be taken to wrap the hose on a reel in a manner that will not pinch, damage, or exceed the manufacturer's recommended minimum bend radius for the hose.

If the hose is stored on a reel, the reel should also be inspected to ensure it has sufficient lubricating oil for proper operation.

During operation of the equipment, the hose and all other components of the system should be periodically examined to ensure that no damage has developed. The pump **shall** be shut down and defective hoses replaced when damage is discovered.

10.8 Nozzles, Nozzle Holders, and Lance Connections – The system **shall** be flushed with water before installing the nozzle. The nozzles **shall** be checked to ensure they are not blocked or damaged and that they seat properly in the holder or manifold. The condition of the threads holding the nozzle in place should be checked to ensure that they are in good condition and not worn. All damage **shall** be repaired, or the parts replaced, before jetting begins.

10.9 Trigger and Valve Controls – Each hand-operated and foot-operated valve **shall** be manually checked to ensure it is clean and properly functioning. The valves **shall** be disassembled to examine the condition of the internal components and to replace worn parts. Valve guards should also be inspected and any defects, such as bent plates, that might interfere with the proper operation of the unit **shall** be corrected. Leaking valves **shall** be replaced immediately.

10.10 Electrical Equipment – Special precautions should be maintained when operating high pressure waterjet systems around electrical components. Before using the equipment, and on at least a daily basis, all electrical boxes, connections, switches, cables, and fittings **shall** be checked for damage. Precautions should be taken to ensure that water cannot enter these components and that they are not liable to be damaged by the entry of water or abrasive from the jetting process. Any connections made **shall** be placed in such a manner that they cannot fall or lie in a pool of water

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created by the jetting operation. The correct direction of rotation of the electric motor should be checked on initial installation and after every reconnection to a power supply.

10.11 Trailers – When using a trailer-mounted unit, the unit **shall** be inspected each time it is moved. This examination should include brakes, lights, jacks and connections for stabilizing the unit in place, the tow bar connection including safety chains, and the tires.

Trailers **shall** be towed by vehicles that are capable of towing the load, and they must be properly connected.

10.12 Use of Recommended Tools – Anyone involved in the assembly, disassembly, and/or repair of waterjet equipment **shall** use only tools recommended by the manufacturer for assembling and disassembling high pressure components. Any tool that can cut into a part, such as a pipe wrench, can create a weak point that can lead to a hazardous condition and serious part failure. Such tools are not recommended for use.

10.13 Compatibility – All the components of a high pressure waterjet system **shall** be checked to make sure that they are of the correct size, thread, and pressure rating for the use intended.

10.14 Freeze Precautions – When it is likely that a high-pressure waterjet system will be exposed to freezing conditions, the unit **shall** be protected. Equipment manufacturers' recommendations **shall** be followed, and the procedures **shall** include steps to circulate winterizing solution through the water lines of the system. This can be carried out by removing the gun from the delivery line and then directing the flow from the hose back to the supply reservoir. Once the correct amount of winterizing solution has been added, the pump can be run until the return flow to the tank shows that winterizing solution is circulating. The dump and any bypass circuits **shall** also be activated to ensure that the water in those lines is similarly treated with winterizing solution.

WARNING: IF THE WATER IN A PUMP OR HOSE APPEARS FROZEN, THEN NEITHER THE PUMP NOR THE DRIVE TO THE PUMP **SHALL** BE STARTED UNTIL THE SYSTEM HAS BEEN THOROUGHLY INSPECTED. IN FREEZING CONDITIONS, THE SYSTEM **SHALL** BE THOROUGHLY FLUSHED TO REMOVE ANY ICE PARTICLES BEFORE THE TIP IS PUT ON THE SYSTEM.

11.0 AUTOMATED EQUIPMENT

Anytime that an automated solution exists for a waterjet application that is practical, it is strongly recommended that this solution be considered for use.

Unless expressly stipulated in this section, all industry best practices described in this publication will be followed when using automated equipment. All waterjetting jobs require a relief valve, and it **shall** be operated by the person nearest the nozzle.

Reduction in PPE requirements can be achieved when using certain automated equipment, provided that the PPE reduction is approved by both the waterjetting contractor and customer/plant management.

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11.1 Automated Shotgunning

11.1.1 Automated shotguns can come in many varieties. Any shotgun that requires the operator to be in direct contact with the gun in any way will require full compliance with all manual shotgunning rules, including all PPE requirements.

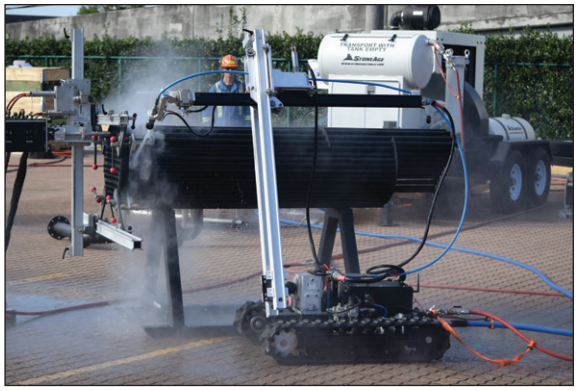


Figure 30. Automated shotgunning equipment.

11.1.2 Automated shotguns that are completely remote controlled:

11.1.2.1 Do not require a hand dump valve, but **shall** be equipped with a remote controlled dump system controlled by the person closest to the nozzle.

11.1.2.2 Barrels on automated equipment do not have a minimum length requirement, but must be mechanically secured at points that ensure stability and control of the barrel at all operating ranges, which **shall** be approved by a Supervisor.



Figure 31. Automated shotgunning equipment.

11.1.2.3 A hose shroud is not required if the hose is not stationed near the operator's body.

11.1.2.4 PPE requirements for a completely remote controlled shotgun may be determined in the Job Safety Analysis (JSA) process if the operator can remain stationed at a safe distance. If stationed within a minimum of 15 feet, the same PPE requirements for manual shotgunning must be met. Exceptions may be made for equipment with environmental cabs or similar protections.

11.1.2.5 In all cases the operator should be stationed as far from the nozzle as practical.

11.2 Automated Rigid Lancing Machines

11.2.1 The use of an anti-withdrawal device is not required as long as the operator can be stationed at least five feet from the equipment being cleaned and the nozzle at all times. The operator may enter the five-foot zone surrounding the nozzle only after:

a. Relieving pressure from the nozzle.

