Code of Practice for

The use of High Pressure Jetting Equipment by Divers

International Marine
Contractors Association

www.imca-int.com

IMCA D 049
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There are also five regional sections which facilitate work on issues affecting members in their local geographic area – Asia-Pacific, Central & North America, Europe & Africa, Middle East & India and South America.

IMCA D 049

This guidance updates AODC 049 which has now been withdrawn. It has been prepared under the direction of the IMCA Diving Division Management Committee.

Some of the changes in this revision deal with new equipment that has been introduced to dive sites, particularly ultra high pressure jetting equipment. However the information provided in all sections has been updated and expanded.

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Appendices

Foreword

The *Code of Practice for the Use of High Pressure Jetting Equipment by Divers* was initially prepared as AODC 049 in August 1988. This revised code has been produced by IMCA through the Safety, Medical, Technical & Training (SMTT) Committee of the Diving Division Management Committee as part of a phased review of AODC guidance notes and subsequent re-issue as IMCA guidance. IMCA D 049 supersedes AODC 049 which is withdrawn.

Some of the changes in this revision deal with new equipment which has been introduced to dive sites, particularly ultra high pressure jetting equipment. However, the information provided in all sections of the document has been updated and expanded. There is a new section dealing with the avoidance of accidents to divers engaged in underwater HP jetting operations. Two relevant IMCA safety flashes have also been identified and included as new appendices.

Further relevant guidance is available in publications aimed at surface based high pressure water jetting operations (see Section 8).

1 Scope

This code of practice covers procedures for the effective and safe operation of underwater high pressure water jetting equipment used by fully submerged divers for cleaning or cutting purposes, and its associated surface support equipment. It is also intended to apply to diver controlled jetting operations on or near the surface where there can be a risk, through contact with the water jet stream or flying debris, of traumatic injury to others working in the vicinity – either in the water, on a platform or facility, or at an adjacent diving system.

High pressure water jetting, as covered by this guidance, relates to all water jetting, including the use of abrasive additives, where there is an energy input to increase the pressure applied to water.

2 Definitions

Additives	include abrasive (grit) entrainment, abrasive slurry mixtures and chemicals that are added to the flow of high pressure water
High pressure (HP)	pressures up to 1,700 bar (25,000 psi)
Ultra high pressure (UHP)	pressures above 1,700 bar (25,000 psi)

3 Introduction

High pressure water jet systems are water delivery systems which have nozzles or other openings whose function is to increase the velocity of water or other liquids. Solid particles may also be introduced, although the exit in all cases is in a free stream. High pressure (HP) water jetting is utilised in the diving industry for a variety of cleaning tasks and, in some instances, as a cutting tool.

Typical uses of HP water jetting equipment include:

- marine growth removal;
- paint coat removal;
- supporting seabed material removal by breaking down clays and stiff soils for air lifting;
- breaking up consolidations within pipework;
- breaking up of drill mud and grout spillages on the seabed.

HP water jetting equipment may also be used as a cutting tool. In certain applications it can cut concrete and steel either with or without the addition of an abrasive material such as grit or copper slag.

Grit entrainment in HP water jetting is commonly used to support weld inspection through the removal of the obscuring paint coatings.

HP water jetting equipment can be used from pressures of a few hundred psi up to many thousands of psi, subject to the safe working pressure (SWP) of the system and the actual requirement for the task.

For the purpose of marine growth removal in the offshore diving industry, HP water jet systems typically have a SWP of 345-690 bar (5,000-10,000 psi). Sometimes pressures as high as 1,000 bar (14,500 psi) may be used.

For the purpose of concrete or steel cutting, with or without grit entrainment, HP water jet systems typically have a SWP of 690-1,700 bar (10,000-25,000 psi).

Ultra high pressure (UHP) water jets operate above 1,700 bar pressure. They are being increasingly used by the offshore industry for the removal of surface coatings, cleaning and cutting.

4 Equipment

HP water jet systems used by divers typically comprise the following parts:

- diesel or electric drive motor;
- pressurising pump;
- HP hose;
- HP hose reel;
- HP jetting gun.

Fixed components of the water jet system should be properly sea-fastened or otherwise secured onto the vessel/dive platform, bearing in mind that they will be subjected to vibration over potentially long periods of time. An adequate spares package should also be supplied with the system.

4.1 Drive Motor and Pressurising Pump Unit

The drive motor and HP pump are usually supplied as a single jetting unit within a steel frame which may be trailer or skid mounted and normally enclosed by an acoustic canopy. The primary components of such units are:

- diesel or electric drive motor;
- HP water pump (piston or centrifugal);
- hydraulic or manual clutch drive;
- starter motor and control panel;
- fuel tank (if diesel);
- water reservoir/header tank;
- pressure gauges;
- isolation and bleed valves.

Additional equipment may be required where hazardous area restrictions apply, e.g. spark arrestors, remote controls, etc.

At no time should a direct drive unit be used unless the prime mover can be disengaged from the pump unit. The pump unit should be capable of long and continuous operation using filtered seawater and should be suitable for use in the marine environment.

Motor and pump units should be supplied with all relevant documentation, e.g. test certificates, maintenance history, rigging and calibration certification, etc. (see Section 4.11).

