2018

Delta P in Diving - Risks and Prevention

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Commercial Diver

March 2018

FOR MY FRIEND KENNY WHO LEFT US ONE NIGHT IN JUNE 1979 BECAUSE OF THIS SHIT

Warning

This document is published for information purposes to enlighten people affected by the condition known as Delta P' and the risks it creates. The content is far from complete and is therefore not sufficient to control the risks specific to each site. Individuals are strongly cautioned to perform their own risk assessment and provide appropriate solutions.

The author therefore discharges all responsibilities in case of an accident.

Acknowledgments:

Many thanks to Hal Lomax for his help in the correct translation of this document

Original title:

Les Deltas P en plongée

Risques et Prévention

Francis Hermans 2017

Contents

Introduction

According to a recent study[1], accidents due to a delta P (differential pressure) are the single most common cause of fatal accidents in the commercial diving sector. For the most part, commercial divers are aware of this phenomenon, but unfortunately many of them seem to underestimate this risk. No less than 127 such accidents occurred between 1975 and the end of 2014 and delta P incidents are usually fatalities. All sectors of commercial diving have exposure to delta P, but the civil engineering divers (inshore), pay the highest price.

Make no mistake - accidents due to differential pressure are not “fate” or “bad luck” and in most cases the accidents that have occurred could have been avoided. This short guide is intended to highlight what delta P is and the ways to protect divers from it.

Definition

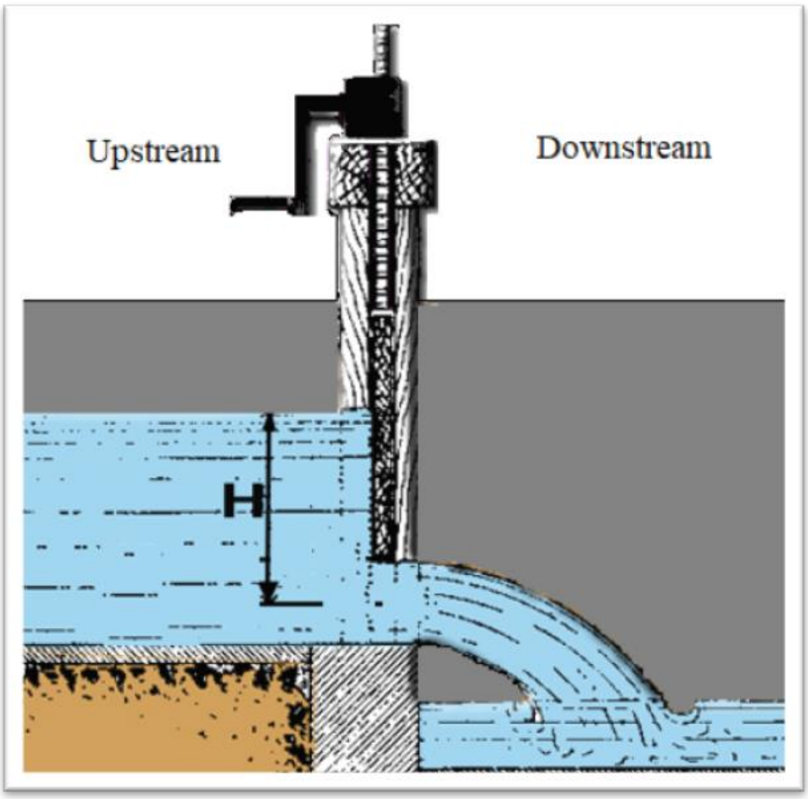
What is delta P (ΔP)?

In simple terms, delta means “difference” in Greek and is represented by a small triangle while “P” in physics, stands for pressure.

Delta P is the pressure difference measured between an upstream pressure and a downstream pressure, or between unequal water heights on either side of a barrier.

In the presence of an opening this pressure difference (H) will allow the passage of a certain amount of liquid (flow) that will move at a higher or lower rate.

Fig. n° 1: Illustration of a delta P at a valve level



The approximate water flow through an opening can be calculated using the formula:

$$Q = \text{Constant} \times \text{Area} \times \sqrt{H}$$

Where

Q = flow rate in m^3 / sec (ft^3 / sec)
Constant = 4.43 (or 8.02)
Area = area of the opening in m^2 (ft^2)
H = height of water (or difference) in meter (ft.)

As example of calculation let us use the fig. n° 1 to calculate the flow and let us imagine that H is equal to 3.8 m (12.6 ft.) and the surface of the opening equal to 1 m^2 (10.76 ft^2).

$$Q = 4.43 \times 1 \times \sqrt{3.8} = 8.63\ m^3/sec$$

Or

$$Q = 8.02 \times 10.76 \times \sqrt{12.46} = 304.61\ ft^3/sec$$

The approximate speed of the flow of water passing through an opening can be calculated using the formula:

$$V = Q / \text{Area}$$

Where

V = speed in m / sec (ft. / sec)
Q = flow rate in m^3 / sec (ft^3 / sec)
Area = area of the opening in m^2 (ft^2)

Taking the example above, we can estimate that the speed of the current passing through this opening will be approximately:

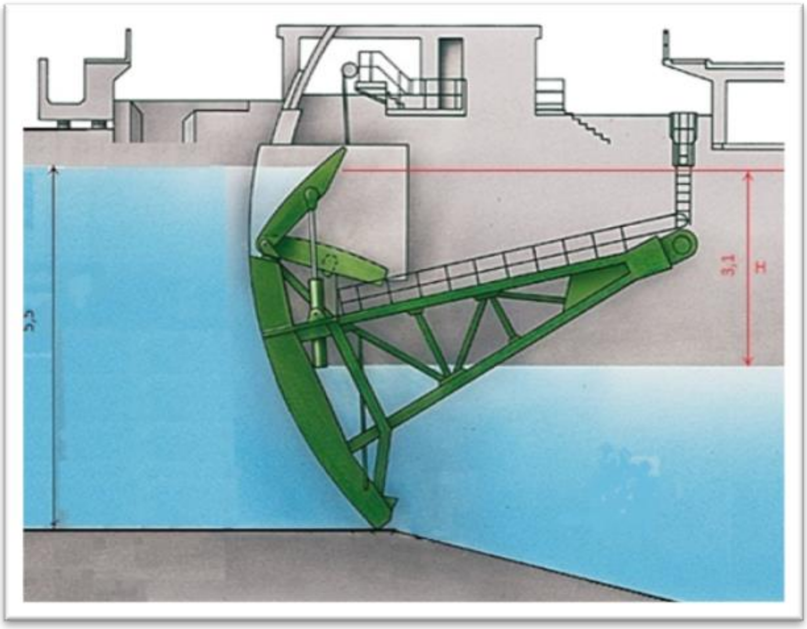
$$V = 8.63 / 1 = 8.63\ m / sec$$

Or

$$V = 304.61 / 10.76 = 28.31\ ft. / sec$$

As illustrated in Fig. n° 2, H can also be represented as equal to difference in height between upstream and downstream.

Fig. n° 2: Illustration of a ΔP in function of a water height difference (H) (extract doc. Internet)



When talking about delta P during a diving operation, we generally refer to a risk that may occur because of the presence of a hole, a fracture or any opening in a structure where there is a difference in water level or pressure that allows water to pass from a high pressure zone to a low pressure zone with a greater or lesser flow.
As long as a solid physical barrier prevents the passage of water between these two areas, the risk of accident is non-existent.
However, as soon as this barrier is broken and a delta P is initiated, the power of the flow then confronts the diver in the vicinity with two phenomena:

- A stream of water which is going to pull him towards the opening.
- A force that is going to push him against or in the opening.