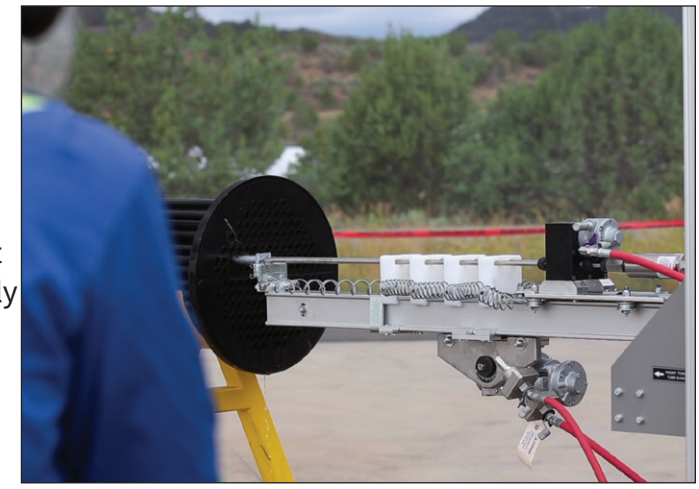


Figure 32. Automated rigid lancing system.

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b. Turning off all air or hydraulic controls to the equipment.

c. The nozzle is inside a tube or a machine guard.

d. Ensuring that no one is within five feet of the foot pedal.

11.2.2 A foot pedal or other relief device **shall** be used by the person closest to the nozzle.

11.2.3 A safety shroud is not required on the lance hose.

11.2.4 A lance stiffener is not required on the lance.

11.2.5 Nozzles are not required to have “pulling” or “neutral” thrust.

11.2.6 Lances may be any length.

11.2.7 It is not necessary to clean the first six inches of a tube with a shotgun; it may be cleaned with the automated lance.

11.2.8 The lance **shall** not be touched or worked on by anyone unless:

a. The pump is taken out of gear and

b. Power to the lancer’s motors has been blocked and the pressure bled in accordance with lockout and tagout requirements.

11.2.9 Workers **shall** not work within five feet of an exposed lance track unless:

a. The pump is taken out of gear and

b. Power to the lancer’s motors has been blocked and the pressure bled in accordance with lockout and tagout requirements.

11.2.10 Do not walk beneath a tube lancer.

11.2.11 Extreme caution must be used around indexers:

11.2.11.1 Never work on a powered indexer unless power to the lancer’s motors has been blocked and the pressure bled in accordance with lockout and tagout requirements.

11.2.11.2 Be cautious of pinch points and exposed moving parts while an indexer is working.

11.2.11.3 Light duty indexers **shall** be on a level surface, stabilized and mechanically attached to the equipment being cleaned.

11.2.11.4 Vertical indexers **shall** be securely mounted to the equipment being cleaned. Guide cables may be necessary to aid in stabilization.

11.2.12 PPE requirements for operators of automated lancing machines will be determined during the JSA process due to the many variations of machines and job set- ups. At a minimum, the dump valve operator **shall** wear a face shield and metatarsal boots in all cases where the dump valve is manually foot controlled. Exceptions may be made for machines with a remote controlled pneumatic or electric dump valve, or for a machine equipped with an environmental cab or similar protections.

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11.3 Automated Flex Lancing Machines

11.3.1 Automated Flex Lancing Machines can be placed into two broad categories; those that use a mechanical or remote means of introducing the hose/nozzle (one or more) to the equipment being cleaned and those that require the operator to manually hold a device that feeds the hose into the equipment being cleaned. Automated hose management systems have unique features with rules in 11.3.4 on the next page.



Figure 33. Automated flex lancing system.

11.3.2 Rules pertaining to flex lance machines that use a mechanical means of indexing the flex lance into a tube, such as an indexer.

11.3.2.1 The use of an independent anti-withdrawal device is not required as long as the flex lance machine is equipped with an internal anti-withdrawal device mechanism and no guards have been removed. The operator may enter the five-foot zone surrounding the nozzle only after:

a. Relieving pressure from the nozzle.

b. Turning off all air or hydraulic controls to the equipment.

c. The nozzle is inside a tube or a machine guard.

WARNING: no one is permitted to enter the five-foot nozzle zone while someone is within five feet of the foot pedal.



Figure 34. Automated flex lancing operation.

11.3.2.2 A guide guard must extend from the indexer to the tube sheet. The “gap” between the guard and the tube sheet **shall** be less than one inch.

11.3.2.3 A foot pedal or other relief device **shall** be used by the person closest to the nozzle.

11.3.2.4 It is not necessary to clean the first six inches of a tube with a shotgun; it may be cleaned with the automated lance.

11.3.2.5 The lance **shall** not be touched or worked on by anyone unless:

a. The pump is taken out of gear and

b. Power to the lancer’s motors has been blocked and the pressure bled in accordance with lockout and tagout requirements.

11.3.2.6 PPE requirements for operators of automated flex lancing machines that use an indexer to guide the flex lance will be determined during the JSA process due to

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the many variations of machines and job set-ups. At a minimum, the dump valve operator **shall** wear a face shield and metatarsal boots in all cases where the dump valve is manually foot controlled. Exceptions may be made for machines with a remote controlled pneumatic or electric dump valve, or for a machine equipped with an environmental cab or similar protections.

11.3.2.7 Extreme caution must be used around indexers:

11.3.2.7.1 Never work on a powered indexer unless power to the lancer's motors has been blocked and the pressure bled in accordance with lockout and tagout requirements.

11.3.2.7.2 Be cautious of pinch points and exposed moving parts while an indexer is working.

11.3.2.7.3 Indexers should be on a level surface and stabilized.

11.3.3 Rules pertaining to flex lance machines that require an operator to hold or control a guard or device used to guide the lance into a tube:

11.3.3.1 In HORIZONTAL applications an anti-withdrawal device mechanically attached to the equipment being cleaned **shall** be used at all times.

11.3.3.2 In VERTICAL applications WHEN CLEANING FROM THE BOTTOM, an anti-withdrawal device mechanically attached to the equipment being cleaned is mandatory. Any "gap" between the device and the tube being cleaned **shall** be one inch or less.

11.3.3.3 In VERTICAL applications WHEN CLEANING FROM THE TOP DOWN, an anti-withdrawal device mechanically attached to the equipment being cleaned is mandatory. Any "gap" between the device and the tube being cleaned **shall** be one inch or less, or:

11.3.3.4 In VERTICAL applications WHEN CLEANING FROM THE TOP DOWN, in lieu of a mechanically attached anti-withdrawal device, a foot control anti- withdrawal unit may be used. Any "gap" between the device and the tube being cleaned **shall** be one inch or less.

