High Pressure Washing

Safe Work Practices

WorkSafeBC

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WorkSafeBC was born out of a compromise between B.C.'s workers and employers in 1917 where workers gave up the right to sue their employers or fellow workers for injuries on the job in return for a no-fault insurance program fully paid for by employers. WorkSafeBC is committed to a safe and healthy workplace, and to providing return-to-work rehabilitation and legislated compensation benefits to workers injured as a result of their employment.

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Library and Archives Canada Cataloguing in Publication Data
Main entry under title:
High pressure washing safe work practices

Publisher's former name, Workers' Compensation Board of British Columbia, also appears on publication.
ISBN 978-0-7726-6028-2

1. Pressure washing - British Columbia - Safety measures. 2. Cleaning machinery and appliances - British Columbia - Safety measures. 3. Industrial hygiene. I. WorkSafeBC. II. Workers' Compensation Board of British Columbia.

T55.3.H53H53 2008 363.1196212 C2008-960134-3

Contents

Acknowledgments

WorkSafeBC wishes to acknowledge the assistance and participation of the following organizations in the preparation and review of the safe work practices discussed in this manual:

- BC Master Blasters Inc.
- Canfor Pulp Limited Partnership
- Ceda-Reactor Ltd.
- Eveready Energy Services Corp.
- Hurricane High Pressure Wash Ltd.
- Operating Engineers Local 115
- Prince George Hydro Mechanical Ltd.
- Teck Cominco Ltd.
- WaterJet Technology Association
- West Fraser Timber Company Ltd.

Introduction

High pressure water is a powerful tool used throughout heavy industry to help maintain the efficiency, production, and capacity of process equipment. Used in various arrangements, high pressure washing equipment and processes replace many of the manual cleaning methods of old.

With the use of high pressure washing processes comes the risk of exposing workers to hazards with the potential to cause serious injury or death. In order to prevent injury, WorkSafeBC has requirements detailed in the Occupational Health and Safety Regulation.

This manual is mainly for three groups:

- Facility owners who contract the services of high pressure washing contractors will find information on what they need to do to comply with the Regulation and what is required to help ensure that they provide a safe workplace to high pressure washing crews working at their site, and workers working in and around the area where power washing is being performed.
- Employers whose business includes the use of high pressure washing equipment will find information on what they need to do to comply with the Regulation and to help ensure the safe delivery of their services.
- Workers who are employed in the high pressure washing industry will find information on safe work practices and what to expect from their employers.

This manual does not replace the Occupational Health and Safety Regulation or the *Workers Compensation Act*. It complements the Regulation and is a tool to help industry work safely. In this manual, the word *must* means that a particular safety step is required by the Regulation. The word *should* indicates that a particular action, although not specified in the Regulation, will improve safety in the workplace. Please note that the word *worker* includes supervisors, managers, and workers.

In addition to the information in this manual, specific information is available from high pressure equipment manufacturers and suppliers. The WaterJet Technology Association has further information and publishes the *Recommendations for the Use of Manually Operated High Pressure Waterjetting Equipment.* See their website at www.wjta.org or phone 314 241-1445.

What is high pressure washing?

High pressure washing systems use a high-velocity stream of water to blast through materials, such as residue that collects inside pipes or vessels.

The term "high pressure washing" refers to a high pressure washing system ***capable*** of generating a pressure of 5,000 pounds per square inch (psi) or more. This includes high pressure washing systems used at lower pressures and high volume.

There are two levels of high pressure washing, based on the water pressure used:

- High pressure waterblasting – 5,000 to 30,000 psi
- Ultra high pressure jetting – greater than 30,000 psi

The term "pressure washing" typically refers to a washing system ***not capable*** of generating at least 5,000 psi. Such systems can be found at a car wash or in the form of portable equipment designed for light commercial or home use.

Uses

The use of high pressure washing equipment is found throughout industry. The most common applications are found in:

- Pulp and paper mills
  - Cleaning
    - ➢ Tanks, vessels, and components
    - ➢ Process piping
    - ➢ Liquor heaters and evaporators
- Power generation
  - Cleaning boilers
  - Removing ash
- Petrochemical plants
  - Cleaning
    - ➢ Heat exchangers
    - ➢ Tanks, vessels, and components
    - ➢ Process piping
- Marine vessel maintenance
  - Surface preparation
  - Coating removal
- Heavy construction
  - Concrete preparation
  - Hydrodemolition

Hazards of high pressure washing

High pressure washing equipment and processes present a variety of hazards to workers. Understanding the hazards is the first step in eliminating or reducing workers' exposure.

Waterjets

Exposure to the high pressure waterjet has the greatest potential for causing serious injury or death. The high pressure waterjet can travel at speeds exceeding 3,300 kilometres per hour. Such a waterjet is powerful enough to slice through solid materials or to damage any part of the human body. Even injuries that appear to be relatively minor can be fatal, as microorganisms can be injected into the body through the injury site, along with air, water, and debris.

The use of this equipment by persons not adequately trained, or persons not provided with the proper tools, equipment, and safe work procedures, significantly increases the risk of injury to workers.

High-velocity impact

Debris propelled by waterjets can injure eyes, skin, and body parts upon impact. Waterjet tools and equipment can be subject to inadvertent movement, with the potential to cause harm to workers.

Chemical exposure

Contact with hazardous chemicals is an everyday risk in the high pressure washing business. The very purpose of the activity is to clean or remove chemical substances and by-products from process equipment and storage tanks. Additional risk of exposure due to facility operation is a reality in many circumstances. Most high pressure washing projects are completed during the operation of a plant where "upset conditions" can result in the unintended release of toxic fluids or gases. Workers not adequately protected through procedures, position, or personal protective equipment (PPE) are likely to be exposed to substances that may cause significant acute or long-term injury.

Musculoskeletal injury

High pressure washing is challenging work. Workers are often required to work in awkward positions or in confined spaces, to lift heavy tools or materials, and to work with high push/pull (reaction) force. Workplace conditions are often wet, and the walking surface can be covered in debris, creating slip/trip hazards. Where risk factors for musculoskeletal injury (MSI) have not been identified and controlled at the workplace, workers are at increased risk of suffering the effects of MSIs.

Musculoskeletal injuries account for about 30% of all workplace injuries.

Machinery and equipment

Mechanical hazards are usually associated with power transmission parts consisting of belts, pulleys, chains, sprockets, gears, shafts, and couplings. Proper safeguarding of power transmission parts within and around a high pressure pump is essential. The risk of contact with the moving parts of a high pressure pump is often increased by the space limitations inside enclosed trucks or trailers.

Safeguarding of equipment must be consistent with CSA Standard Z432, Safeguarding of Machinery.

For additional information about safeguarding, see the WorkSafeBC publication *Safeguarding Machinery and Equipment: General Requirements*.

Confined spaces and stored materials

Confined spaces such as tanks, hoppers, and boilers pose hazards for workers. These spaces may contain toxic gases, and they may not contain enough oxygen to support life.

The materials stored in confined spaces pose hazards, too. When working in a confined space, workers may be at risk of entrapment, engulfment, or being struck by large pieces of falling debris.

Before workers perform work in a confined space, the employer must prepare and implement a confined space entry program, which includes training of workers. The identification, evaluation, and control of confined space hazards are often quite complex. For assistance in assessing the hazards and preparing a written confined space entry program, consult a qualified occupational health and safety professional. For more information, see the WorkSafeBC publication *Confined Space Entry Program: A Reference Manual.*

Risk assessment and controls

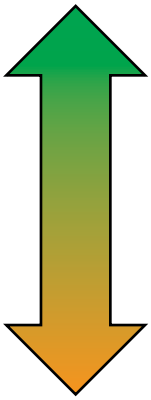
Written safe work procedures are required for all high pressure washing operations (except when they are conducted in a cabinet). The foundation of an effective safe work procedure is a comprehensive risk assessment.

A risk assessment helps to determine the likelihood that hazards will lead to an injury or occupational disease based on three primary factors:

- The probability of a hazardous event's occurrence
- A person's exposure time to a hazardous event
- The consequence of the hazardous event's occurrence

Conducting a risk assessment for each *type* or *process* of a high pressure washing task is essential in identifying the relative risk to workers from any of the hazards. Once risk factors are identified, effective controls can be implemented to protect workers.

As shown in the following table, a typical hierarchy of controls considers several steps in the effort to eliminate or reduce worker exposure to hazards.

HIERARCHY OF HAZARD CONTROLS		EXAMPLES
MOST EFFECTIVE  **LEAST EFFECTIVE**	**1. Elimination or substitution**	**Eliminate the use of hand-held equipment.** • Remove workers from potential contact with the waterjet. **Substitute the use of manual equipment with mechanization.** • Use a rotary lancing machine for cleaning heat exchangers. • Use a deck cleaner for large floor areas.
	2. Engineered control	**Use safeguards to protect workers from the hazard.** • Use a backout preventer when cleaning piping systems. • Use a jetting gun positioner for high-flow applications.
	3. Administrative control	**Use safe work procedures for high pressure washing tasks.** • Use a jetting gun to clean the first 36 centimetres (14 inches) of a pipe. • Use a mark on the flex-lance to indicate 60 cm (24 in.) to nozzle.
	4. Personal protective equipment (PPE)	**Use PPE appropriate for the hazard.** • Use hardhat with face shield and safety glasses. • Use cut-resistant suits to help protect workers from contact with waterjets when no other controls are practicable. • Use respiratory protection.

The following form can be used to conduct a high pressure washing risk assessment.

HIGH PRESSURE WASHING RISK ASSESSMENT FORM				
Company name:	**Date of assessment:**	**Assessment completed by:** 1. 2. 3.		
Activity:	**Equipment:**			
Identify and describe every hazardous condition that a worker may be exposed to (e.g., waterjet cut or puncture, contact with or inhalation of caustic or acidic chemicals, flying debris, engulfment, excessive heat or cold). If you need more space, use a blank sheet of paper.	Describe the worst injury that would reasonably occur due to each hazard. Use the following descriptions as a guide: • Fatal • Major (normally non-reversible: amputation, permanent spinal damage) • Serious (normally reversible: fractures, soft-tissue injury) • Minor (bruising, cuts, light abrasions)	**SEVERITY** Estimated severity of injury: Fatal = 10 Major = 7 Serious = 5 Minor = 1	**LIKELIHOOD** Estimated likelihood of injury:[1] Certain = 10 Probable = 7 Possible = 5 Unlikely = 1	**RISK SCORE** Estimated level of risk:[2] Estimated severity x estimated likelihood = risk score
1.				
2.				
3.				
4.				
Recommendations to reduce the risk to workers[3]				
1.		2.		
3.		4.		

Notes

1. Examples of factors to consider when assessing likelihood: repetition, training and experience, history of previous injuries, proximity to waterjet, method of control, duration of exposure, etc.
2. Use the risk score to develop safe work procedures based on the level of risk.
3. Always follow the hierarchy of controls regardless of the estimated risk.

Use the relative risk scores to help prioritize, develop, and implement appropriate risk controls.

Responsibilities

Facility owners

The owner of a worksite is responsible for providing a safe and healthy workplace. This is in addition to any other responsibilities the owner may have as the employer or prime contractor.