The first phenomenon is due to the fact that the quantity of water on the upstream side begins to move (flow) toward and pass through the opening.
The speed of the current is going to remain more or less constant until a certain distance from the opening and then suddenly the current will increase close to the opening.
To illustrate this, let us take the example of the fig. n° 3 and let us imagine a sector gate situated at the end of a channel of 27.5 m² (296 ft²) of section and that under this segment valve a part of the bottom slab is damaged over a height of 0.1 m (0.33 ft.) and a length of 2 m (6.56 ft.), either an area of 0.2 m² (2.16 ft²).
By taking again the formulas used for the calculation of the flow and velocity of the current, one notes that the quantity of water passing by the defect is equal to:

$$Q = 4.43 \times 0.2 \times \sqrt{3.1} = 1.56 \text{ m}^3 / \text{sec}$$

Or

$$Q = 8.02 \times 2.16 \times \sqrt{10.17} = 55.24 \text{ ft}^3 / \text{sec}$$

And that the speed of passage is equal to:

V = 1.56 / 0.2 = 7.8m / sec

Or

V = 55.24 / 2.16 = 25.57 ft. / sec

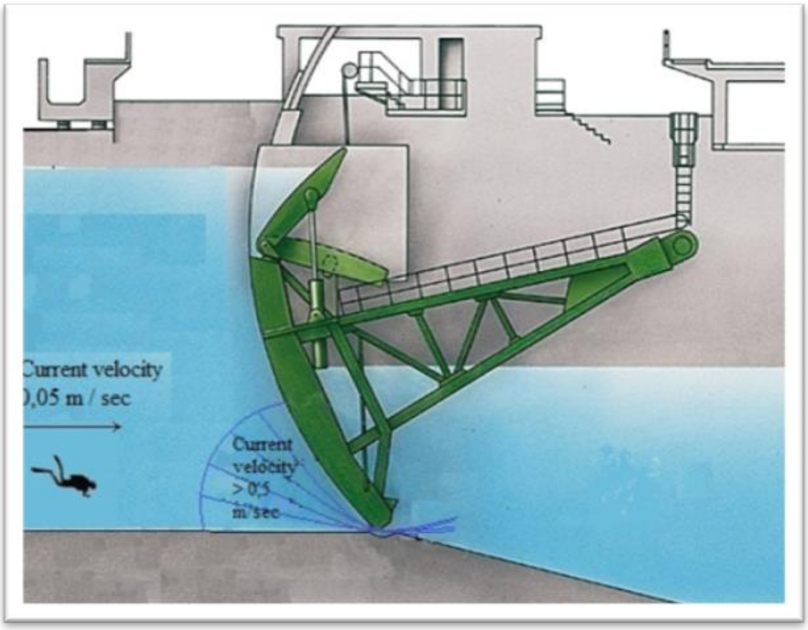
While that in the channel the speed of the current is only equal to:

V = 1.56 / 27.5 = 0.05 m / sec

Or

V = 55.24 / 296 = 0.19 ft. / sec

Fig. n° 3: Illustration of the current velocity in the inlet channel (extract doc. Internet)



In the commercial diving world, it is generally considered that a diver can work without too much difficulty in a current not exceeding 0.5 m / sec (1.64 feet / sec).
Beyond this speed, he will be rapidly swept away if special means are not implemented.
In our example, we can see that at the entrance of the channel, the diver is in a safe area (5 cm / sec) (1.96" / sec).
However, if no safety measures are put in place to prevent him from approaching the gate, he may end up in a danger zone (DZ) where the water flow is quickly going to accelerate and exceed 0.5 m / sec (1.64 feet / sec).

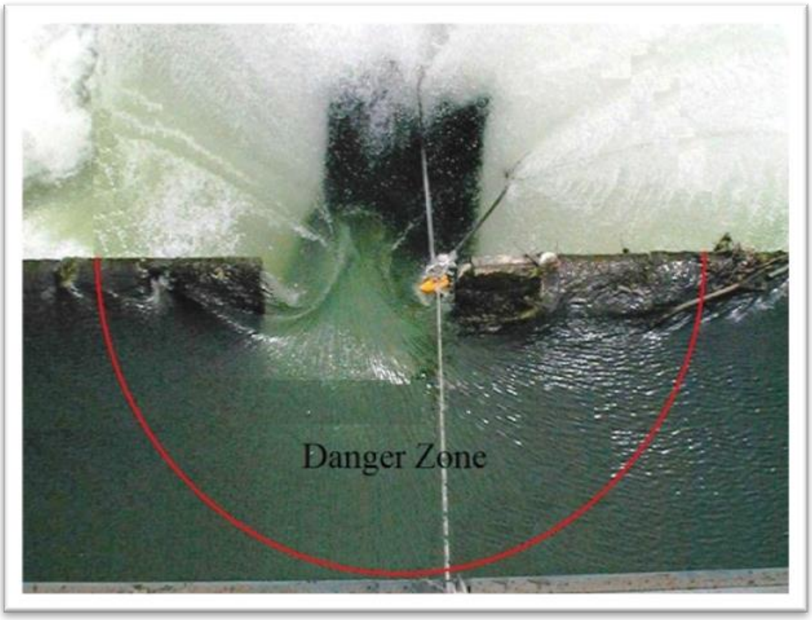
The **theoretical** distance from where the stream of water is suddenly going to increase beyond 0.5 m / sec (1.64 feet / sec) can be calculated using the formula:

$$DZ = \sqrt{Q / (\pi \times C)}$$

Where

DZ = danger zone
Q = flow rate in m^3 / sec (ft^3 / sec)
π = 3.1416
C = constant 1 or (3.28)

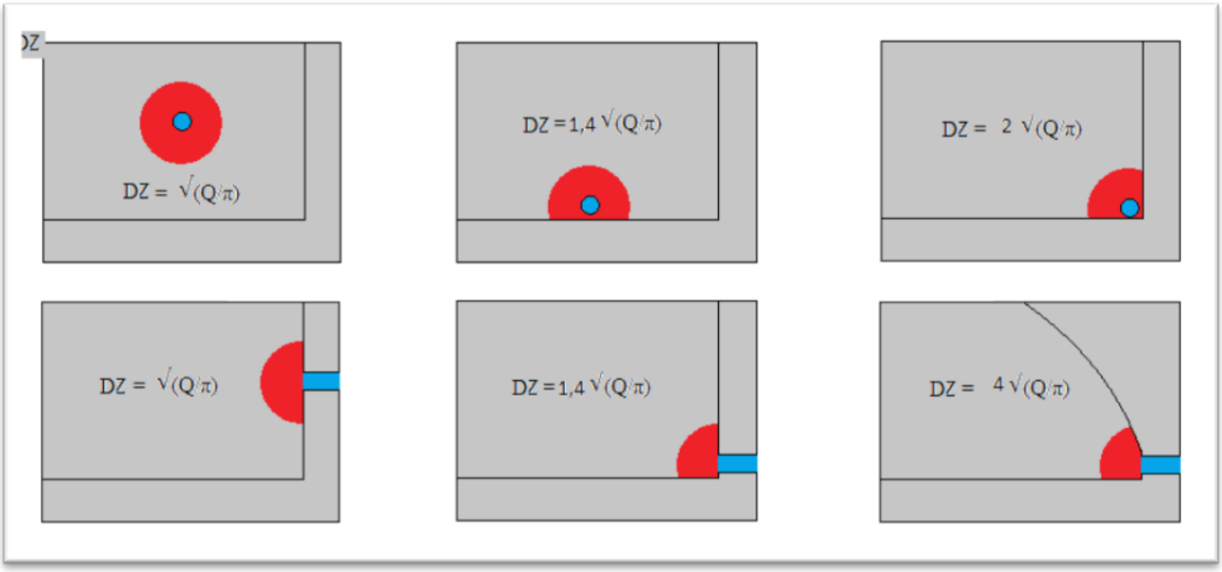
Photo n° 1: Illustration of a danger zone (DZ) (extract doc. Renan Legal)



The exact calculation of the magnitude of this danger zone is, however, rather difficult to determine because it depends on many parameters.
In an ideal configuration, the flow of water in which the molecules will start to take speed will have the shape of a half-sphere.
This situation is usually found when the opening is quite far from the bottom and / or side wall (s) and in this case the above formula can be used to determine the danger zone.
In the other cases, the hemispherical flow will be partially impeded by one or several bulkheads and the basic formula will have to be increased by a factor (fc) depending on the following configurations (see fig. n ° 4):

- fc = 1.4 if the opening is close to two walls at right angles.
- fc = 2 if the opening is close to three walls at right angles.
- fc = 4 if the opening is close to three walls at right angles and one inclined inwards.