11.3.3.5 PPE requirements for operators of automated flex lancing machines that require the operator to hold or control a guard or device used to guide the lance into a tube will be the same as those required for manual flex lancing. Additionally, appropriately protective shin guards **shall** be worn in all top-down vertical applications.

11.3.4 The automated hose management system is uniquely engineered to be used without the need for a mechanically attached anti-withdrawal device, but only after complying fully with all the following conditions.

11.3.4.1 In VERTICAL operations, when cleaning from the top-down only, the manufacturer supplied splash guard assembly **shall** be used. Before the high pressure water is activated, the manufacturer supplied splash guard assembly **shall** be positioned over the tube to be cleaned and the operator's foot positioned firmly on the base plate.

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11.3.4.2 In HORIZONTAL operations, the manufacturer supplied splash guard assembly may not be used unless attached to a mechanically attached anti-withdrawal device or an indexer meeting the requirements of 11.3.2 above.

11.3.4.3 If the manufacturer supplied splash guard assembly is removed or modified, a variance **shall** be completed and approved.

11.3.4.4 Equipment that uses an indexer to guide the flex lance into the tube **shall** comply with rules 11.3.2 through 11.3.2.7.3 above.

11.3.4.5 PPE requirements for operators of this equipment when manually operating the splash guard assembly will be the same as that for manual flex lancing. Additionally, appropriately protective shin guards **shall** be worn in all top-down vertical applications.

11.3.4.6 PPE requirements for operators of this equipment that use an indexer to guide the flex lance will be determined during the JSA process due to the many variations of machines and job set-ups. At a minimum, the dump valve operator **shall** wear a face shield and metatarsal boots.

11.4 Line Moleing Machines (Including the use of 2D & 3D Nozzles)

11.4.1 There are no exceptions to the manual line moleing rules for automated line mole machines. Stinger and anti-withdrawal requirements are explained in sections 9 and 14. As in all operations, the person closest to the nozzle **shall** control the foot pedal or other form of dump valve.



Figure 35. Automated line moleing equipment.

11.4.2 PPE requirements for operators of auto mated line moleing machine **shall** be determined during the JSA process due to the many variations of machines and job set-ups. If a smash plate and anti- reversal are instituted, PPE requirements may be relaxed outside of a minimum 15-foot perimeter. Other personnel who might occasionally position hoses, swivel carts, etc. **shall** also meet the PPE requirements.

11.5 Use of non-automatic two dimensional (2D) and three dimensional (3D) Nozzles for Vessel Cleaning

11.5.1 Where equipment is manually positioned, a foot pedal or other form of dump valve controlled by the worker closest to the equipment should be used.

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11.5.2 In all cases the waterjetting pump operator will remain in close proximity to the waterjetting pump and have a means to immediately shut off the pressure.



Figure 36. Vessel cleaning.

11.5.2.1 The waterjetting pump pressure may only be turned on by the designated waterjet pump operator. Measures **shall** be in place to prevent others from turning on the water pressure during periods when the operator is away from the pump.

11.5.3 An anti-withdrawal device is not required.

11.5.4 A stinger is not required. Nozzles should be checked to ensure they are balanced. A rigid positioning mechanism may be used to reduce oscillation.

11.5.5 A single crew member or "watch-man" **shall** be assigned the duties of monitoring the vessel being cleaned to ensure rules 11.5.6 through 11.5.8.3 are followed during the job and after all breaks or times of inactivity.

11.5.5.1 The watch-man **shall** have a means to immediately communicate with the waterjetting pump operator.

11.5.6 Lockout/tagout procedures **shall** be used before vessel entry can occur.

11.5.7 The watch-man **shall** ensure the vessel and vessel openings and barricaded areas are clear of all personnel each time the pressure is engaged and while the nozzle is running.

11.5.8 All vessel openings **shall** be examined for the following to prevent the jet stream or the tool from exiting the vessel:

11.5.8.1 Vessel openings that are not required to be open **shall** either be bolted shut or securely covered with a warning tag attached.

11.5.8.2 Vessel openings that are required to remain open during the cleaning process **shall** be barricaded with red tape for a distance of at least fifteen feet.

11.5.8.3 In all cases, proper barriers or restrictions **shall** be applied to prevent the jet stream or tool from exiting the vessel, including the possible event of a cable or fastener failure.

11.5.9 Cables, hoisting equipment and all fasteners **shall** be inspected and removed from service if found to be defective in any way.

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11.5.10 PPE requirements for operators of 2D and 3D nozzles **shall** be determined during the JSA process due to the many variations of machines and job set-ups. PPE requirements may be relaxed outside a minimum 15-foot perimeter.

11.6 **Shell Side Bundle Cleaners** – The rules in 11.1.2 of this section applying to automated shotguns will apply to bundle cleaners. Exceptions may be made to the PPE requirement if the machine is equipped with an environmental cab or similar protections.



Figure 37. Shell side bundle cleaning operation.

11.7 **Automated Slab Cleaners** require at a minimum standard waterjetting PPE. Additional PPE may be necessary as determined in the JSA process.



Figure 38. Demonstration of slab cleaner.

11.8 Automated tools and waterjetting equipment that are physically controlled or held by an operator **shall** comply with all manual waterjetting rules and manufacturers' recommendations.

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11.9 Other automated tools not mentioned in this section **shall** comply with all manual waterjetting rules and manufacturers' recommendations or go through the variance process.

12.0 PERMANENT CLEANING AREAS

12.1 **Use of a Permanent Site** – A special area may be set aside for waterjet operations. Standards and controls in these areas **shall** meet or exceed the standards and controls outlined for temporary waterjet areas.

The correct operating procedures for the use of jetting equipment should be prominently and clearly displayed in permanent cleaning areas. The area should be designed to ensure the safety of affected workers, including workflow, barriers/barricades, visibility, ventilation, and energy controls. It should also ensure the proper collection and disposal of both solid and liquid wastes. Regular inspections and maintenance should be performed.

12.2 **Recommendations** – All other parts of these *Industry Best Practices* **shall** apply to the use of permanent cleaning areas.

13.0 DESIGN CRITERIA

13.1 **Safety Factor** – All components designed and that are included in a high pressure waterjetting system **shall** be manufactured to provide a minimum ratio of burst pressure to working pressure of 2.5 to 1.

13.2 **Fittings and Components** – Are used to make a connection or join the parts of a high pressure system together. It is recommended that fittings and components be permanently marked with their maximum rated working pressure or color coded using WJTA's color coding guidelines for high pressure hoses.