Pumps should be fitted with at least one, and preferably two, pressure relief devices (such as a spring loaded valve, air operated valve or burst disc) set just above the maximum safe working pressure of the lowest rated component in the operating system, and in accordance with manufacturers' instructions. Such devices should be capable of passing the full flow of the pump to which they are fitted without significant pressure rise.

When replacing or re-setting a pressure relief mechanism after activation, the reason for its activation should have been addressed beforehand.

Pumps should have a suitably rated gauge that shows the operating pressure being delivered.

Motor and pump units should have a daily, or pre-use, checklist completed to ensure that all fuelling and other maintenance requirements have been met prior to use.

4.2 High Pressure Hoses

HP hoses are used to take the high pressure water output from the pressurising pump to the HP water jet gun. Supply is normally by a single hose delivery system formed from multi-spiral braided hose rated to the required pressures.

Due to the high pressures involved and the erosive properties of any water-borne particles being transported to the worksite via small bore flexible hoses, it is essential that the correct specification hoses are utilised. Appropriate documentation should accompany hoses to the worksite. The hoses should be marked with the manufacturer's symbol, serial number, the maximum permissible operating pressure and the test pressure.

Prior to mobilisation, the HP hoses should be inspected for damage. Any hoses that have obvious signs of damage should be replaced. Signs of damage include kinks, crushing, stretching, blistering, and rusted or broken reinforcing wires.

Pre-use inspection of hoses should continue at the worksite. Water jet system team members should always be aware of sharp edges or similar profiles which could damage or rupture high pressure hoses. Where possible, hoses should be run over a chute or sheave or be otherwise protected from sharp profiles.

Hoses showing any sign of damage at any stage should be removed from service.

The high pressure hoses connecting the various items of equipment should not be used above their maximum working pressure. Only hoses clearly marked with their specification and maximum working pressure should be used.

In the case of loss of pressure to the jetting gun use of the equipment should cease immediately. No attempt should be made to locate the source of the leak whilst the gun and hoses are under pressure. The water jet should be returned to surface for investigation.

Similarly, if a diver suspects a subsea leak on a connection he should not attempt to locate it underwater. He should return the whole system to the surface for investigation and, if necessary, repair.

The minimum length of hose required per jetting gun unit is normally considered to be 1.5 times the maximum anticipated working depth. Longer lengths may be required under some circumstances, e.g. when diving operations are scheduled for jacket interiors and the diving platform is at a significant stand-off distance.

4.3 Hose and Equipment Connections

Connections for equipment and high pressure hoses are subject to a high level of erosion and corrosion, and should be constructed of high quality material suitable for the required pressure and environment. They should be checked and replaced at regular intervals.

HP water jetting systems should only be fitted with components rated for their intended use. Most components will be marked with their maximum working pressure. If for any reason the maximum working pressures of any parts cannot be readily identified, these items should not be used until the maximum working pressures have been reliably determined, e.g. through documentation supplied by the manufacturer or a suitable competent person.

The maximum working pressures of high pressure hose assemblies normally allow a safety factor of 2.5 to 1 in relation to the minimum burst pressure (the point at which hose failure occurs as a result of pressure).

Immediately prior to assembly all connections and couplers should be inspected for damage. Proper correctly sized tools should be used during the assembly of HP hoses and equipment. Connections should not be tightened using tools that have serrated jaws as these can cause damage. The number of couplings on hoses should be kept to a minimum. They should be of non-corroding material and their own pressure ratings should be greater than the maximum working pressure of the main hose.

A variety of connection types are used on high pressure components to suit particular pressure ranges. Not only are there a variety of different connection types, but each uses a different thread type. These can appear similar to the untrained eye and so there is a risk that dissimilar connectors fitted with incompatible threads may be joined. Such improper connections cannot form an adequate mechanical union or high pressure seal. They will inevitably fail under pressure, causing a hazard to workers from exposure to high pressure water or to flying debris.

Only persons trained and competent in identifying the different types of connections and which types to use should be permitted to assemble high pressure hoses and equipment. If HP connections are taken apart and then re-assembled, the components should be checked and declared safe to use by a competent person before the HP jetting system is re-energised.

The use of a suitably rated swivel arrangement three to four metres away from the jetting gun may lessen or remove hand strain for the diver and assist in removing torque from the hose and the gun.

Connections should never be made up, tightened or broken whilst the equipment is pressurised or the power unit is running.

Hose restraining devices (whip checks) of the correct rating should be used to prevent the ends of hoses from whipping around if a hose connection breaks.

4.4 HP Hose Reel

The armouring contained within the HP water jet hose makes any significant length (150m+) heavy and unwieldy both to deploy and recover. Consideration should be given to the use of a powered hose reel which will serve the following functions:

- provide for orderly storage of hose length, preventing damage;
- ease deployment and recovery;
- minimise deck space requirements.

Powered hose reels are usually driven by compressed air or hydraulics.

4.5 HP Jetting Guns

There are two types of HP jetting gun typically in use:

4.5.1 Dump Safety Gun

This type of gun has a fail-safe valve which, when the trigger is released, diverts water from the nozzle to ambient water thereby rapidly reducing pressure flow at the nozzle to safe levels.

The attention of operators is drawn to the severe jolt which can be experienced when the pressure is dumped by releasing the trigger. A choke can be fitted in the dump line to reduce this effect.