General responsibilities

- Maintain the land and premises used as a workplace in a manner that ensures the health and safety of persons at or near the workplace.
- Give the employer or prime contractor at the workplace any information known to the owner that is necessary to identify and eliminate or control hazards.
- Comply with occupational health and safety requirements and orders.

Providing reasonable and safe access to work areas through adequate planning and the use of work platforms is an integral component of the owner's responsibility.

Planning high pressure washing activities

When planning high pressure washing activities at your site, meet with the high pressure washing contractor to review each task. Identify opportunities to maximize efficiency and safety by providing good access to process equipment.

- Advise the high pressure washing contractor of the process and chemical hazards related to their activities.
- Plan work activities to avoid multiple types of maintenance activities in one area at a time. Consider the logical flow of high pressure washing activities (e.g., don't start weld repairs directly above or below high pressure washing activities).
- When cleaning piping systems, provide open access at least every 30 metres (100 feet), and remove flanged elbows or spool sections of pipe.
- Where piping systems consist of many welded-in elbows and corners, consider replacing them with spool sections to improve access and reduce the time required for cleaning.
- Where possible, remove vessel components and clean them at a designated wash pad location away from other personnel.

Employers

Employers have both general and specific responsibilities related to hazard control and worker health and safety. In carrying out these duties, management, from the chief executive officer down to the first-level supervisor, can demonstrate their commitment to health and safety in the workplace.

General responsibilities

- Ensure the health and safety of the employer's workers and other workers present at the workplace.
- Establish occupational health and safety policies and an OHS program.
- Provide general direction to management, supervisors, and workers about their roles and responsibilities in providing a safe and healthy workplace.
- Provide specific direction and delegate authority to those responsible for health and safety.
- Consult and cooperate with individuals carrying out occupational health and safety duties (including joint committee members, worker health and safety representatives, and WorkSafeBC prevention officers).
- Provide workers with the information, instruction, training, and supervision necessary to protect their health and safety.
- Provide supervisors with the support and training necessary to carry out their health and safety responsibilities.
- Provide and maintain protective equipment, devices, and clothing, and ensure that they are used.

Hazard control responsibilities

- Identify potential hazards through inspections and job hazard analysis, then either eliminate or control the hazards without delay.
- Remedy any workplace conditions that are hazardous to worker health or safety.
- Develop written safe work procedures.
- Encourage workers to express concerns and suggest improvements on health and safety issues (for example, through safety talks, meetings, or consultation with worker representatives).

Supervisors

Supervisors should give health and safety the same priority as productivity or quality control. They must know and comply with occupational health and safety requirements. A supervisor is defined in the Occupational Health and Safety Regulation as "a person who instructs, directs and controls workers in the performance of their duties." Any worker (management or staff) who meets this definition of supervisor has the responsibilities of a supervisor for the workers under their control.

A supervisor's duties are wide-ranging and include significant responsibilities for achieving production quotas, optimizing operational efficiencies, and maintaining a safe worksite. Using a system to manage the consistent application of worker training programs, worker assessments, safety meetings, and safety inspections will help ensure the efficient use of supervisory time and resources.

General responsibilities

- Ensure the health and safety of all workers under their direct supervision.
- Know the WorkSafeBC requirements that apply to the work being supervised, and ensure that they are followed.
- Ensure that workers under their supervision are made aware of all known or reasonably foreseeable health and safety hazards where they work.
- Consult and cooperate with joint committee members or worker health and safety representatives, and cooperate with others carrying out occupational health and safety duties (including WorkSafeBC prevention officers).
- Ensure that the appropriate personal protective equipment and clothing are available, properly worn when required, and properly inspected and maintained.
- Investigate unsafe conditions reported to them, and ensure that corrective action is taken without delay.

Workers

Workers have general responsibilities for their own health and safety and those of other workers. In addition, they have the responsibility to refuse unsafe work; discriminatory action cannot be taken against them for refusing to do unsafe work.

General responsibilities

- Cooperate with the joint committee or worker health and safety representative, WorkSafeBC prevention officers, and any other person carrying out occupational health and safety duties.
- Learn and follow safe work procedures.
- Be alert to hazards, and report hazards or problems to the supervisor or employer.
- Use the protective clothing, devices, and equipment provided.
- Perform work in a safe manner.
- Do not engage in horseplay or work while impaired by alcohol, drugs, or other causes.

Responsibility to refuse unsafe work

- Refuse to do work that they have reasonable cause to believe would create an undue hazard to the health and safety of any person.
- Immediately report an unsafe situation to their supervisor or employer.

Job conditions will vary from job to job. Following company safe work procedures is the responsibility of each worker. Contact your supervisor with any questions regarding the application of any safe work procedure.

Principles of high pressure washing

Understanding the basic principles of high pressure washing equipment and hydraulics will help you to conduct meaningful risk assessments and effectively apply safe work procedures.

Pressure and flow

The pressure created in a high pressure washing system is a function of the water flow and the size of the discharge orifice.

It is important to consider the relationship of pressure and flow when assessing hazards and risk.

The amount of back thrust, or "reaction force" (lb-thrust), possible from a high pressure pump can be determined by using the following equation as a measure of power and efficiency:

$0.052 \times \text{gpm} \times \sqrt{\text{psi}} = \text{lb-thrust}$

For example, an operator working with a jetting gun at 10,000 psi and 12 gpm will experience a back thrust equal to:

$0.052 \times 12 \times \sqrt{10{,}000} = 0.052 \times 12 \times 100 =$ **62 lb-thrust**

"It is not recommended that any one person be required to withstand a back thrust [lb-thrust] of more than one third (⅓) of his/her body weight for an extended period of time. For the above example, this means that the operator should weigh [at least 84 kilograms (186 pounds)] in order to operate the nozzle."[1]

In poor conditions (such as uneven or slippery footing, low light, confined spaces, and so on), lower back thrust should be used.

Note

A constant flow of water discharged through a defined orifice size will create a pre-determinable pressure.

Applying the principles

Back thrust is directly related to changes in flow and pressure. An example of the increase in lb-thrust based strictly on flow is as follows:

10,000 psi at 10 gpm

$0.052 \times 10 \times \sqrt{10{,}000} =$ **52 lb-thrust**

10,000 psi at 20 gpm

$0.052 \times 20 \times \sqrt{10{,}000} =$ **104 lb-thrust**

20,000 psi at 10 gpm

$0.052 \times 10 \times \sqrt{20{,}000} =$ **73 lb-thrust**

1 Adapted from *Recommended Practices for the Use of Manually Operated High Pressure Waterjetting Equipment* (St. Louis, MO: WaterJet Technology Association, 1994).

Appendix B contains a table that provides the calculated solutions for the many combinations of pressure, flow, and horsepower.

Using the table values when selecting nozzles based on pressure and flow will help in setting up a high pressure system with an appropriate amount of back thrust to help reduce operator fatigue and maintain proper footing and balance.

Where high reaction forces are required, the use of mechanized equipment will help to provide a safe and effective control method.

Understanding and applying these principles can help reduce the risk of

- ***Losing control of the jetting gun***
- ***Musculoskeletal injuries that result from overexertion or working in awkward positions***

Training

It is the employer's responsibility to ensure that every worker receives adequate instruction to do his or her work safely. This is usually done through education and training. **Education** generally refers to classroom instruction, which may include lectures, discussions, and videos. **Training** generally refers to hands-on, job-specific instruction provided to workers individually or in small groups. Training often includes demonstrations and active participation by workers so that supervisors can confirm that workers understand safe work procedures.

An education and training record must be maintained for each new worker, listing topics covered and date of education or training. Education and training records should be reviewed periodically to ensure that training requirements have been met.

The following are some examples of education and training topics specific to high pressure washing:

Item	Education and training
1	General and specific jobsite safety rules and the Occupational Health and Safety Regulation
2	Understanding basic waterjet hazards
3	Basic principles of high pressure pumps
4	High pressure washing principles (pressure and flow)
5	Equipment and nozzle selection principles
6	Main components of high pressure pumps
7	Manufacturer's operating manual
8	Emergency shutdown procedures
9	General safe work practices for high pressure washing
10	Safe work procedures
11	Hazard identification and risk controls
12	Personal protective equipment
13	First aid and medical aid for waterjet injuries
14	High pressure pump repair and maintenance

Other minimum training requirements (new and young worker) are described in Part 3 of the OHS Regulation.

Supervision of workers

Supervisors must supervise their workers to ensure that they follow safe work procedures. Adequate supervision includes:

- Ensuring proper training of workers
- Using meaningful criteria to measure the effectiveness of worker training. Having workers demonstrate their understanding of the work processes can be an effective way to confirm their knowledge and ability.
- Observing workers after training to ensure that they continue to follow safe work procedures
- Carrying out inspections on a daily basis to ensure that safe work procedures are being followed, including the proper use of protective equipment, devices, and clothing provided
- Enforcing safety rules and safe work procedures
- Conducting pre-job discussions (crew talks) with workers to discuss specific safety issues as they arise

"Qualified" means "being knowledgeable of the work, the hazards involved and the means to control the hazards, by reason of education, training, experience or a combination thereof."

New Workers

Once new workers have received training, a system of continued ***direct*** supervision of new workers by a ***qualified*** person must be maintained until workers have demonstrated the capacity and ability to conduct the work.

Every new worker will develop the necessary skills at a different pace. It is important to conduct ongoing assessment of a new worker's skills and ensure that new workers are not assigned tasks beyond their experience level or ability.

New workers must understand their responsibility to speak with their supervisor when faced with a task or circumstance beyond their level of training or experience.

Tools and equipment

This section describes the basic components and function of a high pressure washing system, and precautions for the safe use of the equipment.

A typical high pressure washing setup consists of several primary components: a high pressure pump, supply and working hoses, fittings, a control gun, and a nozzle assembly. Several components are designed specifically to provide for the safe use of the equipment.

Motor

The motor provides the power to drive the high pressure pump. Typically, the motor is a diesel engine, but it can also be electrically driven. Engine power can range from 100 to 600 horsepower.

High pressure pump

A typical high pressure pump is a positive-displacement plunger-type pump with three or more plungers. Many high pressure pumps can be converted to a higher- or lower-flow pump by changing the size of the plungers.

The high pressure pump is divided into two distinct sections: the power end, which houses the crankshaft and connecting rods, and the fluid end, which houses the plungers and valves.

Power end

The power end of the high pressure pump is similar in principle to the crankcase of an automobile engine. Connected by a drive line to the motor, the case of the pump contains a large crankshaft with connecting rods attached to pony rods. The power end of a high pressure pump is rated for a maximum input horsepower and a maximum rotation speed.

Fluid end

The fluid end of the high pressure pump is similar in principle to the head and valve train assembly of an automobile engine. Connected to the pony rod, the plungers reciprocate within the fluid end. When the plunger is stroked back (toward the power end), intake valves are opened to draw low pressure water into the pump. When the plunger is stroked forward (toward the fluid end), discharge valves are opened to release the high pressure water through the pump and into the high pressure hoses, hand lance, or flex-lance. The fluid end of the high pressure pump is rated for maximum pressure.

Filtration

Adequate filtration of the pump supply water will help reduce wear on the high pressure pump components and reduce the risk of a nozzle becoming blocked with dirt or debris. Filters must be selected, used, and maintained in accordance with the manufacturer's instructions. Check the condition of filters daily, and replace them when dirty.