13.3 **Hose Assemblies** – All fixed components of a hose assembly **shall** minimally comply with the working pressure and color coding specified.

13.4 **Hose Shroud** – The shroud **shall** be constructed and certified by the manufacturer or a third-party testing facility for the rated pressure.

13.5 **High Pressure Couplings** – All waterjet couplings **shall** be pressure-rated. All non-threaded, push-to-connect couplings that can be accidentally disconnected under pressure **shall** not be used effective January 1, 2022.

14.0 DEFINITIONS FOR OPERATING COMPONENTS OF WATERJET SYSTEMS

14.1 **Abrasive** – Any solid particles, either soluble or insoluble in carrier fluid, that are introduced into a waterjet before it hits the target surface. Such particles are often used to increase the effectiveness of pure waterjets for some applications. Abrasives can be used to prepare a surface for painting as well as for cutting materials.

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14.2 Abrasive Feed System – System that includes a storage vessel or hopper for the abrasive, a hose or tube to carry the abrasive to the point where it is inserted into the waterjet, and a device for inserting the abrasive into the waterjet stream.

14.3 Abrasive Jet – A waterjet where solid particles are introduced into the jet stream before the jet hits the target. Such abrasive particles can be introduced in three ways: Entrained Abrasive, External Abrasive, and Slurry Abrasive.

14.3.1 Entrained Abrasive – The particles are added to the jet stream after the jet has accelerated through an orifice, but before the resulting stream has been reshaped through a collimating nozzle.

14.3.2 External Abrasive – The particles are added to the jet stream after it has left the final orifice.

14.3.3 Slurry Abrasive – The particles are added to the water before it is accelerated through an orifice.

14.4 Abrasive Mixing Nozzle – The secondary nozzle used below the mixing chamber to refocus the stream of high pressure water and abrasive in conventionally mixed abrasive waterjet systems. Types of abrasive mixing nozzles include slurry nozzles and cutting heads.

14.5 Anti-Reversal Device – A rigid length extending from the front of the nozzle to the back of the hose crimp, measuring 1.5 times the smallest diameter pipe in the system. The anti-reversal device consists of up to three components: the nozzle, stinger and hose crimp. See definitions of Nozzle, Stinger and Hose Crimp.



Figure 39. Anti-reversal device.

14.6 Anti-Withdrawal Device – A device installed on the pipe entrance to prevent the nozzle on the end of the hose from being pulled out of the pipe under pressure. (See Figure 40a-d)

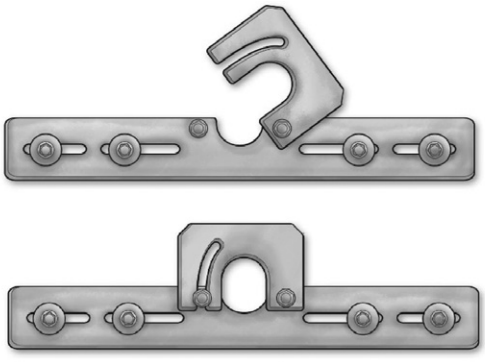


Figure 40a. Backout preventer with an adjustable opening for use in line moleing operations. ©WorkSafeBC. Used with permission.



Figure 40b. Backout preventer mounted to the end of a flanged pipe. ©WorkSafeBC. Used with permission.

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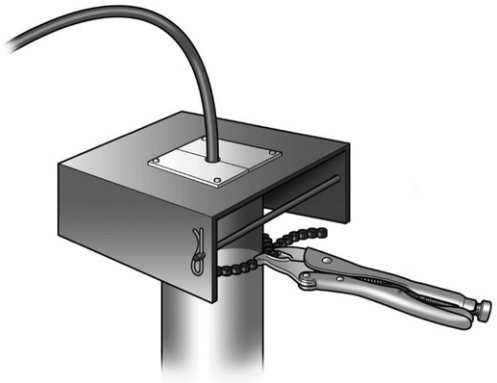


Figure 40c. Backout preventer for use with pipes without a flange. ©WorkSafeBC. Used with permission.

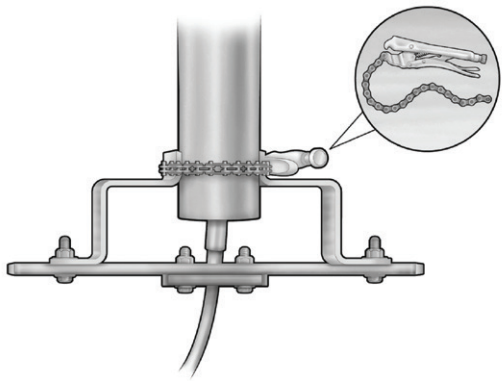


Figure 40d. Backout preventer with adapter for small-diameter pipes. ©WorkSafeBC. Used with permission.

14.7 Automatic Pressure Relief Devices – Devices included in a high pressure waterjet system to provide a way of automatically limiting the system pressure. Pressure relief devices include both reclosing devices (e.g., safety valves, relief valves, safety relief valves) and non-reclosing devices (including rupture discs and fusible plugs). Automatic Pressure Relief Devices can be of several types:

a. Automatic Pressure Regulating Valves;

b. Bursting and Rupture Discs, When Set in a Proper Holder;

c. Pressure Relief Valves; or

d. Fusible Plugs.

An Automatic Pressure Relief Device should be mounted close to the discharge outlet of the pressurizing pump, since the pressure at this point is the highest in the system. This location will also allow a more immediate reduction in pressure, without retaining higher pressures in downstream components of the system.

14.7.1 Automatic Pressure Regulating Valve – Valve used to automatically control the working pressure in the high pressure waterjet system by controlling the bypassing water flow. When the pressure in the system exceeds a set level, the valve will partially open. As the valve opens more, more water is bypassed and less flows to the nozzle. The water passing through the valve can be directed either back to the supply reservoir to the pump or to other disposal.

An Automatic Pressure Regulating Valve may be used to control the operating pressure at which a system operates, and if so, the valve should be checked to ensure that it is set at the correct value before it is used in each waterjet operation.

When there is no demand for high pressure water, this valve may be used to ensure that the system pressure is brought down to a low level. This valve is sometimes referred to as an unloading valve.

14.7.2 Bursting or Rupture Disc – A safety device that is a required component for high-pressure pumps. The device includes a thin metal disc that will fail if the high-pressure system pressure exceeds the rated working pressure of the pump. The

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rupture disc assembly should include a diffuser and method to identify that the disc rating is correct.

14.7.3 Pressure Relief Valve – Valve that is normally held in the closed position by a mechanical device, such as a spring. It is designed to open when the pressure in the system exceeds a set value.