4.5.2 Dry Shut Off Gun

When the trigger is released on this type of gun, the pressure is retained in the supply line. It needs to be used in conjunction with a regulating or unloading valve on the surface. However it should be recognised that this type of system leaves the total length of the hose charged and under full pressure at all times. This type of gun therefore increases the risks to operators and hose handlers from inadvertent operation of the gun or from sudden rupture of the hose/couplings under high pressure.

Users of HP water jetting systems should ensure that dump-style and dry shut off style jetting guns are clearly distinguished from each other to avoid accidental fitting of a dry shut off style jetting gun on a system where there is no regulating or unloading valve on the surface.

4.6 Trigger Mechanisms on Dump Safety and Dry Shut Off Guns

The trigger (control valve) on the gun is operated by a squeeze action of the hand of the operator, who should always have control of this device. The trigger should be a cam lever operated mechanism that requires the operator to hold the control in the 'on' position (continuous pressure type). On release the trigger should immediately return to the safe position and stop the water jet flow. It should be provided with a guard adequate to prevent accidental operation as well as an integral safety catch capable of immobilising the gun in the 'off' position. The safety catch should be consistently used in order to reduce the likelihood of inadvertent operation of the trigger mechanism.

A design of trigger mechanism should be selected which minimises the likelihood of the trigger becoming seized due to the presence of water-borne particles. Such particles will inevitably be present during grit blasting operations and they are also likely to be raised by the cleaning action of the water jet. The trigger mechanism should be inspected and cleaned each time the water jet is recovered to surface at the end of a dive in order further to reduce the likelihood of sticking.

The effort required to maintain a trigger in the 'open' position over extended periods of time can produce significant levels of fatigue in operators. This is increased in underwater operations due to environmental effects such as loss of stability due to water movement, or weightlessness causing loss of momentum. There are designs of trigger mechanisms that reduce the amount of hand pressure required to maintain the trigger in the open position, but are also capable of instant release. Incorporation of such a trigger design in jetting guns should be investigated with equipment suppliers. Water jetting bodies advocate a trigger pressure of no more than 0.8 bar (12 psi) to operate HP jetting guns.

Irrespective of the trigger pressure on a gun it is always advisable to take regular breaks from continuous operation to prevent trigger fatigue and so reduce the temptation for operators to wedge or lash the trigger assembly in the 'open' position.

Locking of the trigger in the 'open' position by wire, tape or other artificial means is an extremely dangerous practice which negates the fail safe design of the trigger mechanism. **Such practices should never be employed by divers or surface operators.**

Foot operated control valves should not be used subsea.

4.7 Lance

The HP jet gun barrel (or 'lance') should be of a length that is practical for the type of operation being undertaken. However, it is emphasised that the inherent potential for accidental self-injury during use of high pressure jetting guns increases as the length of lance decreases. Should a diver lose control of the gun for any reason (e.g. wave or tide action, awkward mid-water positioning, etc.) he will be much more likely to shoot himself with a short lance than with a long one. For this reason, some diving contractors specify a minimum lance length of 60cm (2ft).

It is advisable never to modify the jetting gun with a shorter barrel length than the one originally supplied by the manufacturer. Any barrel length modifications should only be carried out with the agreement and authorisation of the manufacturer.

If a short lance is to be used the potential for injury can be reduced somewhat by the use of a positive locking clamp on a safety ring shield. This will ensure that the diver's hand does not easily slide off the end of the lance. It may also provide some measure of protection from particles driven towards the diver's hand during the course of jetting operations.

4.8 Nozzles

A nozzle is fitted at the end of the lance on HP water jetting guns. The nozzle is a device with one or more openings where the fluid discharges from the system. The nozzle restricts the area of flow of the fluid, accelerating the water to the required velocity and shaping it to the required flow pattern and distribution for a particular application. **Combinations of forward and backward facing nozzles are always used to balance the thrust on water jetting guns used underwater** (see Section 4.9).

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 jetting equipment.

For standard underwater HP water jetting operations, the nozzles are manufactured in steel and are available as either a fan or pencil jet. A straight-ahead pencil jet nozzle fitted to the lance tip 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 surface areas.

The selected nozzle should be suitable for the task required and be compatible with the pressures and any additives used.

Nozzles can become blocked, especially when using abrasive additives. No attempt should be made to clear any blockage whilst the system is still under pressure.

A pressure decrease and change in spray pattern is an indication that the nozzle is worn and may need replacing.

The operation of any non-fixed forward facing nozzles, such as rotary or orbiting nozzles used in cutting or cleaning internal pipework, should only be carried out by divers properly trained in their use. Such jetting operations should be thoroughly risk assessed to consider, among other things, safe standoff distances for the operator, security of the assets being cleaned or cut and the deposit location of cleaning or cutting debris.

4.9 Retro Jets

A retro water jetting gun is fitted with forward and backward facing jets. This reduces the thrust experienced by the operator. The retro balance jet protection tube should be sufficiently long or constructed so as to prevent the operator directing a retro balance jet at himself.

All HP water jetting guns to be handled by divers underwater should be fitted with a rear facing retro jet that discharges at a safe distance behind the diver.

The type of nozzle fitted to the retro jet should be such that it provides a reaction equal to that of the forward jet in order to balance the gun.