Fig. n° 4: Illustration of the effects of the configuration on the hemispherical flow



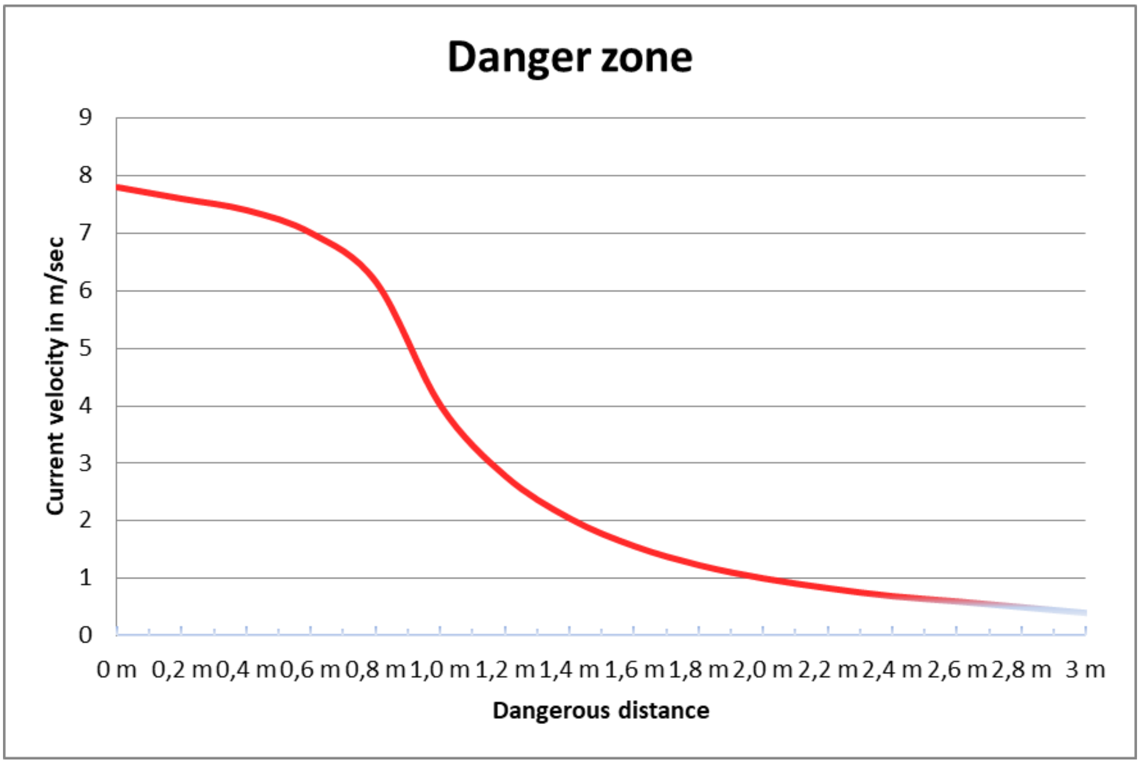
With these formulas we can now determine the **(theoretical)** danger zone for the example in fig. n ° 3.

$$DZ = 4 \sqrt{1.56 / (3.1416 \times 1)} = 2.82 \text{ m}$$

Or

$$DZ = 4 \sqrt{55 / (3.1416 \times 3.28)} = 9.25 \text{ ft.}$$

Graphic n° 1: Determination of the flow velocity (m/sec) in function of the distance (m) following example fig. n° 3.



As can be seen on the graph n°1, the decrease of the current speed depends on the distance from the opening and in this case it is necessary to move 2.8 m (9.25 ft.) away from it to regain a velocity of less than 0.5 m / sec (1.64 feet / sec).
By staying outside this danger zone, the diver does not run a great risk, but as soon as he enters it he will inexorably and quickly be sucked towards the opening where he will be tackled by the pressure of the water.

Table n ° 1: Estimation in meters of the minimum safe distance according to the flow

	Flow (m^3/sec)									
DZ (m)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
$1\sqrt{(Q/\pi)}$	0.17	0.25	0.31	0.36	0.40	0.44	0.47	0.50	0.53	0.56
$1{,}4\sqrt{(Q/\pi)}$	0.25	0.35	0.43	0.50	0.55	0.61	0.66	0.70	0.74	0.79
$2\sqrt{(Q/\pi)}$	0.35	0.50	0.61	0.71	0.80	0.87	0.94	1	1.07	1.13
$4\sqrt{(Q/\pi)}$	0.71	1	1.23	1.43	1.6	1.75	1.89	2	2.14	2.27

The capacity of a diver to free himself from such a trap is variable and will depend in particular on the pressure difference through the opening, the surface of the body or part of the body in contact with the opening, the flow rate around the jammed portion, the frictional force between the body and the opening, and its position as well as the diverse supports he could use.
If we go back to the above example (fig. 3) and imagine that our diver has his fin, leg and pelvis pressed against the opening (a length of +/- 1.4 m (4.6 ft.)), the following formula can be used to calculate the force that is going to hold him in place.

$$F = H \times Area \times D \times 1000$$

Or

$$F = H \times Area \times D$$

Where

F = strength in kg (lb.)
H = water height or pressure difference in meters (ft.)
Area = area of the opening closed by the diver in m^2 (ft^2)
D = density of the liquid in g / cm^3 (lb. /ft^3)

$$F = 3.1 \times (0.1 \times 1.4) \times 1 \times 1000 = 434 \text{ kg}$$

Or

$$F = 10.17 \times (0.33 \times 4.6) \times 62 = 957.15 \text{ lb.}$$

Seeing the figures above, we realize immediately that the diver will unfortunately have no chance of escaping on his own and that his possibility of salvation can only take if the suction stops and pressure balancing occurs, or if he is quickly pulled away by an effective lifting system. Unfortunately, for this second hypothesis, the risk of serious trauma or death is great because the resilience of the human body is not very high.

The risk of accident is always present near delta P and whatever the depth because even under only 0.5 m (1.64 ft.) of water it can generate a serious accident.