14.7.4 Fusible Plug – Plug in the fluid cylinder, marked with the pressure rating. It is designed to open when the pressure in the system exceeds a set value. Fusible plugs are primarily used in pressure washers rather than higher pressure pumps.

14.8 Burst Pressure – The internal pressure within a component of a high pressure waterjet system at which it will fail.

Note: High pressure equipment undergoes a cyclic loading because of the reciprocating movement of pistons. This will fatigue the parts of the system so that, with time, the strength of the components will decline.

14.9 Bypass Valve – Valve that can be adjusted by the operator, either manually or automatically, to control the flow, and thus the pressure, of the jet stream issuing from the nozzle.

14.10 Dry Shutoff Control Valve – Valve that is normally manually controlled by the Nozzle Operator to start and stop the flow of water to the nozzle. Although closing this valve stops the water flow to the nozzle, it keeps the pressure in the supply line at the system's working pressure. When this valve is used, the system **shall** also be fitted with an Automatic Pressure Regulating Valve to ensure that the system's working pressure is not exceeded.

When this valve is used the operator **shall** take care to release the pressure in the water supply lines after the pump has been shut down. This is to ensure that the system is not left under pressure. This valve can also be operated by a secondary power circuit attached to the high pressure waterjet system.

14.11 Double Trigger Gun – A gun which requires that two triggers be activated by the operator, one with each hand, in order to generate a high pressure waterjet.

14.12 Dump System – The system should be equipped with a device that will either shut down the pump, idle it at low revolutions per minute (rpm), bypass the flow, or reduce the discharge pressure to a low level. The dump system **shall** be manually controlled only by the Nozzle Operator. The dump system actuator device **shall** be shielded to prevent accidental operation. This device **shall** be controlled by the operator's hand or foot and **shall** dump the high-pressure water stream if released by the operator. Where the water dumped through a dump system is not immediately released to the open air, but passed into a dump line, the dump line **shall** be secured so that it does not whip when active.

14.12.1 Dump Control Valve – The valve controlling the dump system is manually controlled by the operator of the waterjetting equipment. This valve is closed by the operator to send the water to the nozzle. When the valve is released, it will automatically stop water flow to the lance and/or nozzle assembly, since it opens

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a much larger flow passage through which the water is diverted at low pressure. For this to be effective, both the passage through the valve and the diameter of the relief line should be large enough that no significant resistance to the water flow develops, even at maximum pump output. A valve size should be selected that will not cause generation of significant back pressure at the maximum possible pumping rate of the pump.

This valve can also be used with an electrical or pilot pressure system that includes additional circuits that must be engaged for the valve to actuate. These systems should be designed such that if the valve fails, it opens.

14.12.2 Solenoid and Electrically Operated Control Dump Systems – All electrically controlled dump systems should be of fail-safe design. Voltage of an alternating current (AC) or direct current (DC) dump system, handled by personnel, should not exceed 24 volts and should be fuse protected.

14.13 Filter Strainer – The filter and strainer assembly is used to prevent particles from restricting water flow through orifices in the nozzle or damaging seals of the pump, etc. The filter assembly should meet the manufacturer's recommendations for particle size.

14.14 Flexible Lance – A high pressure hose with a nozzle, used for cleaning the inside of tubes, lines and pipes. Examples may be braided stainless steel or thermoplastic.

14.15 Flow Splitter or Directional Valve – A valve that the operator can adjust to send water from the pressurizing pump to either one or several pieces of waterjet equipment that are supplied by the pump. This valve can be operated either manually or by a secondary power circuit attached to the high pressure waterjet system.

14.16 Foot Pedal (Foot Dump) – Control valve designed so that the operator can activate it using a foot (Figure 41a-b) allowing the operator to use both hands to hold and move the lance and/or nozzle assembly.

The foot pedal should be constructed so that the pressure is released when the pedal is no longer depressed.

When a foot pedal is used, it **shall** be placed within a frame that guards the valve from being accidentally operated, and the pedal assembly **shall** be sturdy enough to prevent accidental movement during use.



Figure 41a. Foot pedal engaged, directing pressure through the system.



Figure 41b. Foot pedal disengaged. Operator's foot is firmly planted when not activating the foot pedal.

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14.17 High Pressure Hose – A flexible hose that can be used to carry water and/or other fluids from one part of the high pressure waterjet system to another. The hose should have a burst rating of a minimum of 2.5 times the intended working pressure it is certified for use at by the manufacturer. The high pressure hose **shall** be tested as per the hose manufacturer's recommendations.

Note: The hose **shall** not be used at a pressure above the manufacturer's recommended working pressure.

Pressure hoses are designed for various pressures and could present a safety hazard if not used for the designated working pressure. In order to better identify the pressure in use, it is recommended that the following color code scheme is used for the applicable maximum working pressure:

PSI	Bar		Color
10,000	690	-	Yellow
15,000	1,034	-	Green
20,000	1,379	-	Blue
30,000	2,068	-	Silver
40,000	2,758	-	Orange
55,000	3,792	-	Red

The color scheme should be easily identifiable at least two feet from both hose ends.

If working between pressures in the chart, the color coding **shall** meet or exceed the maximum rated output pressure of the unit. If the pressure rating of the hose is in between the values in the chart, the hose **shall** be color coded to the lower pressure.

14.17.1 Hose Inspections & Testing – High pressure hoses **shall** be color coded in accordance with WJTA's guidelines for high pressure hoses and tagged with both an identification number unique to each hose, and a manufacturing date.

All high pressure hoses **shall** be visually inspected prior to each use. The inspection should include, but is not limited to, the following:

- Manufacturing date within recommended guidelines
- Color coding as per WJTA recommendations
- Evidence of compromised wire braids
- Evidence of mechanical damage, such as flat spots
- Evidence that the minimum bend radius has been exceeded (usually occurs near hose ends)
- Any signs of distress at the hose end crimp

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- Damage to the threads on the hose end
- Hose lifespan should be limited to four (4) years, with the exception of flex lances, which should be limited to two (2) years. Refer to NAHAD recommendedations for hose lifespan.

Hoses should be tested based on the frequency and procedure recommended by the hose manufacturer.

Any hose that fails any of the above inspection points **shall** be removed from service and tagged accordingly until inspected and recertified per the manufacturer's recommendation. Any hose that has been deemed to be un-repairable **shall** be destroyed.

For more information see the Association of Hose Assemblers and Distributors (NAHAD) listed in Appendix A.