Retro jets are guarded with a venturi type diffuser tube which protects the operator and is positively locked onto the gun. When the water jet is active surrounding seawater enters the diffuser tube through machined holes and dissipates the energy of the retro jet as it travels through the diffuser tube. The design of the diffuser tube should ensure that the exit wash from the tube is no longer of a velocity that can cause harm to the diver or his equipment.

Some guns are also fitted with a shroud which is positioned over the venturi inlet holes to reduce the likelihood of items being drawn into the venturi water flow.

Ideally the diffuser tube should be fixed in place with a visual indicator that highlights the correct minimum of retaining threads engaged before a lock nut is tightened. The integrity of the locking mechanism should be checked prior to each deployment. Divers have been injured by retro jets when diffuser tubes have been poorly designed (e.g. were too short) or have come away during use (see Appendices 4 and 5).

4.10 Accessories

Any accessories that are used with the basic system need to be fully compatible with the basic system fittings. They should also be appropriately rated for the maximum pressures that will be used.

No alterations should be made to any of the basic equipment without the consent of the manufacturer. Any approved modifications could alter an existing risk assessment, which should be revised to consider the changes caused by the alteration.

4.11 Care and Maintenance of Equipment

As a minimum, a daily check on the pump, intake hoses, filters and associated fittings for any damage or leaks should be carried out by a competent person. High pressure hoses, guns and lances should be examined for any sign of damage. In the event of leaks or damage being found, they should be reported to the diving supervisor who may decide to withdraw the equipment from service pending repair or replacement.

Special attention should be given to cleaning the gun trigger mechanism and nozzles after each use, as these could be affected by the ingress of additives or debris.

The fittings on interconnecting hoses should be internally checked at regular intervals. This should be done by disconnecting the fitting and visually inspecting the metal surfaces.

It should be noted that systems using grit or abrasive entrainment additives will be more prone to erosion and wear on the inside of hoses and fittings. This might not be obvious during a visual inspection.

A thorough flush of the system with fresh water should always be carried out after use, on demobilisation and prior to periods of extended storage.

Testing of the pump unit and associated equipment in regular use should be carried out by a competent person every six months and a Certificate of Fitness provided. Where the water jetting system has been hired from an equipment supplier, either as an integral unit or in component parts, a Certificate of Fitness valid for no more than six months from the date of test and examination should be provided by the hirer to the effect that the equipment has been satisfactorily tested prior to commencement of hire.

Subsequent six-monthly testing should be carried out either by the hirer or the contractor on all, or parts of the system as applicable, for the duration of the hire period.

A facility should be in place to enable the testing and recertifying of equipment if it is to be offshore beyond the expiry date of the certificates.

Due to the highly complex nature of some of the HP units currently on the market, full operating and maintenance instructions should be available with each pump. These should be strictly followed.

5 Protection of Personnel

5.1 Life Support Equipment

Water-excluding hard diving helmets complete with hat liners should be worn during subsea HP water jetting operations. Band masks and similar types of breathing apparatus should be avoided.

Grit and other additives used in the gun or raised by the HP jet can interfere with the correct functioning of personal diving equipment. Great care should be taken in checking and cleaning personal diving equipment thoroughly after every dive, especially helmets, their demand valves and other parts of the breathing equipment.

Consideration should also be given to additional items of diving plant and equipment which may be adversely affected by underwater jetting operations, e.g. diver deployment devices (such as saturation diving bells, surface wet bells or baskets) and subsea construction/installation equipment (wires, sheaves, pulleys, underwater tools, etc.). Great care should be taken to check and clean thoroughly any diving plant or project equipment that may have been damaged or impaired by contact with HP water jets, by the ingress of water jetting additives or by debris washed or cut from the worksite during jetting operations.

5.2 Hearing Protection

Because of the high noise levels emitted by water jetting equipment, the effect of noise on the diver should be minimised. In particular, diving helmets as opposed to masks should be worn. Topside personnel should wear hearing protection when in the vicinity of the water jetting machinery.

Certain obligations are placed on designers, manufacturers, importers, suppliers and users of plant and equipment to control and limit noise emissions from them. A number of countries have specific regulations to protect the hearing of those involved in high noise generating work activities. Local regulations should be complied with for the prevention of damage to hearing by noise emissions from plant and equipment.

It should be remembered that both noise and the wearing of hearing protection will reduce the effectiveness of communications between the supervisor, the deck surface crew and the divers. In view of this, hearing protection with built-in speakers should be considered for the deck crews during water jetting operations.

5.3 Personal Protective Equipment (PPE)

Appropriate personal protective equipment should be worn by divers engaged in subsea HP water jetting operations.

Hard protection should be provided to the hands, feet and lower leg as a minimum for hand-held lance operations, and as specified from the findings of risk assessments for other water jetting operations.

Kevlar sectional hard protective over-shoe and over-suit systems are available that both protect and allow free movement of the diver. These can be sourced through equipment suppliers or from one of the water jetting associations.

Soft neoprene booties, soft shoes or soft boots alone should not be worn as protection during jetting operations.

5.4 Training

Subsea HP water jetting is a hazardous activity and should only be carried out by competent personnel.

The diving supervisor should have a sound knowledge of the equipment and the techniques to be employed.

A diver using water jetting equipment should be familiar with use of the equipment relating to the nature of the work which he may be required to do.