Pressure gauge

Every high pressure pump must be equipped with a pressure gauge to indicate system pressure. The gauge should have a scale range of at least 50% above the maximum operating pressure of the high pressure pump. The gauge should be mounted in a position so that the pressure reading is clearly visible to the pump operator when "setting the pressure."

Pressure relief device

Every high pressure pump must be equipped with at least one and preferably two pressure relief devices (Figure 1). The primary relief device should be set for 1.2 times the maximum operating pressure, with the secondary device set for 1.4 times the maximum operating pressure of the high pressure pump.

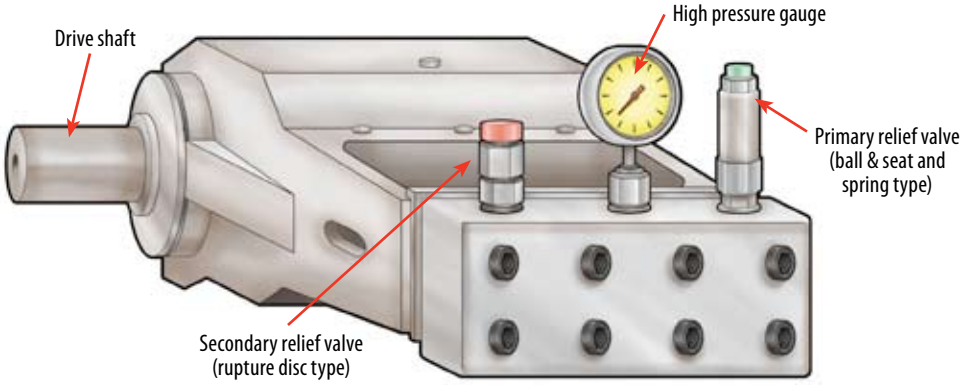


Figure 1. High pressure pump showing pressure relief devices. Position the discharge of the pressure relief away from the operator.

High pressure hoses, fittings, and couplers

Use only equipment, hoses, fittings, couplers, and accessories specifically designed or intended for use with high pressure washing systems. Always check the manufacturer's instructions before using any part, and ensure that components are identified with the maximum allowable working pressure.

High pressure hoses

High pressure hoses used for high pressure washing are specifically designed and manufactured for this application (Figure 2). They are typically composed of a plastic liner reinforced with multiple layers of steel. The outer covering of high pressure hoses can be rubber or plastic.

High pressure hoses are rated for *maximum allowable working pressure* (MAWP) and for *burst pressure.* The burst pressure is the pressure at which the hose will fail. The difference between the MAWP and the burst pressure is the *design factor.* Select a hose with a design factor of at least 2.5 times the maximum allowable working pressure.

High pressure hoses must not be operated above their maximum allowable working pressure.

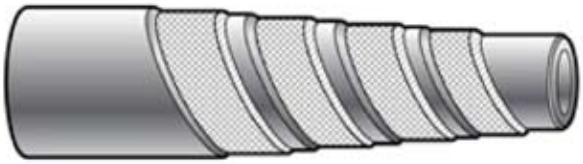


Figure 2. This cutaway image of a high pressure hose shows the inner plastic liner reinforced with multiple layers of steel.

The service life of any high pressure hose can be influenced by many factors, such as age, storage conditions, pressure and heat cycles, chemical exposure, bend radius, vibration, axial and torsional loading, and so on. Always refer to the manufacturer's instructions for inspection protocols and service life limits. Ensure that any hose inspections include inspection of the hose end fitting for damage or signs of excessive wear.

Protective coverings should be used wherever possible to reduce wear and to help prevent damage to high pressure hoses.

Any hoses that have obvious signs of damage must not be used. Signs of damage include

- ***Kinks***
- ***Crushing, stretching, or blistering***
- ***Rusted or broken reinforcing wires***

Fittings and couplers

All equipment components must be rated for their intended use. Most components within a high pressure system will be marked with the MAWP. If a MAWP is not easily identifiable on the equipment, the part must not be

Note

The outer cover is not intended to retain pressure within the hose but is designed to provide some wear protection to the steel reinforcing braid.

used unless the MAWP can be determined through documentation provided by the manufacturer or a professional engineer.

When assembling high pressure fittings and couplers, all connections must be inspected for damage and assembled using proper tools. High pressure components are available with various connection types based on the pressure being used (Figure 3). Each type uses different thread types to provide the mechanical connection between each part and to create the high pressure seal.

Figure 3. High pressure washing components are available with various connection types based on the pressure being used.

Some connector types can appear similar in thread design but, if connected, will not provide an adequate mechanical connection or high pressure seal. Failure to use compatible fittings will result in failure of the connection, creating a hazard to workers from exposure to high pressure water or to shrapnel from exploded parts.

Any person responsible for making high pressure connections must be instructed in identifying the different types of connections and which type to use. The reassembly of any high pressure component must be checked by a qualified person and determined to be safe for use.

Dump valve

The term "dump valve" can refer to two different devices: a hand (trigger) or a foot (pedal) operated dump valve. Essentially they work the same way, with a lever to actuate the position of a small, cartridge-type valve that directs the water through the high pressure circuit (when engaged) or through the low pressure diffuser (when released). The primary difference is that a jetting gun is operated by hand and a foot dump by foot.

In either case, it is essential that the control lever be operated only as designed—by the operator, and without the use of tools, levers, or other devices (rope, wire, plastic zip ties, etc.) to hold the lever in the ON position.

The control lever must be of the type that requires the operator to hold the control in the ON position (continuous pressure type) and that will immediately dump the pressure when released.

Jetting gun

Jetting guns are available in a variety of types, styles, and configurations. The example depicted in Figure 4 is typical of a *dump-style* jetting gun. A dump-style jetting gun discharges the water through a diffuser at the jetting gun when the trigger is released.

CAUTION

Use a safety shroud to help protect the operator in the event of a hose or fitting failure at the jetting gun.

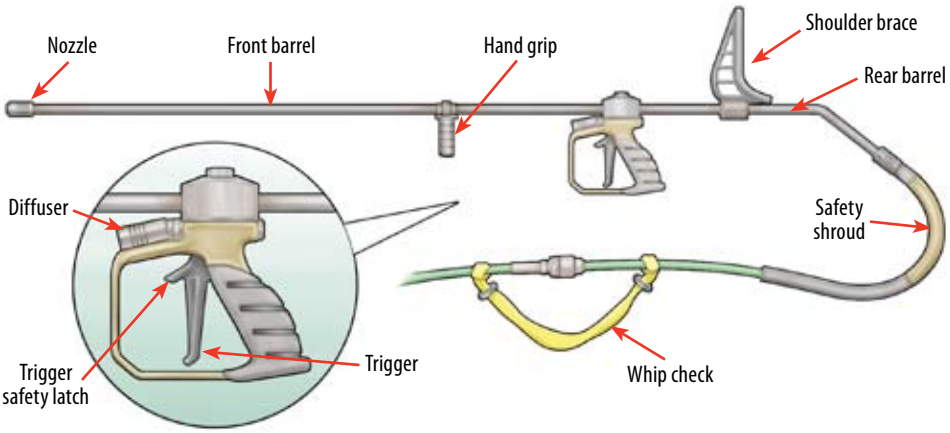


Figure 4. Dump-style jetting gun.

A *dry shut-off style* jetting gun (Figure 5) must be used with an auxiliary pressure regulating valve to discharge the water when the trigger is released.

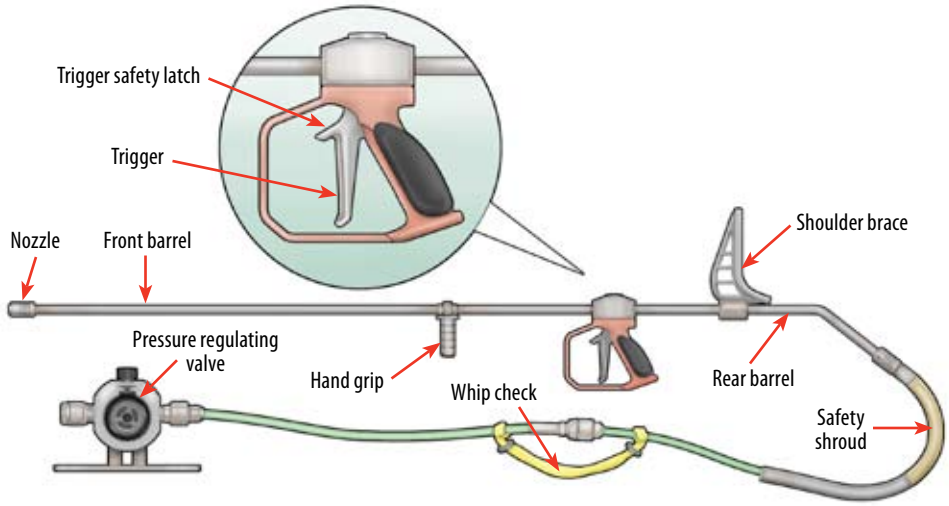


Figure 5. Dry shut-off style jetting gun.

CAUTION

Ensure that dump-style and dry shut-off style jetting guns are clearly distinguished from each other to avoid accidental use of a dry shut-off style jetting gun without an auxiliary pressure regulating valve.

Foot dumps

Foot dumps are available in a variety of styles and are generally operated with the foot (Figure 6). When operating mechanized systems, an air-actuated foot dump is commonly employed.

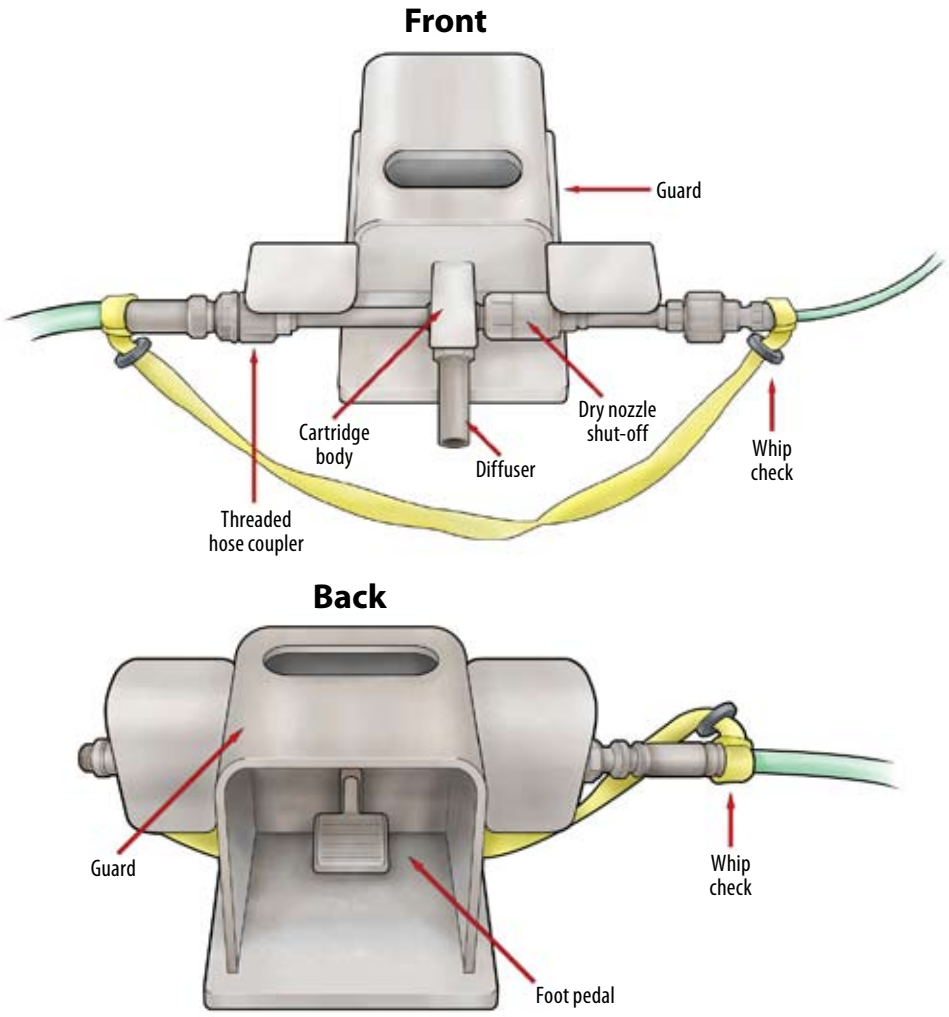


Figure 6. Front and rear views of a foot dump.