14.18 Hose End Fittings – High pressure hose end fittings **shall** be manufactured to be compatible with the hose and **shall** be tested as a unit. It is recommended that fittings be permanently marked with their maximum rated working pressure or color coded using WJTA's color coding guidelines for high pressure hoses.

14.19 High Pressure Waterjet Systems – High pressure waterjet systems are water delivery systems that have nozzles whose function is to increase the speed of liquids. Solid particles or additional chemicals may also be introduced, but the exit in all cases will be a free stream.

In terms of these *Industry Best Practices*, the system **shall** include the pumps (pressure- producing devices), hoses, lances, nozzles, valves, safety devices, and attached heating elements or injection systems.

High pressure waterjets are used in several ranges of pressure. The following divisions are made to clarify these ranges:

14.19.1 High Pressure Water Cleaning – The use of high pressure water, with or without the addition of other liquids or solid particles, to remove unwanted matter from various surfaces, and where the pump is capable of pressures of 5,000 psi (340 bar) or greater.

14.19.2 High Pressure Water Cutting – The use of high pressure water, with or without the addition of other liquids or solid particles, to penetrate into the surface of a material for the purpose of cutting that material, and where the pump is capable of pressures of 5,000 psi (340 bar) or greater.

14.19.3 Pressure Washing – The use of pressurized water, with or without the addition of other liquids or solid particles, to remove unwanted matter from various surfaces, and where the pump is not capable of pressures of 5,000 psi (340 bar) or greater.

14.19.4 Pressure Cutting – The use of pressurized water, with or without the addition of other liquids or solid particles, to penetrate into the surface of a material for the purpose of cutting that material, and where the pump is not capable of pressures of 5,000 psi (340 bar) or greater.

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14.20 Hose Assembly – The hose with a suitable end coupling attached, at each end of the hose, in accordance with the manufacturer's specifications.

14.21 Hose Safety Shroud – A protective covering over a high pressure hose, designed to protect the worker from a high pressure water burst should a hose failure occur and to prevent leakage from a threaded connection or weep hole from impacting a worker. The shroud **shall** be constructed, tested and certified by the manufacturer to prevent a burst from penetrating the shroud. Also, the document or certificate with test results should be made available upon request.

Hose shrouds used on shotguns **shall** be a minimum of 6 feet in length and verified as able to provide protection for the operator in the event of a hose burst or failure. The shroud **shall** be designed to cover the "connection point" of the whip hose to the shotgun whereby the threaded connection and weep holes are located. The shroud **shall** be removable to facilitate high pressure hose inspections. Shrouds longer than 6 feet are acceptable and, in certain situations, should be considered. Hose shrouds should be tagged with both an identification number, unique to each shroud, and a manufacturing date. Due to the sensitive protective position of the shroud, they should be visually inspected before each use.

Hose shrouds should be used wherever it is likely that the high pressure hose will come into close contact with the worker. Typical examples for hose shroud use are:

- To cover the area where the high pressure hose is connected to a rigid lance that is being operated manually.
- To cover hoses and lances connected to a manually operated foot pedal.
- To cover high pressure hoses connected to the waterjet pump in locations where close contact with the high pressure team members is likely during normal pump operation.

If any hose failure occurs inside the safety shroud, the safety shroud **shall** be removed from service and either discarded or returned to the manufacturer for evaluation for future use.

14.22 Hydraulic or Hydraulicing – The condition where debris causes a partial or total blockage so that the nozzle assembly forms a hydraulic piston in the tube or pipe resulting in the forcible ejection of the lance or hose under pressure toward the operator.

14.23 Lancing – An application whereby a rigid or flexible lance and nozzle combination is inserted into, and retracted from, the interior of a pipe or tubular product.

14.24 Line Moleing (Pipe Cleaning) – An application whereby a hose fitted with a nozzle is inserted into, and retracted from, the interior of a pipe. It is a system commonly used with a self-propelling nozzle for cleaning the internal surfaces of pipes or drains.

Line moles can be self-propelled by their backward-directed jets or can be manufactured to be fitted with various shapes, sizes, and combinations of forward-directed and backward-directed jets. A line mole should include, directly behind the

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nozzle assembly, a section of rigid pipe or tubing sufficiently long that it will prevent the line mole from turning around within the pipe.

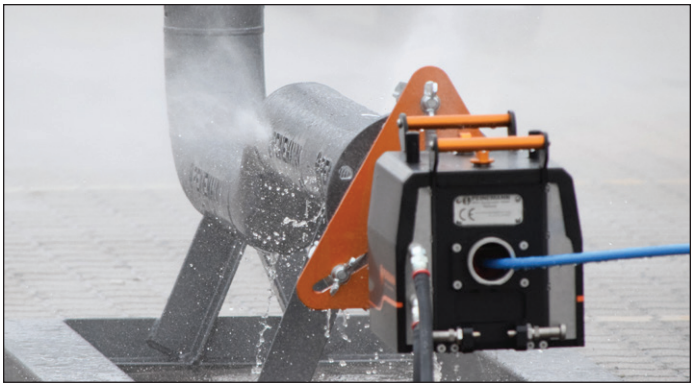


Figure 42. Demonstration of automated line moleing system.

14.25 Nozzle – A device with one or more orifices through which the water discharges from the system. The nozzle restricts the flow area of the fluid, accelerating the water to the required velocity and shaping it to the required flow pattern. Nozzles are also commonly referred to as bits, tips, or orifices.

The nozzle may be further defined by the type of jet that it produces.

14.26 Nozzle Holder – The fitting that holds a nozzle insert and attaches it to the jetting manifold or shotgun lance extension.

14.27 Nozzle Insert – A replaceable nozzle, usually fitted with one orifice and designed to fit into a nozzle holder.

14.28 Supervisor/Crew Leader – A person who has been trained and has demonstrated the knowledge, skill and experience to fulfill the duties in Section 8.4.

14.28.1 Operator/Pump – A person who has been trained and has demonstrated the knowledge, skill and experience to assemble, operate, and maintain a waterjet system.

14.28.2 Technician – A person who has been trained and has demonstrated the knowledge, skill, and experience to assemble, operate, and maintain waterjet equipment during operations (includes operation of automated tools, guns, lances, and so on). Sometimes referred to as Lance Operator or Nozzle Operator.

14.28.3 Trainee – A person in training, whether formal or on-the-job, who does not have enough experience to perform as an operator without direct supervision.