So, let us now take the example of the figure n ° 5 where a discharge pipe of Ø 30 cm (1ft.) evacuates the surplus of a basin of retention.
If a diver passes near and is sucked at the torso, the pressure exerted on him will then be:

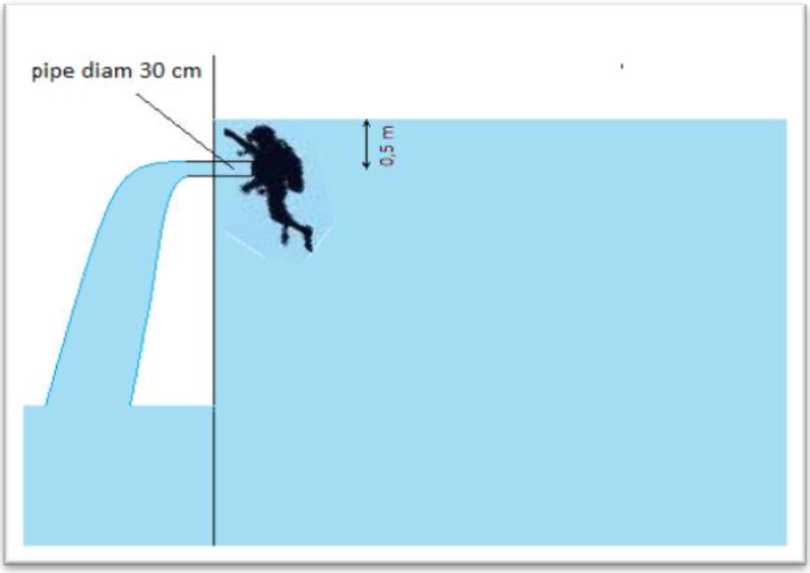
$$F = 0.5 \times (0.3^2 \times 3.1416 / 4) \times 1 \times 1000 = 35.34 \text{ kg}$$

Or

$$F = 1.64 (1^2 \times 3.1416 / 4) \times 62 = 79.85 \text{ lb.}$$

Even if it does not look huge, this force is already enough to hinder breathing and disrupt blood flow.

Fig. n°5: Illustration of a diver caught in delta P at 0.5 m (1.64 ft.) under water



One could also think that delta P over a smaller surface at a greater depth is less dangerous, unfortunately this is not the case.
So, suppose that after the installation of the cofferdam (here below on photo n° 2 and fig. n°6) there is a water difference of 23 m (75.46 ft.) between the (now) empty door chamber and the sill floor of the lock.
There at the level of one of the rails we have a leak on both sides with a surface of about 2 x 10 x 2 = 40 cm² (6.2”)

$$F = 23 \times 0.004 \times 1.025 \times 1000 = 94.3 \text{ kg}$$

Or

$$F = 75.46 \times 0.043 \times 64 = 207.66 \text{ lb.}$$

Thus here also we notice that according to the concerned part of the body, the diver will have quite a lot of problem to get free and the risks of more or less serious injuries will be real.

Photo n° 2: Installation of a cofferdam (doc. Internet)

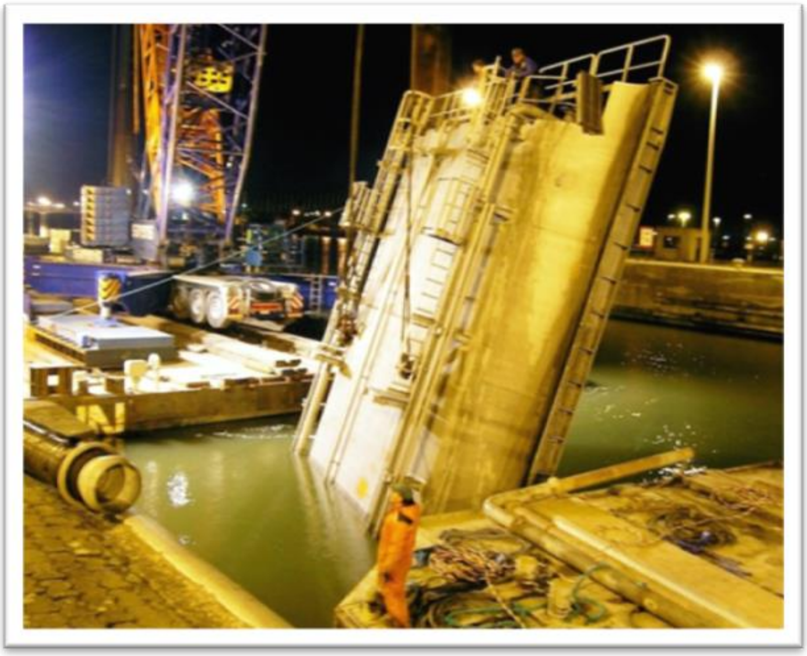
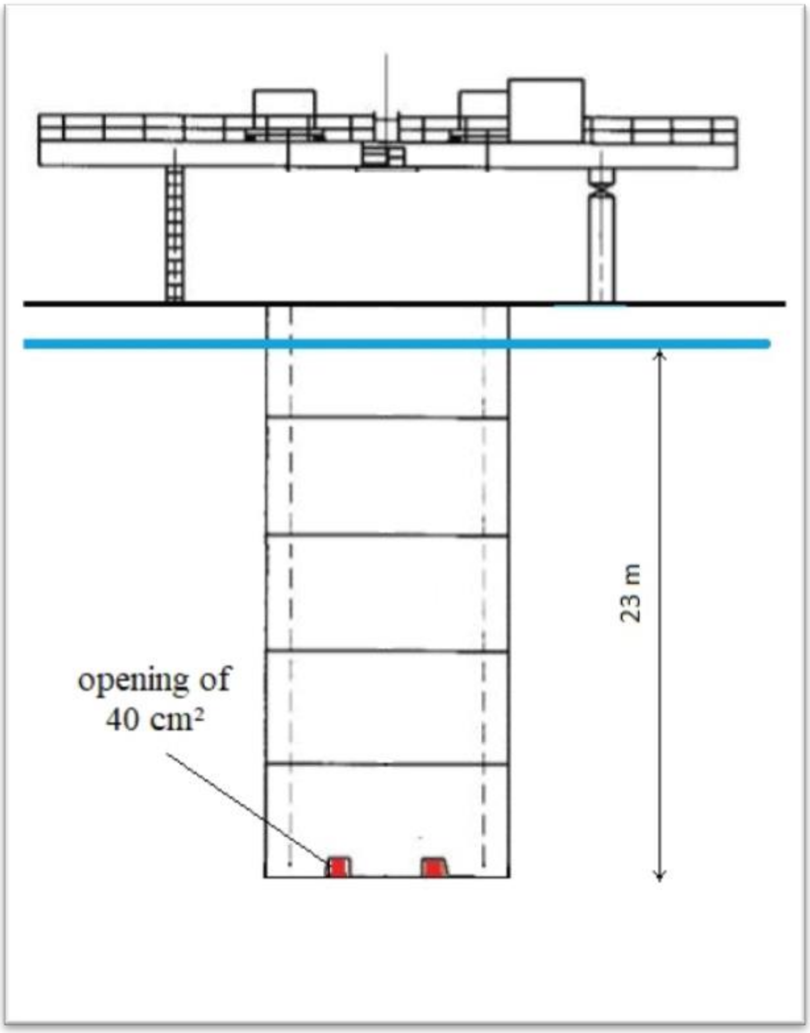


Fig. n° 6: Illustration of a sluice enclave cofferdam (front view)



Another problem that appears in the two previous examples is due to the fact that because of the low flow that passes through the opening, the dangerous zone (DZ) is in both cases very small.
Thus for the risk located at 0.5 m (1.64 ft.) under water, the danger zone will only be:

$$DZ = \sqrt{0.219 / (3.1416 \times 1)} = 0.26 \text{ m}$$

Or

$$DZ = \sqrt{8.06 / (3.1416 \times 3.28)} = 0.88 \text{ ft.}$$

While for the leak on the cofferdam it will be:

$$DZ = 1.4 \sqrt{0.084 / (3.1416 \times 1)} = 0.23 \text{ m}$$

Or

$$DZ = 1.4 \sqrt{2.96 / (3.1416 \times 3.28)} = 0.75 \text{ ft.}$$

This small distance can represent an additional risk for the diver, especially in cases where he works in an environment where visibility is reduced or even zero and that is why in the following pages, we will see the methods that are going to allow us to detect this risk.