The diving supervisor should satisfy himself that the diver is familiar with any necessary safety devices and procedures, fully appreciates the inherent hazards and risks associated with the equipment and is competent in its use.

It is the contractor's responsibility to ensure that personnel are adequately trained and familiar with the equipment. Training should be provided either in-house or by a competent training establishment. At the very least training should take place at the worksite to demonstrate the equipment, its safe use, and any safety shut down mechanisms and procedures, should the need arise, so that everyone is fully conversant with the operation to be undertaken.

The main differences between high and ultra high pressure water jetting should be understood in these training sessions.

Additional training should take place when using UHP water jetting processes where the delivery pressure is higher than 1,700 bar (25,000 psi).

5.5 Injuries

Diving personnel should be fully aware of the potential severity of injury which can result from injection of water at high pressure through the skin.

A pressure of around 7 bar (100 psi) will penetrate the skin.

Extensive tissue damage can be caused along with a danger of severe infection developing, even if the entrance wound is very small.

Every injury caused by high pressure water jetting should be reported, treated immediately and specialist medical advice sought. In this regard a specific recommendation from the Diving Medical Advisory Committee is attached at Appendix 1.

First aid administered on site should include the control of any bleeding along with elevation of the wound site. Medical advice should be sought immediately, especially if the injured diver is in saturation and will need to be decompressed before being transferred to a medical facility.

To assist with treatment in the event of injury to a diver from a high pressure water jet, a plastic card is available which highlights the nature of the incident. This card should be given to the attending medic or doctor (see Appendix 2). In the absence of the plastic card, the page in Appendix 2 can be cut out and sent with the patient to the medical facility.

Contact details for emergency medical assistance and the location of the nearest suitable medical facility should be known and documented in the emergency response plan before water jetting operations commence.

6 Operational Procedures

6.1 Working Practice

Water jetting should only be carried out under the instruction of the diving supervisor.

Regular breaks from continuous operation should be taken to prevent diver fatigue.

No divers should be involved in coincident diving operations if their safety could in any way be jeopardised by the close proximity of HP jetting operations, irrespective of how those jetting operations are being conducted, e.g. by other divers, persons using atmospheric diving suits, or by any type of underwater vehicle. Exclusion zones should be defined.

If a remotely operated vehicle (ROV) is available at a work site, consideration should be given to using it for diver monitoring during jetting operations, in accordance with AODC 032 – *Remotely operated vehicle intervention during diving operations*, provided that no additional hazards would be introduced by doing so. In addition to an ROV, diver hat mounted cameras may also be of assistance to the supervisor in view of the difficulties with audio communication between the diver and the surface during noisy jetting operations. It is absolutely essential, due to the noise generated during jetting operations, that some alternative form of signal is used to attract, when needs be, the diver's attention, e.g. flashing of the hat light by the supervisor.

When operating near the surface, or at the air/water interface, care should be taken to ensure that no other personnel are in such close proximity to jetting operations that their safety could in any way be jeopardised and that the area is kept clear of rigid or inflatable workboats, until the work is known to have been completed and the pump shut down.

The working area both topside and subsea should be kept free from tripping hazards or other debris. Adequate lighting should be provided at the subsea worksite and topside machinery site.

Prior to deployment and recovery of the water jet gun to and from the underwater worksite the pressurising water pump should be disengaged from the drive motor and any remaining pressure in the delivery hose should be released. It may be necessary to operate the trigger in order to release residual pressure in the hose. The trigger safety catch should always be engaged during deployment and recovery of the water jet gun.

High pressure water should only be supplied on request from the diver operating the subsea tool, with the lowest effective pressure to achieve the task to be used.

The signal to start the pump should only be given by the diver to the supervisor when he has reached his working position and is ready to start jetting. The supervisor should inform the diver that he is about to receive pressure from the surface unit.

Pressure should never be increased during a water jetting operation without informing the diver operating the subsea equipment.

Should the diver need to relocate his position during jetting operations the pressurising water pump should be disengaged from the drive motor and any remaining pressure in the delivery hose released prior to the start of the move. The trigger safety catch should be engaged throughout the move. The signal to start the pump should only be given by the diver to the supervisor when he has reached his new working position and is ready to start jetting.

On completion, saturation divers should ensure that their diving suits and umbilicals are cleaned of all jetting debris before entering the diving bell after using a water jet as this debris might be contaminated.

Subsea visibility could become impaired once water jetting commences. Care should be taken in diver positioning and the routing of hoses.

The lance can be easily damaged if either the lance or retro-jet housing is used to knock off hard marine growth. The lance should only be used for jetting.

Saturation diving bells, surface deployed wet bells or deployment baskets should be positioned upstream of the worksite.

6.2 Testing of Equipment before Use

All systems should incorporate at least one safety fluid shut off or dump device. After setting up the equipment on the surface, all shut off or dump devices should be checked to ensure that they are fully operative. In addition, it should be demonstrated that the safety systems have undergone routine inspection and maintenance and have been included in the equipment planned maintenance system (PMS) whilst deployed at the worksite.

Pressure should be increased slowly up to operating pressure when testing equipment.

6.3 Warning Notices

Adequate warning notices should be clearly displayed, stating that high pressure water jetting operations are underway and that the pump is running. Consideration should be given to the use of hazard barrier tape to identify the hazardous area on-deck and discourage entry to the area by unauthorised personnel.