14.29 Orifice – The opening at the end of a nozzle through which the water or fluid jet exits from the system.

14.30 Pressure Gauge – The high pressure waterjet system **shall** be equipped with a gauge indicating the pressure being developed. Gauges **shall** have a scale range of at least fifty percent (50%) above the maximum working pressure of the system and should be fitted with a pressure snubber for more accurate pressure reading and should be certified annually. The gauge is to be checked before each use to ensure that it reads zero. A pump without a fully functioning gauge **shall** not be operated.

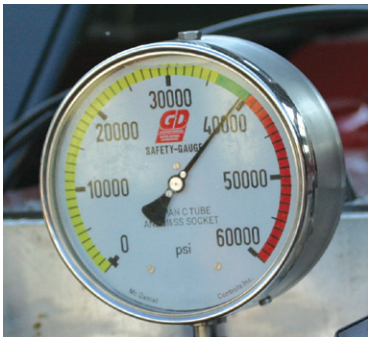


Figure 43. Pressure gauge.

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14.31 Pressure Intensifier – A pump that increases the pressure of water supplied to it, using the reduction in area of a common piston to multiply the pressure from the driving fluid, which is usually oil.

14.32 Pressure Loss – The amount of pressure expended in moving water through a hose or lance. The pressure at the nozzle will always be less than the pressure at the pump.

14.33 Pressure Pump – A pump that will increase the pressure of water delivered to it and deliver it into a common manifold to which either flexible hoses or rigid tubing connecting to lances and nozzles is attached. These pumps can be either mobile or permanently mounted and are most often of a positive displacement plunger style that will provide a constant flow of water at a given speed of rotation.

The pump should have a permanently mounted tag designed to provide the following information:

a. Name of manufacturer;

b. Model, serial number, and year of manufacture;

c. Maximum performance in terms of gallons or liters per minute and pressure in bar or psi; and

d. An outline of recommended safety procedures.

14.34 Rigid Lance – A rigid seamless metal tube rated for the pressure of the unit, used to extend the nozzle from the end of the hose.

14.35 Rigid Lancing – An application whereby a rigid lance is fitted with a nozzle, nozzle assembly, or nozzle manifold. This lance is inserted into, and retracted from, the interior of a tube, tank, or vessel.

14.36 Rupture Disc – See definition 14.7.2.

14.37 Self-Rotating Nozzle Assembly – A device, including a bearing or swivel assembly, that fits onto a hose or lance section. The device contains at least two jets offset so that the reaction force from the jets causes the nozzle assembly to rotate without any additional external force being applied.

14.38 Shotgun/Jetting Gun– The hand-operated device that is often used in manual waterjetting (Figure 44). It is normally connected to the high pressure system by a high pressure hose assembly. The gun is made up of a control valve, mounted within a guard, a lance section, and then a nozzle assembly, which may include one or more nozzles. The gun may also include a support bracket and shoulder pad and/or one or more support handles.

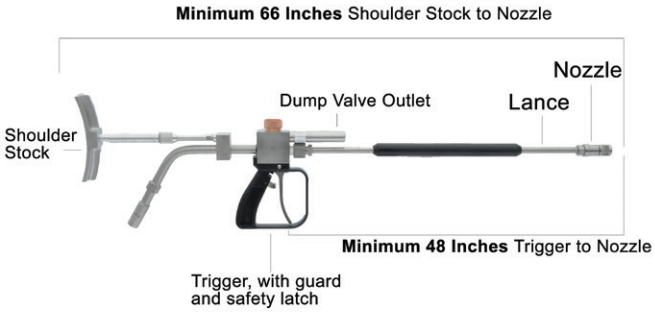


Figure 44. Standard shotgun length.

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The gun can be further defined by the type of control valve that is used to release the pressure. If the pressure is dumped to atmosphere when the valve is released, then the gun is a dump gun; if the pressure is retained in the system by using a Dry Shutoff Control Valve, then the gun is a dry shutoff gun.

14.39 Shotgun/Jetting Gun Trigger – The control valve has a trigger that makes it easier for the operator to control the device. This lever, or trigger, **shall** be designed for easy operation by an operator wearing gloves. The trigger **shall** include a catch or other method of lock-out so that it cannot be operated until this catch is released. The trigger should be constructed so that the pressure is released when the trigger is no longer depressed.

14.40 Shotgunning – A hand-held application whereby an assembly of a lance and a nozzle can be manually manipulated in virtually all planes of operation.

14.41 Smash Plate – A special anti-withdrawal device installed that covers the entire entrance of the line to prevent the nozzle on the end of the hose from exiting the line under pressure if the nozzle reverses direction. The smash plate should have openings or clearance from the line entrance to allow effluent and debris to flow out without creating a blockage. The openings must be sized so as not to allow the nozzle to pass through. A smash plate **shall** be used whenever cleaning a vertical line from the bottom up.

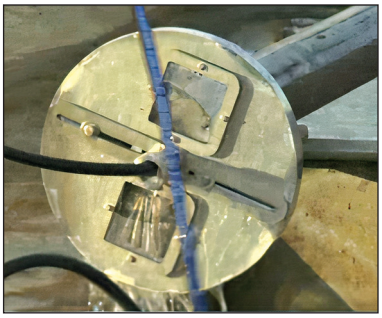


Figure 45. Smash plate.

14.42 Spray Bar – A special manifold designed to distribute nozzles along a linear tube or pipe. A spray bar is most often used to provide an array of fan jets that overlap, and is frequently used to clean large areas.

14.43 Stinger – A length of seamless rigid tubing or pipe mounted behind the nozzle assembly for use with a flexible lance or hose along with a coupler.

14.44 Stop Work Authority – Power given to all workers and members of waterjetting teams to immediately shut down any or all phases of a job, should they witness an unsafe act or condition. Job activities cannot be resumed until appropriate corrections are in place.

14.45 Support Handle – An additional handle that can be attached to a jetting gun to provide additional support for the operator in directing the gun. A support handle can be fitted with a switch for additional control functions.

14.46 Variance – An action that deviates from a policy, procedure, or best practice, approved by a competent and recognized authority; variance requests are typically written, detailing why the variance is requested and how the alternate approach is appropriate and safe, then, submitted for review by a designated competent authority.

14.47 Waterjet – A rapidly moving stream of different shapes and types of water exiting from a nozzle orifice. The speed of the jet depends on the pressure drop across the nozzle orifice.

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14.47.1 Fan Jet – A jet designed to spread out as it leaves the orifice. The divergence is usually, but not necessarily, restricted to one plane. The degree at which the jet tapers out from the central axis is often used to designate the jet produced. A typical application is for cleaning larger areas requiring less energy to remove unwanted matter.