When attaching a discharge hose to the diffuser, ensure that there is unrestricted flow from the diffuser valve to avoid creating back pressure within the foot dump, which could hinder the function of the control.

Nozzles

Nozzles are available for many applications in a variety of types, designs, and sizes. It is important to select and use the right nozzle for each task to ensure the safe application and productive use of high pressure washing equipment.

There are three primary applications of nozzles for use with high pressure washing equipment.

Jetting gun nozzles

Jetting gun nozzles are configured to provide a straight-ahead jet or fan jet pattern. Each type will provide efficiencies for conducting different types of cleaning tasks (Figure 7). A straight-ahead jet will deliver the maximum force to the surface and is best used for cutting or breaking hard materials. A fan jet will deliver a wide spray pattern and is best used for cleaning large surfaces of soft coatings or contaminants.

Self-rotating nozzles offer the option of combining the attributes of both types of standard jetting gun nozzles by providing two or more straight-ahead jets offset to create rotational reaction forces and provide a wide spray pattern.

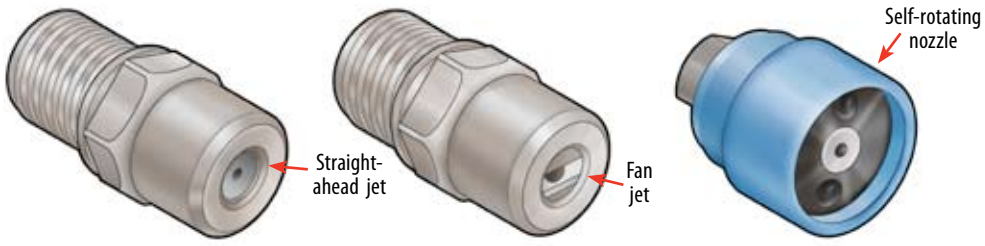


Figure 7. Different types of jetting gun nozzles.

Flex-lance nozzles

Flex-lance nozzles are configured with multiple orifices to self-propel the nozzle and provide a 360° jet pattern for cleaning the internal surfaces of pipes and tubes (Figure 8). The nozzles are arranged with forward-facing, rear-facing, and side-facing orifices to provide balance and self-propelling properties (Figure 9).

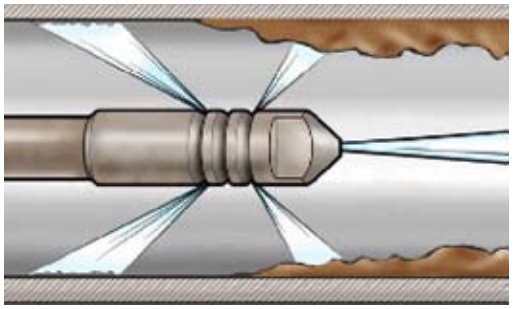


Figure 8. Flex-lance nozzles are used in cleaning the internal surfaces of pipes and tubes.

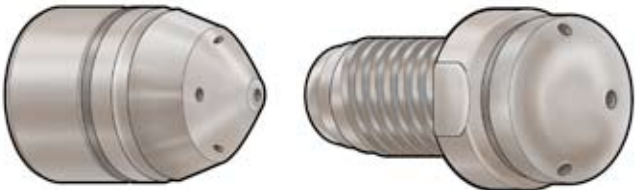


Figure 9. Flex-lance nozzles showing different orifices.

Before installing any nozzle on a flex-lance, ensure that the orifice pattern is designed with rear-facing orifices to provide forward thrust.

CAUTION

Always check the nozzle orifices before use to ensure that they are clear of debris that could block the flow of water and cause overpressurization of the system or an unbalanced nozzle.

Mechanized tool nozzles

Nozzles used with mechanized tools are available for many applications and are generally designed to deliver maximum flow at a desired pressure. With the use of mechanized tools, reaction forces to the operator and the need for self-propelling nozzles are often not a consideration.

Nozzles can be custom-made with cutting heads by a waterjetting manufacturer, and include one or more orifices (Figure 10).

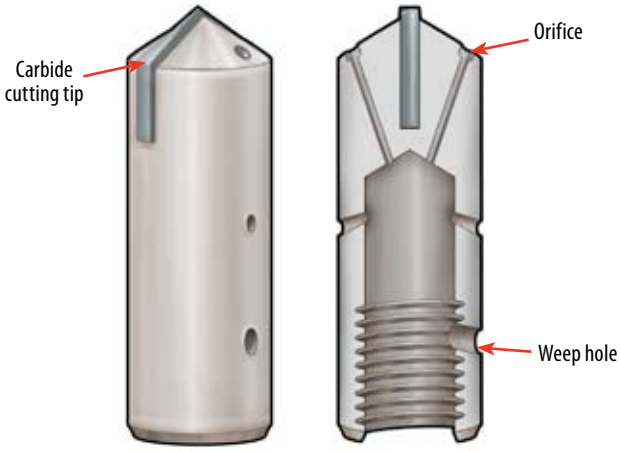


Figure 10. Mechanized tool nozzles.

Mechanized tools

The advantage of using mechanized tools and nozzles is the increased level of safety and high cleaning efficiency that they generally provide (Figure 11). Where operators can be removed from the manual cleaning process, their exposure to waterjets is significantly reduced, and safety and productivity are improved. The substitution of manual cleaning techniques with mechanized tools is consistent with the hierarchy of controls outlined on page 5.

Mechanized tooling options can be readily applied to projects that are repetitive, planned, or of short or long duration. The use of mechanized tools in confined spaces further reduces risk to workers and can often enable work to be completed sooner than if manual cleaning is planned (for example, work can be started before vessel entry is possible).

Figure 11a. Mechanized tank cleaning using a self-rotating 3D nozzle.

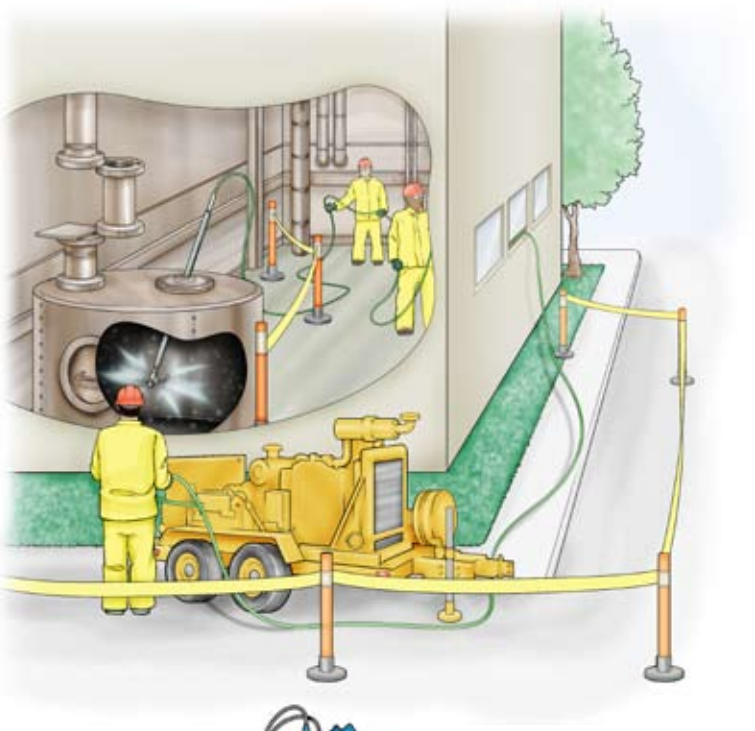
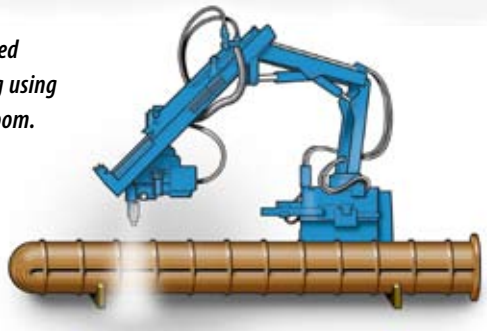


Figure 11b. Mechanized shell-side bundle cleaning using a remotely operated boom.



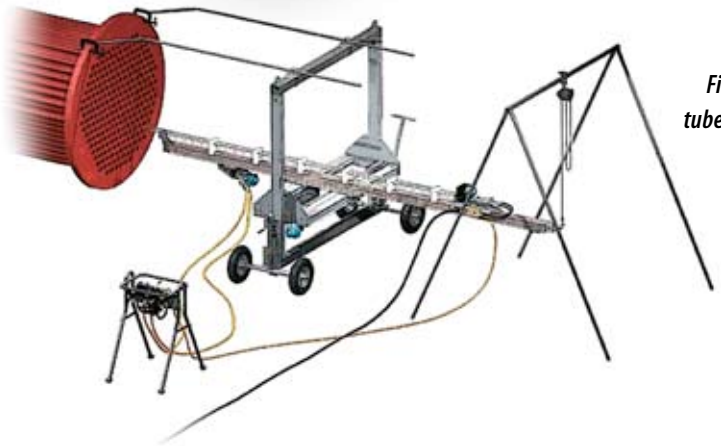


Figure 11c. Mechanized tube cleaning using a rotary lancing machine.

Figure 11. The use of mechanized tools and nozzles provides greater safety and high cleaning efficiency.

Flex-lancing safety devices

Many safety devices are currently available to provide improved levels of protection to workers. This section explains how stingers and backout preventers work, and discusses the precautions required when using them.

Stingers

To prevent the nozzle from turning around inside the pipe (line reversal) and shooting out under pressure from the open end of the pipe, attach an appropriately pressure-rated, rigid metal connecting tube (called a stinger) between the flex-lance hose end fitting and the cleaning nozzle (Figure 12).