Detection of delta P

A good way to avoid being caught by Delta P is to know the locations where the phenomenon typically occurs. This can be done by a:

- Surface detection without diving.
- Diving detection.

The first thing to do when working in a risk zone is to go upstream and downstream of the structure to identify if any whirlpools, vortexes or eddies are visible.

Photo n° 3: Vortex created by delta P (doc. Internet)

Photo n° 4: Downstream eddy on a dam (doc. Internet)

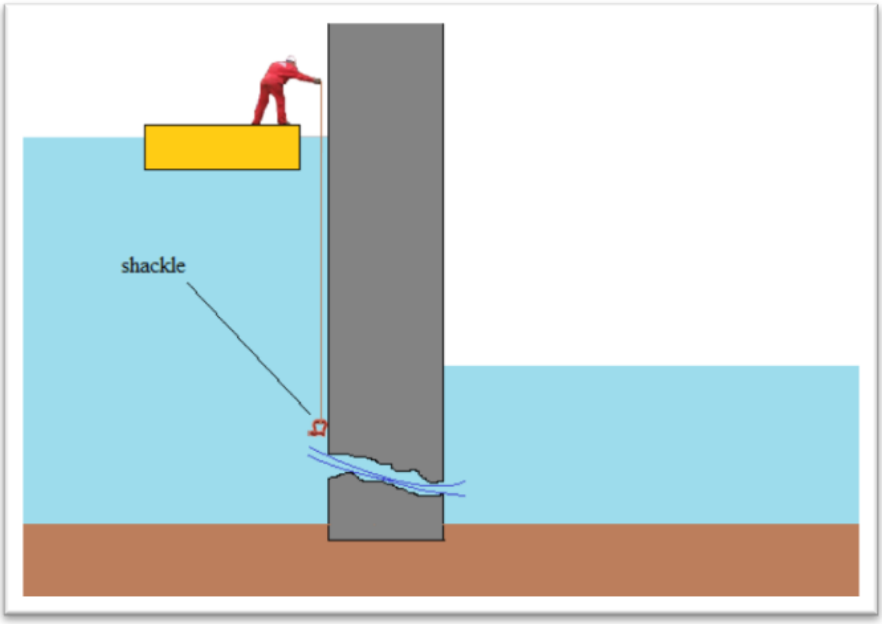
The presence of one or more of these phenomena would be the proof of a passage of water between the two zones.
Unfortunately in many situations no disturbance can be noticed on the surface because they are related to the flow and the depth of the delta P.
In this case, one of the following methods can be used:

- Manual detection.
- Detection by CCTV (video camera).
- ROV detection.
- Detection by an acoustic Doppler current profiler.

Manual detection

The first method we can use when we suspect or search for delta P of low amplitude is to slowly lower a rope (+/- Ø 10 mm) weighted with a small shackle (SWL 3.5 to 5 t) in front of the suspect zone.
As soon as the shackle approaches the area where the water flux begins to accelerate, it will start to oscillate and cause a vibration on the rope that will be transmitted to the surface.
The method suggested above can only be used in water where there is no current because otherwise the shackle would vibrate without stopping and would because of its low weight be carried by the current.
To look for larger areas of delta P, the small shackle can be replaced by a larger one or a by a bag with a capacity of about 20 litres (0.7 ft^3) filled with sand or clay.
Here again, as soon as the bag passes into the reaction zone, it will be attracted and sucked into the opening and we will then be able to realize the importance of the flow rate according to the force used to extract the bag.

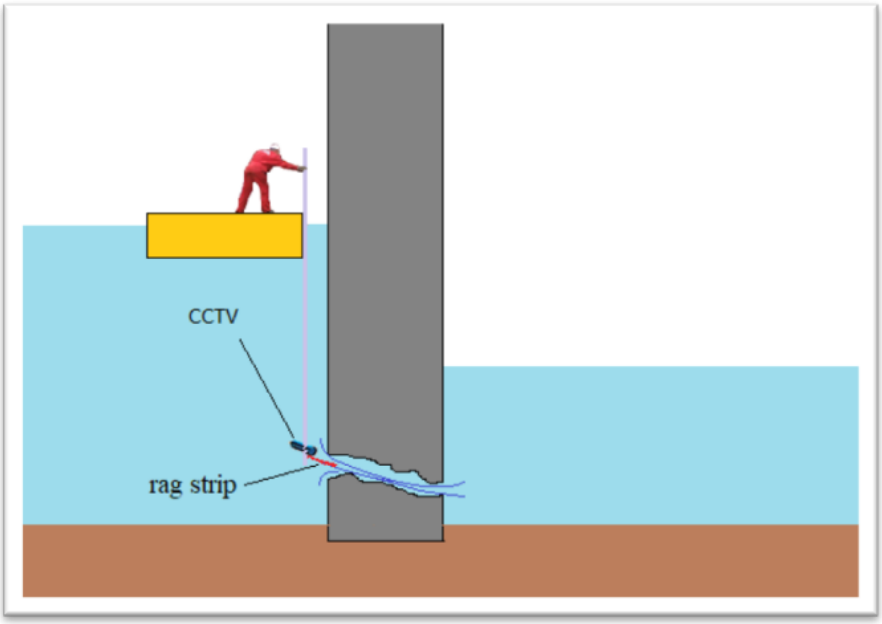
Fig. n° 7: Illustration of delta P detection with a shackle



Detection by camera (CCTV)

Another method that can be used from the surface in relatively clear water (> 20 cm or 7”) and shallow water (<5 m or 16 ft.) is to put a waterproof camera on an aluminium tube or other material and fix a rag strip about 60 cm (2ft.) long on it.
In the presence of delta P, we will see on the screen that the cotton strip is sucked towards the opening.

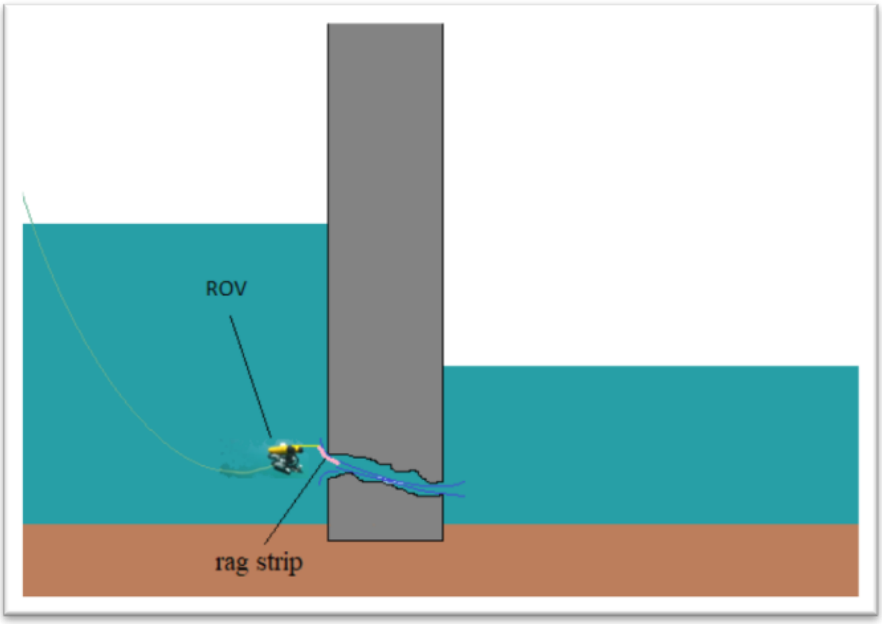
Fig. n° 8: Illustration of a delta P detection with a CCTV



Detection by ROV

For greater depths and when the surface to be inspected is important, the implementation of a remotely operated vehicle (ROV) can be the ultimate solution for finding and detecting delta P in water with some visibility.
This type of remote-controlled machine has the advantage to avoid the sending of a diver.
On the other hand according to the type used, they can be more or less expensive and in case of jamming the cost can be relatively high.
This loss would of course be regrettable, but the price to be paid for his replacement will in all cases always be cheaper than the life of a commercial diver.
To reduce the risk of loss, it is preferable to install a small pole equipped with a cotton strip in front of the ROV, which will allow the operator to be warned in time of the presence of a suction zone.