14.47.2 Thrust Jet/Puller – A jet that is directed in the reverse direction of motion of the nozzle. A thrust jet is typically used to provide a thrust force to move the nozzle into the workpiece and to provide jets to clean in otherwise inaccessible locations. It may also be used to balance the forward jet thus providing zero thrust for underwater applications or those on scaffolding.

14.47.3 Straight Jet – A straight jet exits from a circular orifice and is used to carry the maximum force to the target with a minimum of energy dispersion. A typical application is for cutting or for general cleaning of matter with higher shear and/or bond strength. A straight jet is also known as a zero-degree jet, since it is not designed to spread.



Figure 46a. Whip check.



Figure 46b. Whip check.



Figure 46c. Whip check.

14.48 Whip Check – A short length of braided wire, cable or nylon looped over both ends of a hose-to-fitting connection or over both ends of two hoses that are connected by a non-torqued coupling. A whip check is designed to stop the ends of the hose from whipping around if the coupling breaks. Additional terms for whip check are whip lock, safety cable, or safety lock. A whip check **shall** be of cable or nylon and in good working order (e.g., not rusted, frayed, or degraded whereby its purpose is compromised).

14.49 Working Area – The work site, within the barriers set up to provide warning and restricted access, in which waterjetting will take place.

14.50 Working Pressure – The maximum pressure, recommended by the manufacturer, at which a component is to be used. This pressure is sometimes referred to as the operating pressure. A system is not to be operated above the lowest working pressure of any of its components.



Figure 47. Working area.

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APPENDIX A - REFERENCES

ANSI Z490.1-2016 – Criteria for Accepted Practices in Safety, Health & Environmental Training

MSHA Part 46 – Surface Mining

MSHA Part 48 – Underground Mining

Association of Hose Assemblers and Distributors (NAHAD) Hose Safety Institute – Industry Best Practices for Hydroblast Hose Assembly Applications, 2014 Edition

OSHA 29 CFR 1910 – General Industry Standards

OSHA 1926 – Construction Standards

Proceedings of the First through Tenth American Water Jet Conferences (formerly U.S. Water Jet Conference), 1981-1999

Proceedings of the WJTA Conference (formerly WJTA American Waterjet Conference and WJTA-IMCA Conference), 2001-2019

Stichting Industriële Reiniging (SIR) Manual for High-Pressure Cleaning, 8th Edition 2020

WorkSafeBC High Pressure Washing Safe Work Practices, 2008 Edition

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APPENDIX B - JOB SAFETY ANALYSIS (JSA)

WJTA WATERJET TECHNOLOGY ASSOCIATION	**Job Safety Analysis (JSA)** **Daily Tailgate Meeting**	Date: Owner:

JSA/TOOLBOX TO BE COMPLETED BEFORE EVERY SHIFT AND WHENEVER HAZARDS ARE ENCOUNTERED (Document General Information Below)

Client/Customer/Plant	Location	Job #
Date	Time	Shift Day Night Spilt
Unit	Vessel and/or Equipment #	Permit #
Project Manager	Client/Customer Contact	Plant/Facility Emergency Number/Radio Channel
Safety Shower Location	Eyewash Station Location	Fire Extinguisher Location
Weather (circle all the apply) Hot Cold Fair Raining Snowing Windy	Wind Sock Location/Direction	First Aid Kit Location
Primary Evacuation/Muster Point	Secondary Evacuation/Muster Point	MSDS Available

I certify that I understand the hazards involved with this job and will comply with the requirements of this JSA/Toolbox

Name	Employee Number	Name	Employee Number	Name	Employee Number

Reminder: Update/Revise JSA/Toolbox as job scope or hazards change

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APPENDIX B - JOB SAFETY ANALYSIS (JSA) - CONTINUED

Brief Job Description

HAZARD ANALYSIS PROCESS (Document Tasks, Hazards, and Controls)		
Task(s) **Include tools and equipment to be used**	**Hazards**	**How will the hazards be eliminated or managed? (Include PPE required)**

AREA HAZARDS AND CONTROLS	
Area Hazards	**How will the hazards be eliminated or managed (include additional PPE if required)**

Reminder: Update/Revise JSA/Toolbox as job scope or hazards change

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APPENDIX B - JOB SAFETY ANALYSIS (JSA) - CONTINUED

Task(s) Include tools and equipment to be used	Hazards	How will the hazards be eliminated or managed? (Include PPE required)

Reminder: Update/Revise JSA/Toolbox as job scope or hazards change

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APPENDIX C - SAMPLE PRE-JOB CHECKLIST

VEHICLE INSPECTION CHECKLIST

Unit Number/Division:	**Date Inspected:**
Mileage/Hours Front:	**Mileage/Hours Rear:**

ITEM INSPECTED	PASS	FAIL	REMARKS
Waterblaster Items			
Condition of Trailer: Stands/Wheels/Lights			
Waterblaster Grouding System/Condition			
Engine: Fluids/Electrical/Gauges			
Clutch: Grease Points Greased			
PTO Grease Points Greased/Oil Level			
Power End Oil Condition/Level			
Belt Condition & Tension			
Filters Checked/Replaced if Required			
Supply Piping Routed Correctly/Condition			
Pressure Gauge Condition/Last Certification			
Pressure Relief Valve Condition/Rating			
Rupture Disk(s) Condition/Rating			
Bypass Valve Cartridge/Diffuser Condition			
Safety Warning Decals Present/Condition			
Supply Lines Flushed			
Lubrication Lines Flowing			
Coffee Cup Filter Test			
Hoses Inspected/Condition			
Couplings Inspected/Condition			
Whip Checks Inspected/Condition			
Gun Stock/Trigger/Trigger Lock Inspected			
Gun Barrel 4' Minimum/66" Overall Length			
Shotgun Cartridge/Cap Inspected/Condition			
Safety Shroud/Whip Hose Inspect/Condition			
Foot Pedal Cartridge/Inspected/Condition			
Lances Inspected/Condition			
Fittings Inspected/Condition			
Field Items			
All Employees have Waterblast Safety Card			
Delivery Lines Flushed			
Tip Condition/Proper Size			
Anti-Withdrawal Inspected/Installed			
Anti-Reversal Inspected/Installed			
Barricades & Barriers Installed/Inspected			
Area Clean/Good Footing			
PPE Proper/Inspected			
Leak Check Performed (1,000 psi)			
Line of Sight Established			
Operator at Pump			
Area Cleaned Upon Completion			
Hoses Drained and Re-coupled			
Pump Antifreezed (if required)			

Inspectors Name/Signature	Managers Name/Signature

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