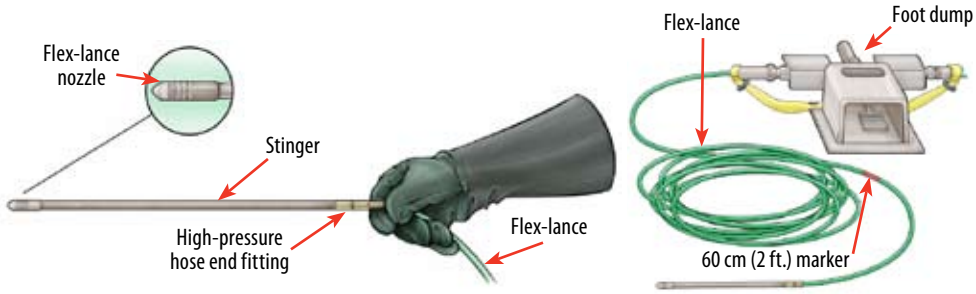


Figure 12. A stinger is a rigid metal connecting tube between the flex-lance hose end fitting and the cleaning nozzle.

Stingers come in different lengths. The stinger must be long enough to ensure that the nozzle cannot turn back on itself inside the pipe (line reversal). Generally, a stinger with a length equal to the maximum inside diameter of the pipe will prevent a line reversal. Where a piping system widens "down line" or opens into a tank or vessel, additional consideration must be given to the stinger assembly and safe work procedures to ensure operator safety and prevent line reversal. Stingers must be used in accordance with manufacturers' instructions.

A stinger also lets the operator know where the nozzle is when cleaning near the open end of the pipe or tube. When the stinger becomes visible, the operator knows that the nozzle is near the open end.

When cleaning fixed tube bundles (heat exchangers), use as long a stinger as possible, or consider using manual positioning devices (such as a hose catcher) as a restraining device (Figure 13).

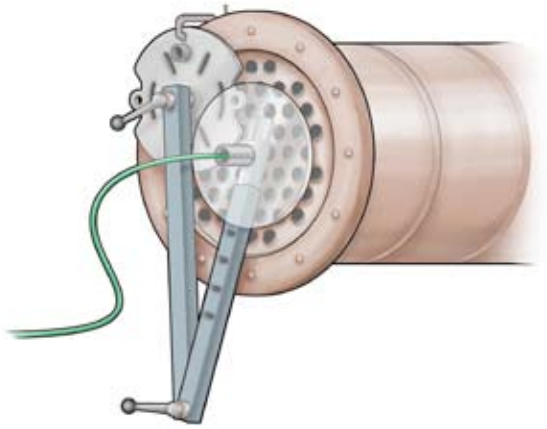


Figure 13. A hose catcher used as a restraining device.

Where the use of a restraining device is not practicable, consider the use of mechanized equipment that eliminates the need for the operator to handle the flex-lance.

Backout preventers

An effective means of restraint must be used on a flex-lance where the unplanned movement of the hose or nozzle could endanger a worker. The device must be able to withstand the forces that it will be subjected to, and capable of safely performing the functions for which it is used. A backout preventer is such a means of restraint in flex-lancing operations.

When used in accordance with its design, a backout preventer:

- Helps prevent the flex-lance from backing out of the pipe due to gravity, a plugged nozzle orifice, an obstruction in the pipe, or hydraulicing. (Hydraulicing occurs when there is not enough room between the nozzle and the wall of the tube or pipe to allow water or debris to pass. Pressure builds up, and the flex-lance is forced backward, toward the operator.)
- Helps prevent the pressurized flex-lance from being inadvertently pulled out of the open end of the pipe.

CAUTION

A backout preventer will not provide prevention or protection from a flex-lance line reversal. Use safe work practices to eliminate worker exposure to this condition. Refer to page 36 for more information related to line reversal prevention techniques.

A backout preventer is attached at the open end of the pipe using the flange or with the use of adapters (where there is no flange). The hose, stinger, and nozzle are put into the pipe through an adjustable opening in the backout preventer prior to pressurization. The adjustable opening is then made smaller to enable the hose to move freely while preventing the nozzle, hose fitting, or stinger from exiting (Figure 14).

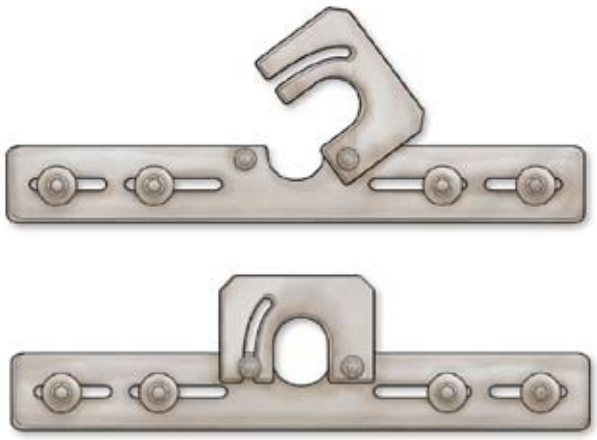


Figure 14. Backout preventer showing the adjustable opening.

Backout preventers can be used with both large- and small-diameter pipes. A variety of sizes and configurations are commercially available to suit most applications, with or without a flanged surface (Figure 15). When cleaning heat exchangers, consider using manual positioning devices, such as a hose catcher assembly, as a backout preventer. Where possible, consider the use of mechanized equipment that eliminates the need for the operator to handle the flex-lance hose.

CAUTION

When cleaning vertical piping from the bottom, use a deflector shield or fully enclosed backout preventer to help prevent the flex-lance from "falling" through the open area around the backout preventer.

Figure 15a. Backout preventer mounted to end of flanged pipe.

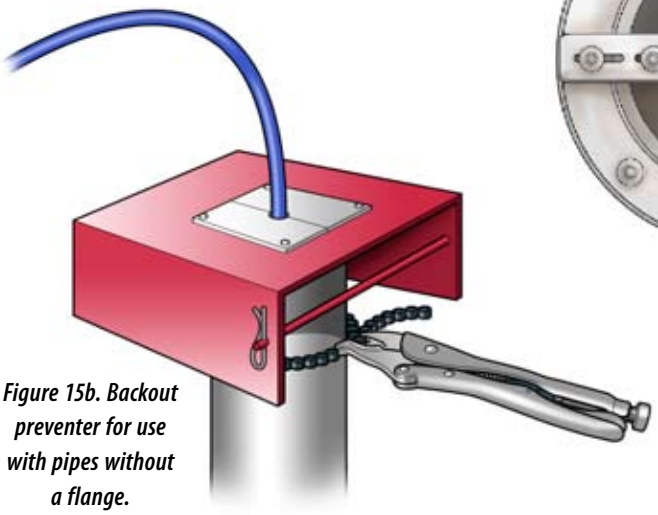


Figure 15b. Backout preventer for use with pipes without a flange.

Figure 15c. Backout preventer with adapter for small-diameter pipes.

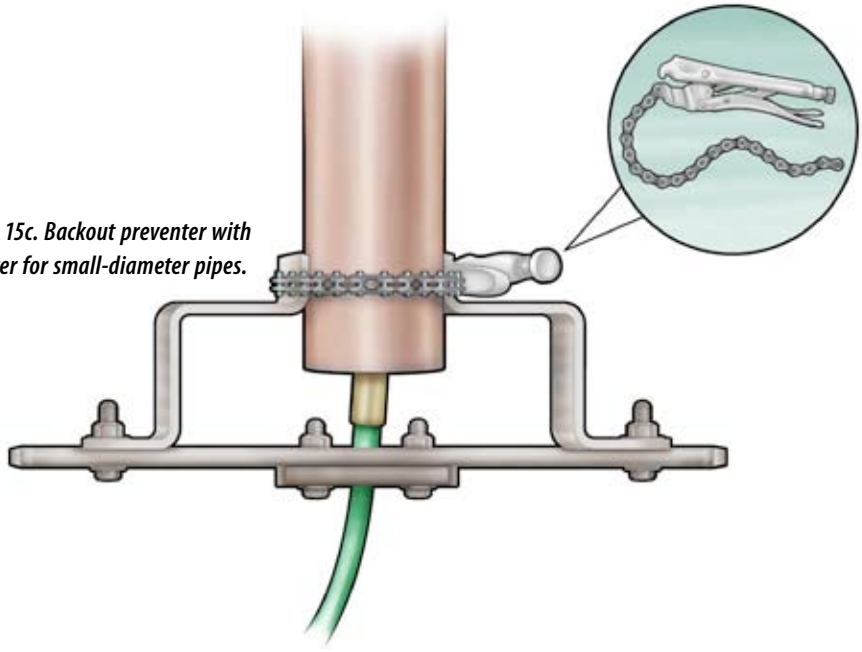


Figure 15. Backout preventers are available in a variety of sizes and configurations.

Backout preventers may be commercially manufactured or, if required, may be job-built. Like all safety devices, a job-built device must be capable of safely performing the function for which it is used.

Safe work practices – general

This section discusses safe work practices for using manually operated high pressure washing equipment. This section does not attempt to cover all safety aspects of every task. Instead, it provides basic information to help ensure the consistent application of industry-accepted safe work practices.

Personal protective equipment

When performing any high pressure washing activity, protect yourself from hazards by wearing the following personal protective equipment (PPE):

- CSA-approved safety eyewear or mono-goggles
- CSA-approved face shield
- Rain suit
- CSA-approved safety footwear
- Metatarsal protection
- Hearing protection
- Hand protection (rubber gloves)
- Safety headgear

When indicated in the hazard/risk assessment, additional personal protective equipment may be required. Safety garments specifically designed for high pressure washing or to protect workers from exposure to chemical substances, heat, cold, noise, and so on may be required where other controls do not adequately protect workers.

Crew size

At least three workers should be involved in a high pressure washing operation:

- A pump operator to control the high pressure pump
- A lance operator to control the cleaning lance
- A third worker to assist as necessary by
  - Managing hoses
  - Providing relief
  - Controlling access to the work area
  - Establishing effective communication with the pump operator where there is no line of sight between the pump operator and the lance operator

Where the manufacturer's instructions do not specify the minimum number of workers required, a risk assessment must be done to determine the requirement. Where there is direct line of sight between the pump operator and the lance operator, it may be possible to use a crew of only two workers.

Pre-use inspections

Pre-use inspections of all high pressure washing equipment and components must be done. Inspections should include, at minimum,

- The items identified in the operator's manual
- The rejection criteria for each inspectioned item

Rated components

The maximum allowable working pressure (MAWP) of any high pressure component is determined by the manufacturer based on engineering principles and anticipated operating parameters. Where components of differing MAWP will be used within a high pressure system, a pressure-limiting device (engineered control) should be used to limit the system pressure to no more than the lowest MAWP of any component.

The use of administrative controls *alone* (matching nozzle size to pump output to limit pressure) does not provide effective control of an overpressurization situation in the event of an upset condition (such as a plugged nozzle).

Whip checks

Hoses must be connected by means of properly rated couplings, with "whip checks" in place. A whip check is a short length of reinforced nylon cloth or cable looped over each end of two hoses that are connected by a coupling. Whip checks are designed to prevent the ends of the hoses from whipping around if the coupling breaks.

Figure 16. A whip check.

Hose layout

Hoses should be laid out to avoid areas of frequent foot traffic or areas where mobile equipment may cause damage to the hoses. Where possible, suspend hoses over doorways, avoid stairwells, and lay hoses next to

building walls. Hoses that are suspended must be tied off in a manner that prevents excessive sway, avoids undue strain on fittings, and does not create short-radius bends in the hose.