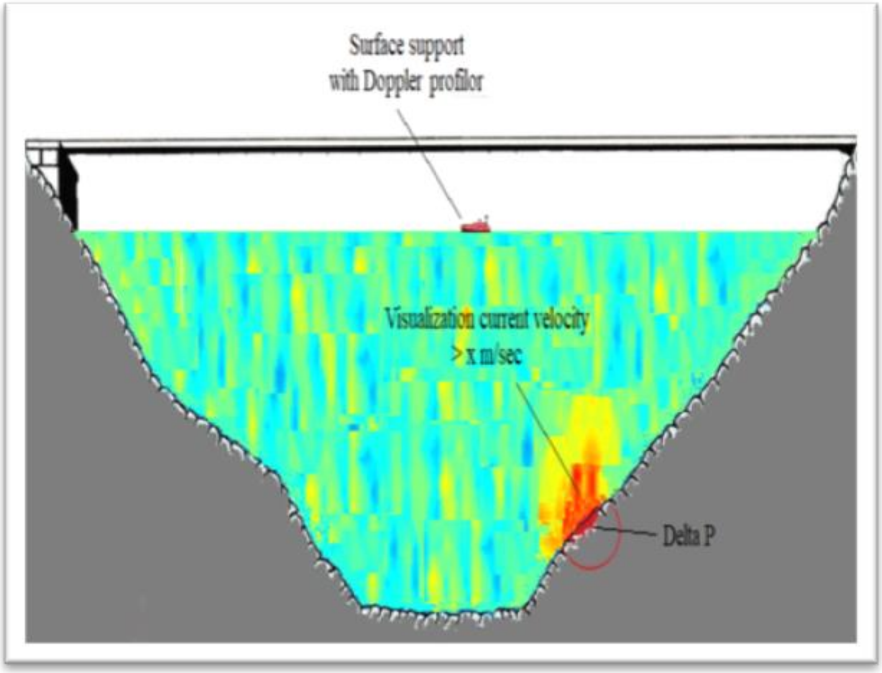
Fig. n° 9: Illustration of detection with a ROV



Detection by an acoustic Doppler current profiler

Lastly, and although this is not their primary function, there are now extremely high-performance and precise devices called Acoustic Doppler current profilers (aDcp), which are equipped with beam sensors that make it possible to measure water heights and the corresponding current speeds.
Usable in stationary or mobile mode, we could consider using these types of devices to scan along a suspicious area.
Software then interprets the results and visualizes the speed of the current from a colour code.

Fig. n° 10: Illustration of detection with an aDcp and visualization software



Diving detection

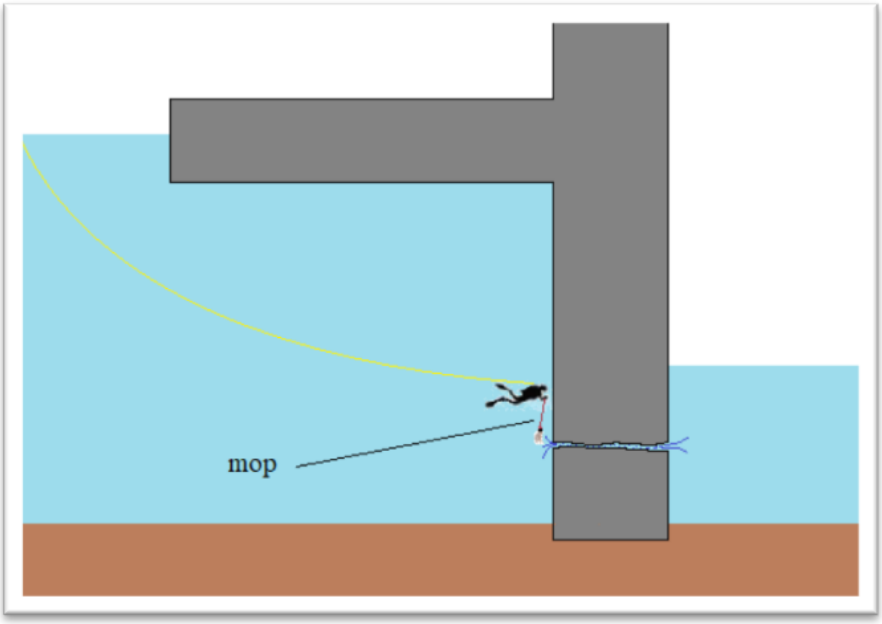
Sometimes, the identification from the surface is not possible because of accessibility problems, or the investigation by other means showed nothing but doubt remains.
An inspection dive is then necessary to determine whether the area presents a risk or not.
The safest method of diving to detect a delta P is when it is possible to dive downstream of the structure to check whether a current is present.
If downstream diving is not possible, the upstream research should be done with the utmost caution.
In this case one of the following methods can be used:

- Control with visibility.
- Control without visibility.

Control with visibility

The safest way to move in the water is to stay in the horizontal position which limits the risk of getting your legs sucked in a fault.
In clear water, the diver may use an old mop or a handle equipped with rag strips that can inform him in advance of the presence of a stream of water.
When the visibility is low and does not allow us to see the end of the mop, it is then better to install an underwater camera equipped with a strip of rags on a handle of about 1.5 to 2 m (5 to 7 ft.) and in this case it will be up to the dive supervisor to inform the diver of the hazard.

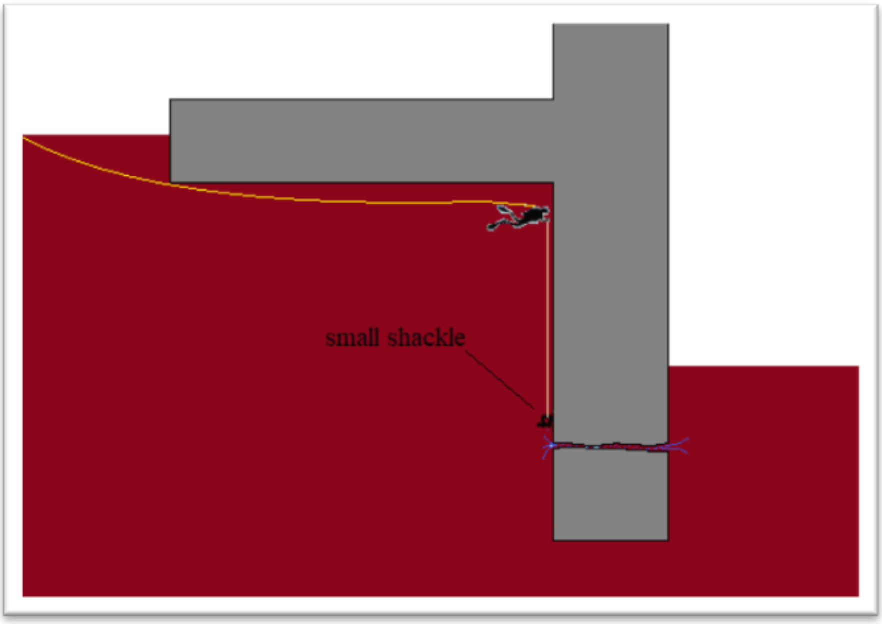
Fig. n° 11: Illustration of an underwater control with visibility



Control without visibility

In case of zero visibility as is often the case in inshore diving, a good means of detection is for the diver to move in a horizontal position with a small rope hanging under him (Ø 5 mm) of 3-5 meters (10 – 17 ft.) weighted with a small shackle.
The slightest current will start to vibrate the shackle and warn the diver of the presence of danger.