Public address announcements should also be made before commencement and on completion of water jetting activities, if available on site.

6.4 Handling of Hoses

Great care should be taken in the handling and routing of high pressure hoses on the quayside, the deck of a surface vessel or around subsea infrastructure in order to avoid chafing, denting or abrasion against sharp edges.

Hoses should be supplied in long lengths with as few couplings as possible.

Hoses should be tied off at convenient locations to assist in minimising movement due to pressure supply changes or tidal/current movement.

Hoses should never be tied off to any part of any diving equipment.

6.5 Frost Precautions

When icy conditions are anticipated, adequate frost precautions should be taken by either draining the equipment after use or using a suitable antifreeze.

Under no circumstances should the pump be started if any freezing of the equipment is suspected, and this needs to be checked prior to any start-up of the unit. If ice has been retained in the system and the pump is started then it is possible for ice to be ejected from the hose at high velocity. In such circumstances 'ice bullets' may travel some 20-30 metres with possibly lethal consequences.

6.6 DP Interference

Noise and turbulence from HP jetting operations may interfere with the acoustic reference systems of a dynamically positioned ship.

DP operators should be consulted prior to the commencement of HP water jetting operations.

6.7 Communications

Audio communications can become greatly impaired during underwater jetting. It is the responsibility of the diving supervisor to monitor the diver's work and breathing pattern and to act quickly if any change in breathing rhythm or any sudden change in performance is observed.

The diving supervisor should be able to initiate shut down of the pump unit in case of emergency. This will require him either to be in direct and immediate contact at all times with the person responsible for operation of the pump during jetting operations, or to have an emergency cut off switch close to hand.

An alternative method of communication should be determined and in place in case the equipment noise compromises any radio or telephone communications between the deck crew operating the pump and the diving supervisor.

A person stationed at the pump during operations, in view of the diving supervisor and communicating by hand signals, could be considered for this. Any system of hand signals should be established and understood by all prior to the commencement of water jetting operations.

6.8 Abrasive Additives

There are two common methods of introducing an abrasive additive into the flow of water for cleaning and cutting operations: venturi injection or direct injection.

i) Venturi injection is where a hopper containing the abrasive, either dry or in a slurry mixture, is drawn into the high pressure flow via a separate supply hose.

ii) Direct feed is where abrasive is mixed into a break tank or pressurised container. A single hose then carries the water and abrasive to the cutting nozzle.

Uniform particle size, free from foreign material, should be used to minimise system blockages.

6.9 High Pressure Jet Cutting

Abrasive HP and UHP jet cutting techniques can be used for cutting most materials and are suitable for use where a cold cutting technique is required.

Protection should be provided to any components or structures that are within range of the cutting jet during cutting operations.

Components or structures being cut should be properly supported or secured prior to cutting commencing.

Before the commencement of cutting operations it should be established that any trapped or contained pressure has been released from the item to be cut, and that it is not load bearing.

6.10 Ultra High Pressure (UHP) Jetting

The jet velocity of a UHP system operating at 2,500 bar is in excess of 2,400 kilometres per hour.

The energy output from a 2,500 bar pump unit is approximately 18 times greater than the output from a 350 bar pump unit.

Risk assessments should consider this exponential increase in energy output as the pressure increases.

Water flow in UHP systems is usually lower than in HP systems. This means that the nozzle reaction force is not as high, even though the energy released is much greater. As a result UHP jetting guns will feel easier to control, but this should not result in complacency of the operator as the risks from greater energy release are high.

In the case of accidental contact a UHP jet will cut through tissue faster than an HP jet operating at substantially lower pressure. There is a risk of severe injuries e.g. amputation. However, the higher flow rates used in HP jetting cause greater damage to surrounding tissues as contaminated water is forced between the muscle planes. The actual energy applied to the body is related to both pressure and flow rate. Therefore pressure and flow rate should be considered in selecting appropriate personal protective equipment (PPE).

Jetting	Pressure	Typical Flow Rates
High pressure (HP)	Up to 1,700 bar	50-60 l/m
Ultra high pressure (UHP)	Above 1,700 bar	20 l/m

Table 1 – Comparison of pressure and flow rates in typical HP and UHP jetting systems

Special PPE for UHP water jetting is available and should be worn by divers operating UHP equipment. The types of special PPE available include clothing with enhanced penetration resistance and/or sectional rigid body protection, as well as boots with improved metatarsal protection (see references 1 and 5).

All components, including hoses, connections, and nozzles, in the UHP system should be suitable for UHP use.

Wherever possible, hand-held UHP cutting should be avoided and remote means employed, such as ROV mounted or jig mounted lances or nozzles.

7 Avoidance of Accidents during Underwater HP and UHP Water Jetting Operations

Direct injury through contact with the water jet stream itself is the most common cause of serious injury to divers engaged in water jetting operations. Divers engaged in underwater HP and UHP jetting operations consistently appear to come into contact with HP jet streams for the same handful of reasons:

1. Poor design of the equipment (in particular the barrel, retro jet, and trigger mechanism on the jetting gun).

2. Modification of the equipment without input and agreement from the manufacturer (in particular unauthorised modification of the barrel, retro jet, and trigger mechanism on the jetting gun).

3. Weld/component failure caused by inadequate maintenance of the equipment in accordance with manufacturer recommendations.