Worker positioning

Work activities should be planned to provide reasonable access to the equipment being cleaned. Overhead work should be avoided as it can cause unstable worker positioning, can lead to musculoskeletal injury, and is highly inefficient.

Work platforms

Adequately sized work platforms must be used to provide workers with safe access to elevated work areas (Figure 17). Work from ladders or surfaces not intended for workers can lead to loss of control of high pressure washing lances.

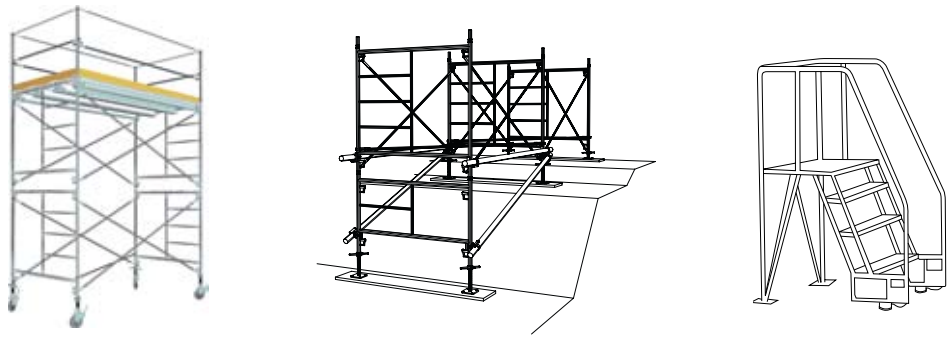


Figure 17. Different types of work platforms.

Work area

The work area must be clearly identified and controlled with effective signage and barrier tape to restrict access to authorized workers only. Additional personnel or physical barriers may be required to restrict access to areas not visible to the operators.

Cold weather

When working in a cold climate (below freezing) and cleaning activity is curtailed, arrange equipment to prevent it from freezing. Low pressure water should flow through hoses to keep the hoses from freezing. Ensure that high pressure water will not be inadvertently activated.

Hazards

Where manual high pressure washing is used for cleaning surfaces (such as tank walls, vessels, or exterior surfaces of equipment), the process is known as "hand lancing." Other common terms are "shotgunning," "blasting," and "gunning" (Figure 18).

Figure 18. Hand lancing involves the use of a manually operated jetting gun. In the image above, a worker uses a jetting gun to clean the open end of a pipe.

There are four main hazards when hand lancing:

- Operator contact with the waterjet due to modification of equipment
- Loss of control of the jetting gun due to poor footing and positioning, exposing others to risk of contact with the waterjet
- Component failure due to improper use, exposing the operator to contact from high pressure water or damaged parts
- Failure to maintain an adequate safe work zone, exposing other workers to risk of contact with the waterjet or debris

Outlined below is an overview of safe work practices developed to eliminate or reduce worker exposure to waterjet hazards when hand lancing.

General

- The object to be cleaned must not be hand-held or secured with the foot or another body part. Small objects must be securely fastened to a vice or similar tool.
- When hand lancing, the operator should always maintain a body position that affords the greatest control of the lance.
- Where multiple lance operators are cleaning in a restricted area, such as a pulp mill digester, a physical barrier should be installed or safe work procedures developed to ensure that adequate spacing is maintained between the workers.
- Work areas must be maintained and cleared of debris to provide firm footing for workers. Lighting and ventilation of confined spaces must be adequate to ensure that workers have good visibility and clean, respirable air.
- Reaction forces should be considered and regulated based on the ability of the worker to maintain control of the jetting gun. Where a higher reaction force is required, consider the use of mechanical devices to complete the task.
- Never use the jetting gun as a pry bar or in any other fashion that would place undue stress on any part of the gun.
- Never modify the jetting gun with shorter barrel lengths than originally equipped or with trigger devices. Only a manufacturer's authorized modifications are acceptable.
- Never leave a high pressure system unattended. Always disengage the high pressure pump when workers will not be in the immediate work area.
- Never point a jetting gun at anyone, whether under pressure or not.
- Never use a device or tool to hold down the trigger on a jetting gun (Figure 19). The trigger must always be operated by hand only.

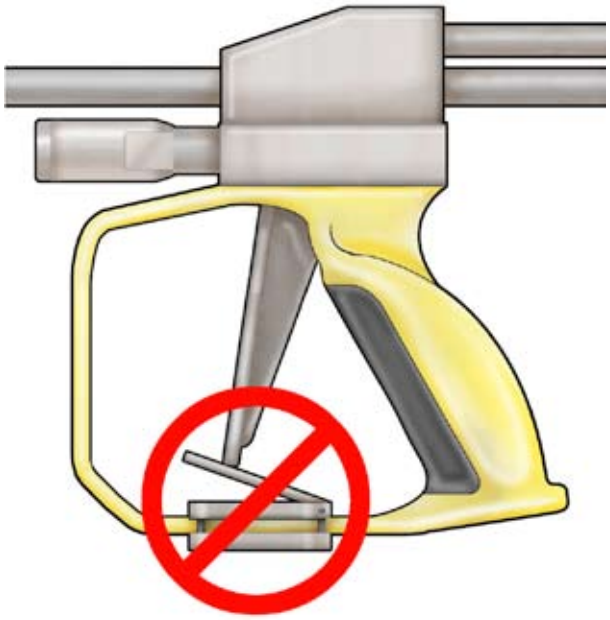


Figure 19. Never use a trigger-assist device or other tool designed to hold down the trigger of a jetting gun.

Augers and conveyors

- Ensure that equipment is locked out when there is any risk of workers or high pressure washing equipment coming in contact with rotating or moving components.

Bins and hoppers

- Ensure that workers are positioned to avoid contact or engulfment by materials "hung up" in storage tanks, bins, hoppers, and so on.

Confined spaces

- Ensure that the confined space risk assessment includes the potential for release or creation of hazardous air contaminants. When high pressure water is used to clean a surface, toxic materials can be released as fine, airborne particles. Use appropriate respiratory protection as identified in a risk assessment.
- Ensure that lighting is designed for use in wet applications and is powered by an electrical panel with appropriate ground fault circuit interrupters.

Hazards

Where high pressure washing is used for cleaning the internal surfaces of tubes or piping (e.g., liquor heaters, evaporators, and process piping), the process is known as flex-lancing (Figure 20). For pipes that are long or that have bends in them, a flexible lance (or flex-lance) is usually employed. The flex-lance is typically a hose with an inside diameter between ⅛ inch and ½ inch. A self-propelled cleaning head or nozzle attached to the end of the flex-lance is inserted into the pipe or tube and moves forward through the pipe or tube as water blasts out in different directions under high pressure.

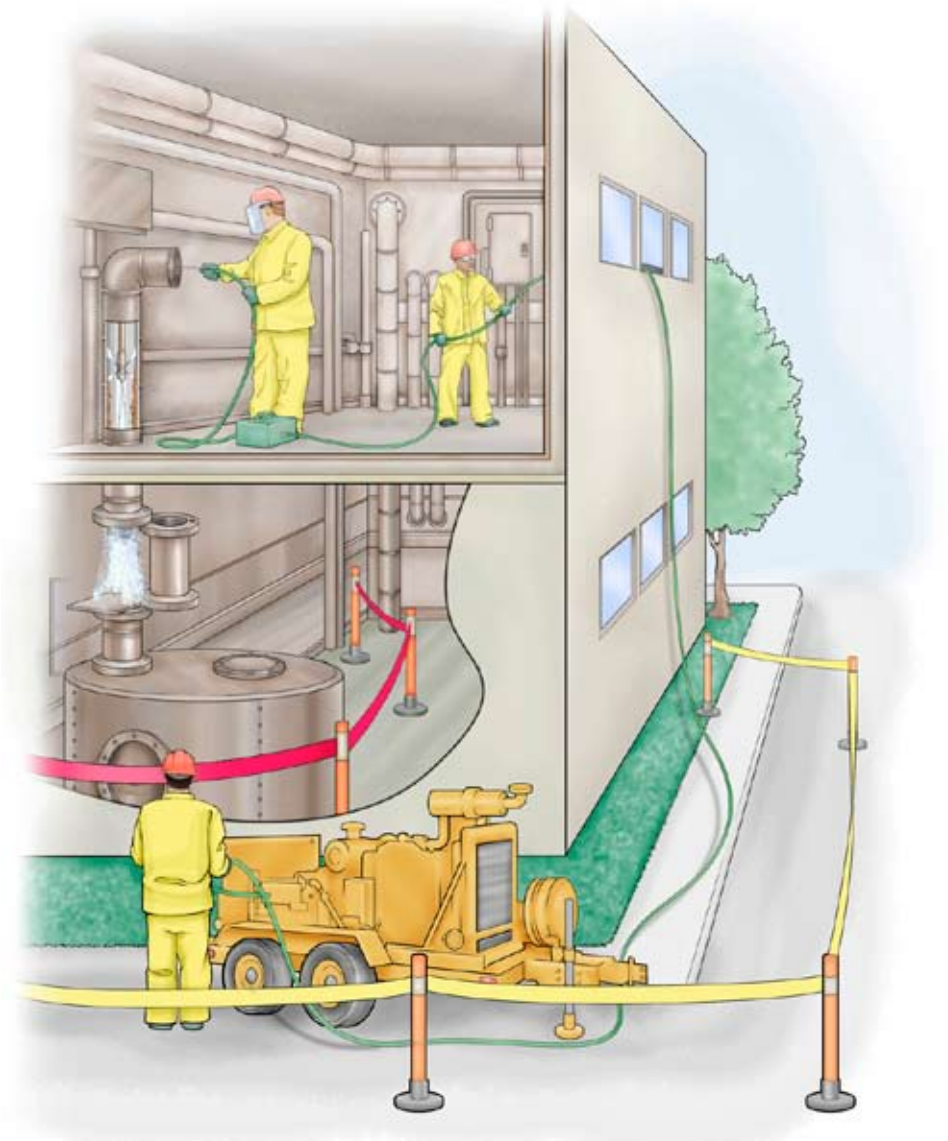


Figure 20. The use of high pressure water to clean the internal surfaces of tubes or piping is called flex-lancing.

The WorkSafeBC Hazard Alert Poster "Waterjet cleaning using a flex-lance" recounts a fatal flex-lance accident and discusses ways to prevent such accidents in the future. To view Hazard Alerts, visit WorkSafeBC.com, click "Publications," and then under "Health and safety," click "Hazard alert posters."

There are four main hazards when flex-lancing:

- The operator loses control of the flex-lance when cleaning near the open end of the pipe, and the nozzle exits the pipe.
- The nozzle turns around inside the pipe (line reversal) and exits the open end.
- The nozzle exits the far (open) end of the pipe, exposing other workers to the risk of contact with a waterjet.
- There is not enough room between the nozzle and the wall of the tube or pipe to allow water or debris to pass. Pressure builds up, and the flex-lance is forced backward, toward the operator. (This situation is called "hydraulicing.")

The following sections provide an overview of safe work practices developed to eliminate or reduce worker exposure to waterjet hazards when flex-lancing.