Fig. n° 12: Illustration of a control without visibility



Whichever method is used, it is advisable to extend the inspection area by at least 5 meters (10 ft.) on both sides of a suspect area.
It should be noted that underwater delta P is often audible and is heard in the form of a whistle or rumble, depending on the speed or volume of the flow passing through the opening.
Divers should therefore listen carefully when approaching a suspected delta P area for a whistling, hissing, or rumbling sound.
This will be a definite indication of delta P conditions.

Means of prevention

When diving in or near a delta P area, the best way to avoid an accident is to eliminate the risk. Various methods can be used depending on the situation:

- Balancing the water levels.
- The lock-out procedure.
- Clogging.
- Setting up protection.
- Setting up a current deflection system.
- Setting up a displacement restraint system.

Balancing the water levels

Balancing the water levels between two distinct zones is the best way to avoid accidents because if there is no difference in water level there is no water flow. Unfortunately, there are a lot of places where balancing the water levels is not possible; for example on certain types of dams. On the other hand, when this technique is put in place, it must be ensured that the situation does not change during the day because of certain phenomena (tide, flood, etc.).

Lock-out procedure

Locking-out is the method used to isolate an element whose opening or starting could unexpectedly trigger delta P while a diver is in the water.
There is no typical lock-out procedure, but for it to be effective, it has to take two forms:

1. A written warning or notice
2. A physical lock or barrier

The written warning or display must indicate the presence of divers in the water and stipulate manoeuvres or machine starts are not permitted without the approval of the diving supervisor.
In certain situations, for example when working on boats, language problems may exist.
The notice must therefore be written in a language understandable by the crew responsible for the lockout. This sole warning message is however not enough because it is not always respected to the letter and therefore it is also necessary to block by a physical lock or a barrier,

the gear that could be started unexpectedly. This physical lock must prevent any attempt at start-up.

Photo n° 5: Example of an warning display (doc. Internet)

One of the most effective ways is to shut off the power supply triggering the start by removing the fuses.

Photo n° 6: Example of an electrical lockout (doc. Internet)

Another way is to lock the system mechanically with padlocks. In both cases, the fuse (s) and/or keys will be held by the diving supervisor until the end of the dive.

Photo n° 7: Example of a mechanically padlocks lockout (doc. Internet).

It must also be remembered that in some structures pumps, valves, gates, etc. may be energized automatically and remotely. It is therefore absolutely essential to verify in advance where the start order comes from, and to get in touch with this service and ensure a lockout.

Clogging

Clogging (sealing) an opening can be an effective technique when other methods cannot be implemented. Depending on the size of the opening, the products generally used are:

- Blast furnace ash.
- Coal cinders.
- Cotton tows.
- Cotton rags.
- Clay bags.
- Loose clay.
- Manure (cow or sheep).
- Ropes.
- Rope fences.
- Sealing sheet and collision mat.

Although banned in some countries because of its pollution problems, the ash of blast furnace is still used because it is an effective way to seal small openings ≤ 5 millimetres (0.2”).

It is usually dumped at the surface right above the leaks where it then slowly descends by gravity to the level of the opening in which it is then sucked.
Thanks to their roughness, slag clings quickly to each other to form a tight plug. Coal cinders work in much the same way.

Photo n° 8: Blast furnace ash (doc. Internet)

Tow and cotton rags, which are generally delivered in bundles, can be used by the diver to seal small openings ≤ 5 millimetres (0.2”) even if only a weak suction is present.

Photo n° 9: Cotton tow (doc. Internet)

Photo n°10: Old cotton rags (doc. Internet)

Ropes and hawsers are very effective for the clogging of openings ≤ 150 millimetres (6”).

Photo n° 11: Old hawser (doc. Internet)

The chosen diameter must be greater than the width of the opening or if it is not the case then it is necessary to braid 3 strands together.

Whenever possible, it is best to set up the rope from the surface without diving. For this one must select a length of 2 to 3 meters (7-10 ft.), one end will be weighted and the other one maintained by a thinner rope.

As soon as the suction is felt in the rope, it will be necessary to immediately give a maximum slack in it which will allow the rope to set up in place across the opening in the manner of a dog poo. The operation will be done as many times as necessary.

The bags described above which are used for leak detection can at the same time be used to seal openings ≤ 100 millimetres (4”). It is strongly recommended to use clay instead of sand because, depending on the type of bag used, the pressure may cause the sand to disintegrate, while the plasticity of the clay avoids this phenomenon.

Photo n° 12: Clay bag (doc. Internet)

Fig. n°13: Illustration of the setting up of clay bags

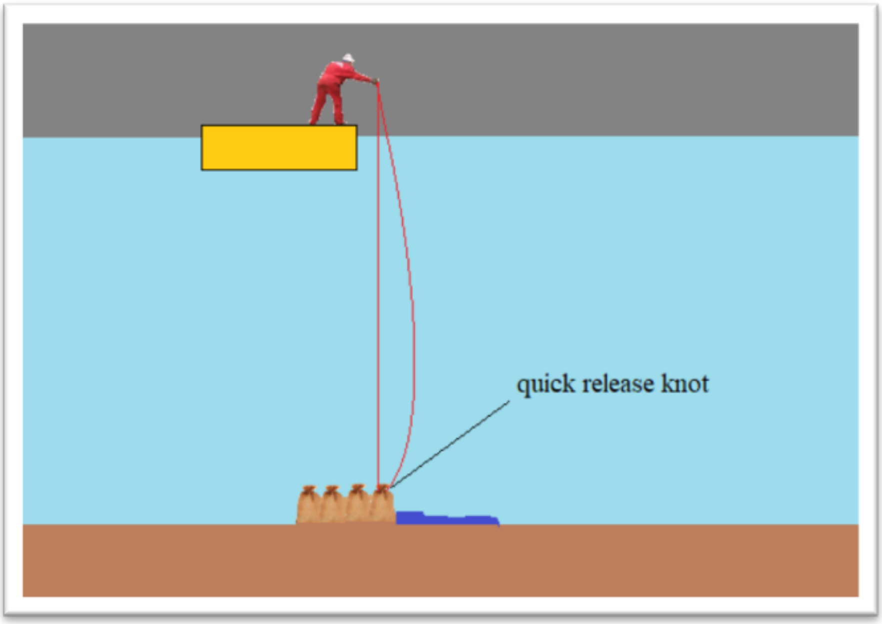


Photo n° 13: For openings of ≤ 200 mm (8") the rope may be replaced by old hemp fence (s) or the like (doc. Internet)

For larger openings at shallow depth, loose clay is also a great way to seal.
This must be put in place in sufficient quantity using a suitable means (grab, grapple, etc.).

Photo n° 14: Loose clay (doc. Internet)

Sealing sheets are mainly used to seal leaks on a cofferdam and have the advantage of treating a large area at once.