4. Weld/component failure due to damage caused by improper use of the equipment, e.g. use of the jetting gun as a pry bar, hammer or in other fashions likely to place undue stresses on the gun.

5. Loss of control of the trajectory of the jet stream during jetting operations. This may occur if the diver is not comfortably positioned and secure, e.g. during mid-water work. It may also occur if the retro on the jetting gun is ineffective and the gun becomes strongly unbalanced.

6. Complacency (inadequately trained divers and jetting team members often underestimate the risks associated with underwater HP water jetting operations).

A number of the failings listed above are evident in the incidents described by the two safety flashes attached to this document (see Appendices 4 and 5).

Observation of the safe working practices recommended in this guidance is likely to eliminate or greatly reduce the risk of diver contact with water jet streams.

8 References

1. *Code of Practice (Blue Edition) for the Use of High Pressure and Ultra High Pressure Water Jetting Equipment*; the Water Jetting Association; 2012 edition; ISBN: 1-874278-02-4.

2. *Recommended Practices for the Use of High Pressure Waterjetting Equipment*; the Water Jet Technology Association; fourth edition; 2011.

3. *High Pressure Washing: Safe Work Practices*; WorksafeBC; October 2008.

4. AODC 032 – *Remotely operated vehicle intervention during diving operations*.

5. *Protective Clothing and Footwear for use with Ultra High Pressure Water Jetting*; SIM 3/2002/22; the Health and Safety Executive; 31 May 2002.

6. *High Pressure Underwater Jetting*; AODC Safety Video.

Diving Medical Advisory Committee Recommendation: Accidents with High Pressure Water Jets

DMAC 03 – January 1981

With increased underwater activity relating to repair and inspection, it is becoming clear that accidents with high pressure water jets will occur. The following comments about the management of such accidents have been made by the Diving Medical Advisory Committee:

1. The wound caused may appear insignificant and give little indication of the extent of the injury beneath and the damage to deeper tissue.

2. Initial mild damage to the wall of an organ may result in subsequent rupture, particularly if infection has been introduced.

3. The development of subsequent infection is particularly important in abdominal and joint injuries.

4. The outcome depends upon the extent of initial injury and the presence or absence of infection, and even though the injury seems trivial on the surface and the patient has no complaints, it is of great importance to arrange for surgical examination as quickly as possible.

5. Where surgical examination is not immediately possible in a remote situation, first aid measures are confined to dressing the wound and observing the patient closely for the development of further complaints over four or five days. The development of fever and a rising pulse rate suggests that the injury is serious, together with persistence or occurrence of pain.

6. Where surgical advice or examination is unavailable or delayed, consideration should be given to providing the patient with a course of antibiotic therapy.

Advice to Attending Medic or Doctor

In the absence of a generic plastic information card, this page should be printed or cut from this document and sent with the patient to the medical facility.

The following general information should be communicated to the medical team.

"This man has been involved with high pressure water jetting at pressures up to 14,500 lb/in (100 MPa, 1000 bar, 1019 kg/cm^2) with a jet velocity of up to 900 miles (1440 km) per hour.

Please take this into account when making your diagnosis.

Unusual infections with micro-aerophilic organisms occurring at lower temperatures have been recorded. These may be gram negative pathogens such as are found in sewage and seawater. Bacterial swabs and blood cultures may therefore be helpful."

To assist with treatment in the event of injury to a diver from a high pressure water jet, a plastic card is available which highlights the overall nature of the incident. This card should be given to the attending medic or doctor.

It would also be helpful to provide specific information of the jetting activity.

Actual jetting pressure ..... bar/psi

Source of water supply (Filtered seawater, fresh water or other medium)

.....

Added chemicals (Include data sheets if available)

.....

Details of grit or abrasives added (Size, composition, data sheets)

.....

Details of possible residues from water jetting operation (Soft or hard marine growth, corroded metal, paint or concrete coatings)

.....

The generic plastic information card is available from:

The Water Jetting Association, Thames Innovation Centre, Veridion Way, Erith, Kent DA18 4AL
Tel +44 (0) 20 8320 1090
Email enquiries@waterjetting.org.uk

Useful Contacts

Australia	Ausjet PO Box 179 Thirroul NSW 2515	Telephone Fax Email Website	+61 (0) 430 391 166 +61 (0) 2 4268 1781 support@ausjetinc.com.au www.ausjetinc.com.au
Italy	AIW – Associazione Italiana Waterjet c/o Politecnico di Milano Dipartimento di Meccanica via Bonardi 9 20133 Milan	Telephone Fax Email: Website:	+39 02 2399 4925 +39 02 7063 8377 aiw@aiw.polimi.it www.aiw.polimi.it
UK	The Water Jetting Association Thames Innovation Centre Veridion Way Erith Kent DA18 4AL	Telephone Fax Skype Email Website	+44 (0) 20 8320 1090 +44 (0) 7595 517048 +44 (0) 20 8320 1094 +44 (0) 20 3287 6640 enquiries@waterjetting.org.uk www.waterjetting.org.uk
	Diving Medical Advisory Committee (DMAC) Eighth Floor, 52 Grosvenor Gardens London SW1W 0AU	Telephone: Fax: Email: Website:	+44 (0) 20 7824 5520 +44 (0) 20 7824 5521 info@dmac-diving.org www.dmac-diving.org
USA	Water Jet Technology Association 906 Olive Street, Suite 1200 Saint Louis, MO 63101	Telephone Fax Email Website	+1 (314) 241 1445 +1 (314) 241 1449 wjta@wjta.org www.wjta.org

Extract from IMCA Safety Flash 05/11: Diver Safety – High Pressure Water Jetting Operations

The Australian National Offshore Petroleum Safety Authority (NOPSA) has recently published Safety Alert 46 (attached) regarding diver safety during high pressure water jetting operations. The alert highlights an incident where a diver sustained a serious injury when the retro diffuser tube became detached from the gun allowing the full force of the retro jet to penetrate the diver's arm.