General

- The flex-lance operator should stand in a position that is safe and allows control of the flex-lance.
- The flex-lance operator must always maintain control of the flex-lance.
- ***The flex-lance operator must operate the foot dump valve.*** The operator can react more quickly than any other worker if the pressure must be decreased quickly.
- Keep the length of hose between the flex-lance operator and the pipe or tube as short as possible. Long hoses store a great deal of energy, and flex-lances have a tendency to recoil.
- Use a work platform or scaffold to provide stable footing if the flex-lance operator needs to be raised to a safe working position. The platform must have enough room for the flex-lance operator to operate the foot dump valve and maintain control of the flex-lance.
- Keep the working surface, including any platform or scaffold, clear of debris that may accumulate during the cleaning process.
- Depressurize the flex-lance before removing it from a pipe or tube.
- Use a stinger when completing any flex-lance cleaning. The stinger must be long enough to ensure that the nozzle cannot turn back on itself inside the pipe (line reversal). Generally, a stinger with a length equal to the maximum inside diameter of the pipe will prevent a line reversal (Figure 21).
- Never place your hand over a jetting nozzle.
- To help avoid hydraulicing, use a hose and nozzle assembly with a diameter no larger than two-thirds the inside diameter of the tube or pipe.

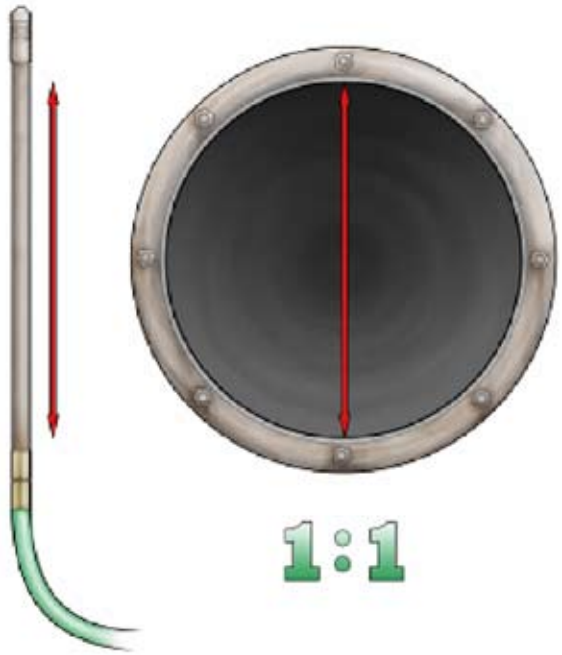


Figure 21. Generally, a stinger with a length equal to the maximum inside diameter of the pipe will prevent the nozzle from turning back on itself inside the pipe (line reversal).

Piping systems

- Clean the open end and at least the first 36 cm (14 in.) of the pipe with a jetting gun or other means, ***not a flex-lance.***
- Use an effective means of restraint when cleaning piping systems. A backout preventer is such a means of restraint in flex-lancing operations.
- Work should be done between foot and shoulder height, as it is difficult to control the flex-lance if it is higher than the shoulder (Figure 22). Manipulation of the flex-lance from awkward positions can put excessive strain on the backout preventer, causing it to be jarred out of adjustment. The risk assessment must take this into consideration when assessing hazards related to worker positioning and the need for work platforms.
- Mark the flex-lance hose 60 cm (2 ft.) from the nozzle. This mark will tell you how close the nozzle is to the open end of the pipe. When the mark wears off, mark the hose again.

Figure 22. Work should be done between foot and shoulder height, as it is difficult to control the flex-lance if it is higher than the shoulder.

Fixed tube bundles

- Wherever practicable, consider the use of mechanized equipment to protect workers from contact with the waterjet.
- Use an effective means of restraint when using a flex-lance. A backout preventer/hose positioner is such a means of restraint in flex-lancing operations (see page 26).

Evaporators and concentrators (vessel entry)

- Wherever practicable, consider the use of mechanized equipment to protect workers from contact with the waterjet.
- Use an effective means of restraint when using a flex-lance. A backout preventer/hose positioner is such a means of restraint in flex-lancing operations.

- If the use of a backout preventer/hose positioner is not practicable in an evaporator or concentrator, alternate methods of providing effective restraint include:
  - Using a stinger that is 60 cm (24 in.) or longer
  - Applying safe work procedures that include depressurizing the line before pulling it back toward the operator
- Ensure that ample access and egress are provided. Distribution covers, domes, or lids above the tubesheet must be removed or otherwise positioned to provide clear access and freedom of movement to workers inside the vessel. (A tubesheet is the top or bottom "sheet" of a heat exchanger where the tubes are held in place.) An effective means of rescue must be ensured before starting any high pressure cleaning task inside a confined space.
- Ensure that workers are provided with training and instruction for cleaning heavily fouled tubes where the risk of hydraulicing is elevated.
- Never assign more than one worker to high pressure clean inside an evaporator or concentrator unless there is effective separation and a physical barrier to provide protection to all workers.
- Ensure that workers are not assigned tasks beyond their level of training and experience.
- Ensure that the area at the bottom of the vessel is clearly identified and controlled with effective signage and barrier tape to restrict access to any workers.
- Ensure that operators are advised of the tube length, so they can avoid running excessive lengths of flex-lance out the bottom of the vessel.

First aid

"A person injured by being hit with 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 may have punctured the skin, flesh, and internal organs through a very small hole. The spread of microorganisms through a wound of this type is a very real concern."[2]

First aid must include assessment of the patient, assessment of the wound, dressing of the wound, and immediate referral to medical aid.

Ensure that first aid services personnel are aware of the nature of the injury and special precautions required.

Review first aid and rescue procedures to ensure that provisions are made to provide services in areas that have restricted access or in confined spaces.

Workers engaged in high pressure washing activities should carry a current version of the Medical Information Wallet Card published by the Waterjet Technology Association, and present it to the attending physician in the event of a waterjet injury.

2 Adapted from *Recommended Practices for the Use of Manually Operated High Pressure Waterjetting Equipment* (St. Louis, MO: WaterJet Technology Association, 1994).

Appendix A – Pressure and flow calculations

PRESSURE / FLOW THRUST CALCULATIONS											0.052 x GPM x √PSI = LB-THRUST
Flow (gpm)	Pressure (psi)										
	5,000	7,500	10,000	12,500	15,000	17,500	20,000	25,000	30,000	36,000	40,000
3	11	14	16	17	19	21	22	25	27	30	31
4	15	18	21	23	25	28	29	33	36	39	42
5	18	23	26	29	32	34	37	41	45	49	52
6	22	27	31	35	38	41	44	49	54	59	62
7	26	32	36	41	45	48	51	58	63	69	73
8	29	36	42	47	51	55	59	66	72	79	83
9	33	41	47	52	57	62	66	74	81	89	94
10	37	45	52	58	64	69	74	82	90	99	104
11	40	50	57	64	70	76	81	90			
12	44	54	62	70	76	83	88	99			
13	48	59	68	76	83	89	96	107			
14	51	63	73	81	89	96	103	115			
15	55	68	78	87	96	103	110	123			
16	59	72	83	93	102	110	118	132			
17	63	77	88	99	108	117	125	140			
18	66	81	94	105	115	124	132	148			
19	70	86	99	110	121	131	140	156			
20	74	90	104	116	127	138	147	164			
21	77	95	109	122	134	144	154	173			
22	81	99	114	128	140	151	162	181			
23	85	104	120	134	146	158	169	189			
24	88	108	125	140	153	165	176	197			
25	92	113	130	145	159	172	184	206			
26	96	117	135	151	166	179	191	214			
27	99	122	140	157	172	186	199	222			
28	103	126	146	163	178	193	206	230			
29	107	131	151	169	185	199	213	238			
30	110	135	156	174	191	206	221	247			
31	114	140	161	180	197	213	228	255			
32	118	144	166	186	204	220	235	263			
33	121	149	172	192	210	227	243	271			
34	125	153	177	198	217	234	250	280			
35	129	158	182	203	223	241	257	288			
36	132	162	187	209	229	248	265	296			
37	136	167	192	215	236	255	272	304			
38	140	171	198	221	242	261	279	312			
39	143	176	203	227	248	268	287	321			
40	147	180	208	233	255	275	294	329			
45	165	203	234	262	287	310	331	370			
50	184	225	260	291	318	344	368	411			
60	221	270	312	349	382	413	441	493			
70	257	315	364	407	446	482	515	576			
80	294	360	416	465	509	550	588	658			
90	331	405	468	523	573	619	662	740			
100	368	450	520	581	637	688	735	822			

Appendix B – Hydraulic horsepower calculations

HYDRAULIC HORSEPOWER CALCULATIONS											(GPM x PSI) ÷ 1,715 = HHP
Flow (gpm)	Pressure (psi)										
	5,000	7,500	10,000	12,500	15,000	17,500	20,000	25,000	30,000	36,000	40,000
3	9	13	17	22	26	31	35	44	52	63	70
4	12	17	23	29	35	41	47	58	70	84	93
5	15	22	29	36	44	51	58	73	87	105	117
6	17	26	35	44	52	61	70	87	105	126	140
7	20	31	41	51	61	71	82	102	122	147	163
8	23	35	47	58	70	82	93	117	140	168	187
9	26	39	52	66	79	92	105	131	157	189	210
10	29	44	58	73	87	102	117	146	175	210	233
11	32	48	64	80	96	112	128	160			
12	35	52	70	87	105	122	140	175			
13	38	57	76	95	114	133	152	190			
14	41	61	82	102	122	143	163	204			
15	44	66	87	109	131	153	175	219			
16	47	70	93	117	140	163	187	233			
17	50	74	99	124	149	173	198	248			
18	52	79	105	131	157	184	210	262			
19	55	83	111	138	166	194	222	277			
20	58	87	117	146	175	204	233	292			
21	61	92	122	153	184	214	245	306			
22	64	96	128	160	192	224	257	321			
23	67	101	134	168	201	235	268	335			
24	70	105	140	175	210	245	280	350			
25	73	109	146	182	219	255	292	364			
26	76	114	152	190	227	265	303	379			
27	79	118	157	197	236	276	315	394			
28	82	122	163	204	245	286	327	408			
29	85	127	169	211	254	296	338	423			
30	87	131	175	219	262	306	350	437			
31	90	136	181	226	271	316	362	452			
32	93	140	187	233	280	327	373	466			
33	96	144	192	241	289	337	385	481			
34	99	149	198	248	297	347	397	496			
35	102	153	204	255	306	357	408	510			
36	105	157	210	262	315	367	420	525			
37	108	162	216	270	324	378	431	539			
38	111	166	222	277	332	388	443	554			
39	114	171	227	284	341	398	455	569			
40	117	175	233	292	350	408	466	583			
45	131	197	262	328	394	459	525	656			
50	146	219	292	364	437	510	583	729			
60	175	262	350	437	525	612	700	875			
70	204	306	408	510	612	714	816	1,020			
80	233	350	466	583	700	816	933	1,166			
90	262	394	525	656	787	918	1,050	1,312			
100	292	437	583	729	875	1,020	1,166	1,458			

Appendix C – Conversion table

US		Multiplier	Metric	
Pressure				
1	psi	× .069	.069	bar
14.5	psi		1	bar
10,000	psi		690	bar
15,000	psi		1038	bar
Flow				
1	gpm (US)	× 3.785	3.785	Lpm
26	gpm (US)		98	Lpm
50	gpm (US)		189	Lpm
66	gpm (US)		250	Lpm
Power				
1	hp	× .7457	.7457	kW
67	hp		50	kW
150	hp		112	kW
500	hp		372	kW
Length				
1	in	× 25.4	25.4	mm
¼	in		6.35	mm
½	in		12.7	mm
⅜	in		9.52	mm
Volume				
10	ft^3	× .028	.28	m^3
10	yd^3	× .764	7.6	m^3
10	gal (liq)	× 3.785	30.7	L
1	drum (US petroleum)	× 159	159	L

Appendix D – Definitions

High pressure washing equipment is used in many different worksites throughout British Columbia. Consistent understanding and application of the words used to describe the many parts of a high pressure washing system or operation is important in helping to ensure effective communication on the job site.

Many of the definitions below are reprinted from the publication *Code of Practice for the Use of High Pressure Waterjetting Equipment,* published by The Waterjetting Association (United Kingdom). WorkSafeBC gratefully acknowledges the Association for granting permission to use this material.

Automatic pressure relief devices – Devices included in a high pressure waterjet system to provide a means of automatically limiting the system pressure. Automatic pressure relief devices can be of several types:

- Automatic pressure-regulating valves
- Bursting and rupture discs, when set in a proper holder
- Bypass valves
- Pressure relief valves

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.

Backout preventer – A safety device designed to restrain a flex-lance to within a piping system and to help prevent the flex-lance operator from inadvertently pulling the flex-lance out of the piping system.

Flex-lance – A high pressure flexible hose section carrying water to the nozzle; normally located between the trigger or control valve and the nozzle.

Foot dump – A control valve designed so that the operator can activate it using a foot. This enables the operator to use both hands to hold and move the lance and/or nozzle assembly.

The foot dump must be under the exclusive and immediate control of the flex-lance operator.

The foot dump control must be mounted within a frame or otherwise shielded to prevent inadvertent activation.

Jetting gun – A hand-operated device that is often used in manual high pressure washing. The jetting gun is made up of

- A control valve mounted with a guard
- A shoulder rest
- A lance section
- A nozzle assembly

Additional features may include

- A shoulder pad
- One or more support handles

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.

High pressure washing – Generally refers to activities related to the use of industrial high pressure cleaning equipment capable of generating pressures of 5,000 psi or more.

High pressure waterblasting – Specifically refers to activities related to the use of industrial high pressure cleaning equipment at 5,000 to 30,000 psi.

Hydraulicing – A hazardous condition where the flex-lance (or rigid lance) is forced backward, toward the operator, when there is not enough room between the nozzle and the wall of the tube or pipe to allow the bypass of water or effluent. Generally occurs when cleaning heavily fouled tubes (e.g., black liquor evaporators) or tubes of very small diameter. The general guideline is to use a hose and nozzle assembly with a diameter no larger than two-thirds the inside diameter of the tube or pipe.

Moleing (flex-lancing, go-devilling) – An application where a flexible high pressure hose fitted with a self-propelling nozzle (mole) is used to clean the internal surfaces of piping systems or tubes.

Moles (nozzles, go-devils, comealong nozzles) – 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 mole should include, directly behind the nozzle assembly, a stinger sufficiently long that it will prevent the mole from turning around within the pipe.

Nozzle – A device with one or more orifices through which the water discharges from the system. The nozzle restricts that area of flow 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.

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

Pressure washing – Generally refers to activities related to the use of pressure cleaning equipment under 5,000 psi.

Rigid lancing – An application where a length (usually more than 3 metres or 10 feet) of rigid tubing or pipe is fitted with a nozzle and is used primarily to clean tubes. Can be hand-held or form part of a mechanized lancing system.

Stinger – A length of rigid pipe fitted between the flex-lance end fitting and the cleaning nozzle. A stinger is used to prevent the nozzle from turning around inside the pipe (line reversal) and to provide additional positive control of the flex-lance. A stinger must be at least as long as the inside diameter of the pipe being cleaned.

Ultra high pressure jetting – Specifically refers to activities related to the use of industrial high pressure cleaning equipment at pressures over 30,000 psi.

Whip check – A short length of cloth or cable looped over each end of two hoses that are connected by a coupling. A whip check is designed to stop the ends of the hose from whipping around if the coupling breaks.

Appendix E – Occupational Health and Safety Regulation

This appendix contains excerpts from the Occupational Heath and Safety Regulation that relate specifically to high pressure washing activities. The sections listed are not intended to represent all the employer's regulatory obligations.

4.3 Safe machinery and equipment

(1) The employer must ensure that each tool, machine and piece of equipment in the workplace is
  (a) capable of safely performing the functions for which it is used, and
  (b) selected, used and operated in accordance with
    (i) the manufacturer's instructions, if available,
    (ii) safe work practices, and
    (iii) the requirements of this Regulation.

(2) Unless otherwise specified by this Regulation, the installation, inspection, testing, repair and maintenance of a tool, machine or piece of equipment must be carried out
  (a) in accordance with the manufacturer's instructions and any standard the tool, machine or piece of equipment is required to meet, or
  (b) as specified by a professional engineer.

(3) A tool, machine or piece of equipment determined to be unsafe for use must be identified in a manner which will ensure it is not inadvertently returned to service until it is made safe for use.

(4) Unless otherwise specified by this Regulation, any modification of a tool, machine or piece of equipment must be carried out in accordance with
  (a) the manufacturer's instructions, if available,
  (b) safe work practices, and
  (c) the requirements of this Regulation.

Note

The procedure for determining if an item is unsafe for use is provided by the requirements for the correction of unsafe conditions and refusal of unsafe work in Part 3 (Rights and Responsibilities).

4.7 Information on rated capacity

If a machine or piece of equipment has a rated capacity which varies with the reach or configuration of the machine or equipment, or has other operating limitations,
  (a) appropriate instructions, load charts and warning notices must be affixed to the machine or equipment so as to be visible to the operator when the operator is at the controls, or
  (b) the information, in written form, must be available to the operator.

4.10 Authorization

(1) A machine or piece of equipment may only be operated by authorized persons.

(2) A person must not be authorized to operate a machine or piece of equipment until the person has been adequately instructed and trained, and has demonstrated an ability to safely operate it.

12.15 Restraining devices

Effective means of restraint must be used

(a) on a connection of a hose or a pipe if inadvertent disconnection could be dangerous to a worker,

(b) if unplanned movement of an object or component could endanger a worker, or

(c) to secure an object from falling and endangering a worker.

12.97 Definitions

In sections 12.97 to 12.111

"cabinet" means an enclosure designed to permit abrasive blasting, high pressure washing or a similar operation to be conducted safely inside the enclosure by a worker who is outside the enclosure;

"enclosure" means a temporary or permanent enclosure of a work area provided with exhaust ventilation and makeup air to reduce exposure of workers inside the enclosure and prevent the uncontrolled release of air contaminants from the enclosure;

"high pressure washing" or "jetting" means the use of water or other liquid delivered from a pump at a pressure exceeding 34 MPa (5,000 psi), with or without the addition of solid particles, to remove unwanted matter from a surface or to penetrate into the surface of a material for the purpose of cutting that material.

12.99 Work procedures outside a cabinet

If abrasive blasting, high pressure washing or a similar operation is conducted by a worker outside a cabinet, written safe work procedures addressing the hazards and necessary controls must be prepared and implemented by the employer.

12.105 Restricted work zones

(1) When abrasive blasting or a similar operation is conducted outside a structure, the process must be restricted to a work zone which is identified by signs or similar means as being a contaminated area.

(2) Only properly protected workers who are necessary to perform the work are permitted inside an enclosure or a restricted work zone where abrasive blasting or a similar operation is conducted.

12.106 Operating controls

(1) The operating controls for a sandblasting machine or jetting gun must be
  (a) located near the nozzle in a position where the operator's hands will be when using the device,
  (b) the continuous pressure type that immediately stops the flow of material when released, and
  (c) protected from inadvertent activation.

(2) Subsection (1)(a) does not apply to sandblasting machines or jetting guns used in operations where hand operated controls are clearly impracticable, in which case the operator must use a foot operated control or equivalent safety device, both of a design acceptable to the Board.

[Amended by B.C. Reg. 253/2001, effective January 28, 2002.]

Note

An example of a work process in which the hand operation of a sandblasting machine or jetting gun is impracticable is the cleaning of small diameter pipes when the lance must be inserted completely inside the piping for effective cleaning.

12.108 Jetting gun

A jetting gun must not be modified except as authorized by the manufacturer.

12.109 Holding work

A worker must not hand hold an object while it is being cleaned or cut by a jetting gun.

12.110 Hose restraint

High pressure hoses, pipes, and fittings must be supported to prevent excessive sway and movement.

12.111 Personal protective equipment

(1) A nozzle or jetting gun operator must wear personal protective clothing and equipment on the body, hands, arms, legs and feet, including the metatarsal area, made of canvas, leather or other material which will protect the worker's skin from injury in the event of contact with the flow from the nozzle.

(2) Unless the process is isolated from the operator in a separate cabinet, suitable respiratory protective equipment must be provided and worn whenever abrasive blasting or a similar operation is conducted.

WorkSafeBC Offices

Visit our web site at WorkSafeBC.com.

Abbotsford
2774 Trethewey Street V2T 3R1
Phone 604 276-3100
1 800 292-2219
Fax 604 556-2077

Burnaby
450 – 6450 Roberts Street V5G 4E1
Phone 604 276-3100
1 888 621-7233
Fax 604 232-5950

Coquitlam
104 – 3020 Lincoln Avenue V3B 6B4
Phone 604 276-3100
1 888 967-5377
Fax 604 232-1946

Courtenay
801 30th Street V9N 8G6
Phone 250 334-8765
1 800 663-7921
Fax 250 334-8757

Kamloops
321 Battle Street V2C 6P1
Phone 250 371-6003
1 800 663-3935
Fax 250 371-6031

Kelowna
110 – 2045 Enterprise Way V1Y 9T5
Phone 250 717-4313
1 888 922-4466
Fax 250 717-4380

Nanaimo
4980 Wills Road V9T 6C6
Phone 250 751-8040
1 800 663-7382
Fax 250 751-8046

Nelson
524 Kootenay Street V1L 6B4
Phone 250 352-2824
1 800 663-4962
Fax 250 352-1816

North Vancouver
400 – 224 Esplanade W. V7M 1A4
Phone 604 276-3100
1 888 875-6999
Fax 604 232-1558

Prince George
1066 Vancouver Street V2L 5M4
Phone 250 561-3700
1 800 663-6623
Fax 250 561-3710

Surrey
100 – 5500 152 Street V3S 5J9
Phone 604 276-3100
1 888 621-7233
Fax 604 232-7077

Terrace
4450 Lakelse Avenue V8G 1P2
Phone 250 615-6605
1 800 663-3871
Fax 250 615-6633

Victoria
4514 Chatterton Way V8X 5H2
Phone 250 881-3418
1 800 663-7593
Fax 250 881-3482

Head Office / Richmond
Prevention Information Line:
Phone 604 276-3100
1 888 621-7233 (621-SAFE)

Administration:
6951 Westminster Highway
Phone 604 273-2266

Mailing Address:
PO Box 5350 Stn Terminal
Vancouver BC V6B 5L5

After Hours
Health & Safety Emergency
604 273-7711
1 866 922-4357 (WCB-HELP)

R06/06

10/08 Printed in Canada BK123