This information can also be found at www.nopsema.gov.au/assets/alert/Alert46.pdf

NOPSA Safety Alert 46

Diver Safety – High Pressure Water Jetting Operations

What happened?

A saturation diver undertaking High Pressure (HP) Water Jetting Operations sustained a serious injury when the retro diffuser tube became detached from the gun allowing the full force of the retro jet to penetrate the diver's arm.

This accident serves as a reminder of the risks to divers involved with using this type of equipment and in particular those risks posed by the retro jet of underwater jetting guns.

What could go wrong?

HP water jetting equipment has been in use in the offshore petroleum and diving industries for many years and a number of related incidents have occurred. Many of these were caused by the forward lance, however NOPSA is aware of at least two other incidents in which divers operating this type of equipment have sustained injuries from the retro jet.

Whilst there are a number of types and designs of HP water jetting guns for underwater use, they all employ a retro diffuser tube to balance the force of the forward jet. Additionally, some guns utilise a shroud which is positioned over the venturi inlet holes to reduce the likelihood of items being drawn into the venturi water flow.

As this type of equipment requires the retro jet to be necessarily positioned close to the body of the diver operating the gun, the retro diffuser tube is designed to protect the diver from the retro jet and dissipate the energy by allowing surrounding seawater to enter through machined holes in the retro diffuser tube. The retro diffuser tube should be designed such that the exit wash from the tube is no longer of a velocity that can cause harm to the diver or equipment (umbilicals for example).

Underwater HP water jetting guns are subjected to a number of dynamic forces which act on safety critical components including the retro tube. The retro diffuser tube is the only control barrier protecting the diver operating the gun from the retro jet, therefore great care is required to ensure this barrier is appropriately designed, tested and is functioning correctly.

Injuries caused by HP water jets are typically serious with high risk of infection due to injection of debris and other water borne contaminants. This is a particular consideration for divers in saturation who will have to complete lengthy decompression before they have full access to medical intervention.

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A164934 11 April 2011 nopsa.gov.au

Diver Safety – High Pressure Water Jetting Operations

Key Lessons:

Prior to using HP water jetting equipment NOPSA strongly recommends thorough checks are carried out by competent persons to ensure that the associated risks are reduced to a level that is as low as reasonably practicable.

Whilst not a complete list, those considering use of such equipment should ensure that:

- The manufacturer's operating instructions and recommendations are detailed within documentation that is held on site with the equipment;
- The equipment is assembled and used in accordance with the manufacturer's operating instructions and recommendations;
- The design of equipment used is appropriate for the intended use and has been rigorously tested and proven before use;
- All components, including the retro diffuser tube and venturi shroud (if fitted) are correctly assembled and secured in accordance with manufacturer's instructions;
- The equipment is inspected, tested and maintained in accordance with the manufacturer's instructions, supplemented with regular inspections to check for signs of:
  - physical damage and wear; and
  - erosion, especially on the inner wall of retro tube and around the venturi holes. (Grit and other debris resulting from the activity can be entrained into the retro tube via the venturi holes, giving rise to erosion potential).

Operators of facilities are reminded that they have a duty to take all reasonably practicable steps to provide and maintain equipment that is safe and without risk to health.

Diving contractors are similarly reminded that they have the responsibility to take all necessary steps to provide and maintain equipment that reduces risks to the safety and health of divers to as low as reasonably practicable.

Contact

For further information email alerts@nopsa.gov.au and quote Alert 46.

Extract from IMCA Safety Flash 06/07: Diver Injury Using Cavitation Blaster

A member has reported that a diver sustained a high pressure water injection injury whilst using a recently developed 4500 psi cavitation water blaster.

Cavitation gun

Retro jet showing proximity of nozzle to end of baffle (approx 3 cm)

During marine growth removal operations the diver released the trigger on the cavitation gun to reposition his body. When the diver reapplied pressure to the trigger, the cavitation gun kicked back towards the diver, causing the retro end of the gun to come into close proximity of his wrist and forearm. The retro jet subsequently caused a high pressure (approximately 1000 psi) seawater injection injury to the diver's forearm.

The injured diver was successfully treated with antibiotics at an onshore hospital facility and did not require surgery.

The risk assessment had not highlighted the fact that the retro jet posed a high pressure injection risk to the diver.

The incident investigation discovered that the diver had not been wearing the 11 inch long butyl rubber gloves as recommended by the system manufacturer but it was unclear if wearing these would have prevented the injury.

The manufacturer has now modified the retro jet by moving the nozzle further back inside the rear baffle. The company involved will be carrying out a full examination of the modification before allowing the cavitation blaster back into use.