Photo n° 15: Sealing sheet (doc. Internet)

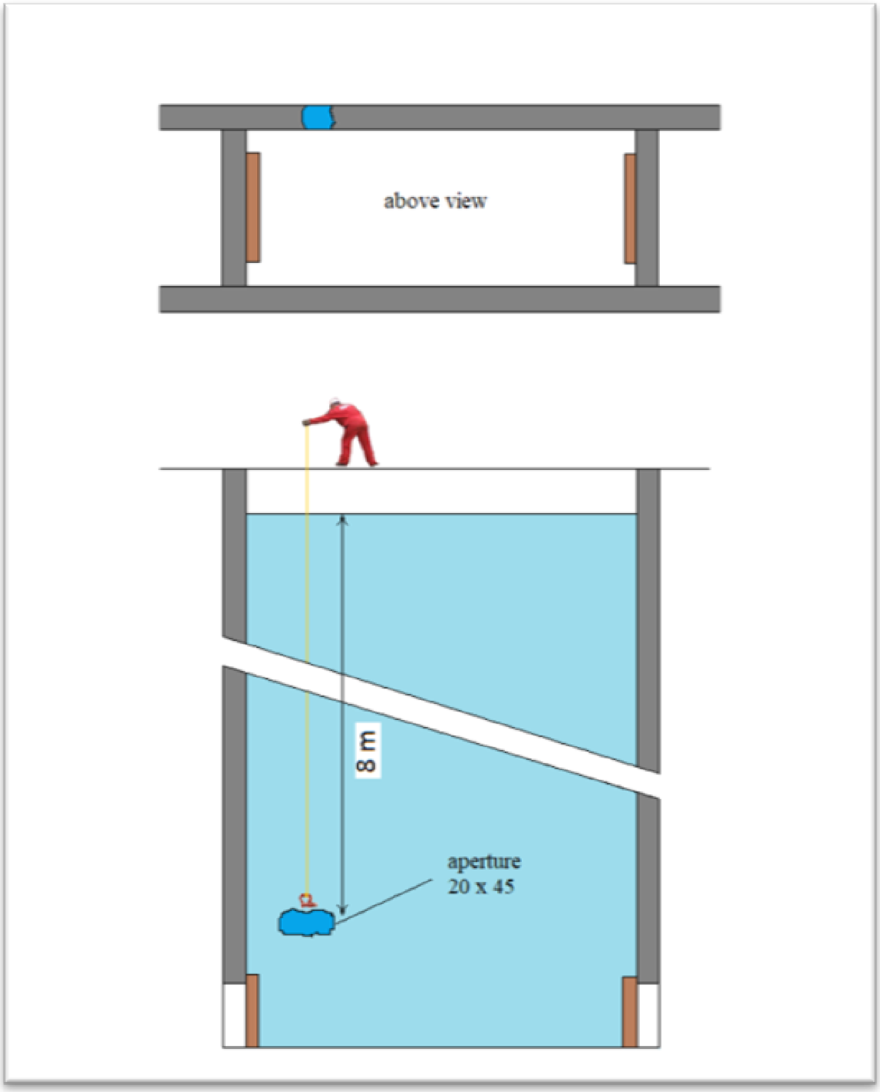
More solid tarpaulins called "collision mat" some of which are magnetic can be used to seal the damage on the hulls of the boats.

Photo n° 16: Collision mat (doc. Internet)

To illustrate clogging, let us take as an example a small job done in 2006 that consisted of performing a video inspection of two buck gates in a well 12 meters (40 ft.) deep.
The problem was the presence of a large water leak estimated at about 4000 m³ / h (141259 ft³ / h) in one of the side walls.

At first, it was necessary to locate the position and the depth of the delta P hazard. As we had access around the well, we chose to do this without diving, using the rope and big shackle technique. Thanks to this, we could quickly locate that the fault was at 8 meters (26 ft.) under water (see figure below).

Fig. n° 14: Illustration of the search of the opening



Knowing the depth and flow per hour of the leak, it was estimated that the area and dimensions of the opening should be about:

Flow per second = 4000: 3600 = +/- 1.1 m³ / sec
Area = 1.1: 4.43: √ 8 = 0.088 m²
Approximate dimensions = √ 0.088 = 0.296 m

Or

Flow per second = 139608: 3600 = +/- 38.78 ft³ / sec
Area = 38.78: 8.02: √ 26 = 0,947 ft²
Approximate dimensions = √ 0.947 = 0.974 ft.

To seal this opening, we had planned to use bags of clay and/or a big hawser, but since we did not know the configuration of the hole we feared that the bags were too small.
In addition, it was calculated that depending on the (theoretical) area of the opening and the depth, the pressure on the bag (s) would probably be too great and they could therefore be swallowed.

Estimated pressure = 8 x 0.088 x 1 x 1000 = 704 kg

Or

Estimated pressure = 26 x 0.947 x 62 = 1526 lb.

We therefore opted for the use of a big hawser Ø 120 mm (6") and so we prepared a piece of 5 meters (16 ft.) long at the end of which we have at one side hooked a shackle of 15 kg (33 lb.) and maintained it at the other side with a smaller rope held on the surface.
To prevent the shackle and the hawser from being immediately caught by the current, it was lowered into the corner opposite the leak, then once at the right height it was gently moved to the suction.
As soon as the rope started to react we let it go without holding it. This allowed the hawser to be immediately sucked into the opening and clog it.
The sealing was almost instantaneous because the noise caused by the leak immediately stopped and at the same time, we could also feel that the rope was blocked.
A new control using this time a rope with a small shackle and the descent of the camera confirmed the tightness.
As a further safety measure, we waited another hour to make sure that the hawser remained in place, and then the video inspection could be done without problems.

Fig. n° 15: Illustration of the lowering of the hawser

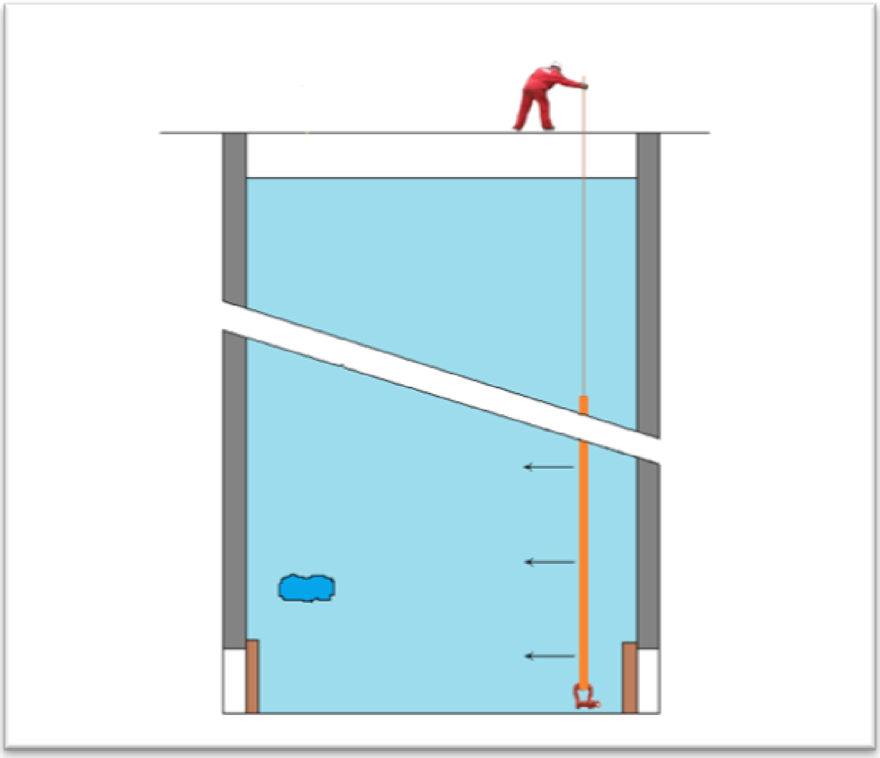
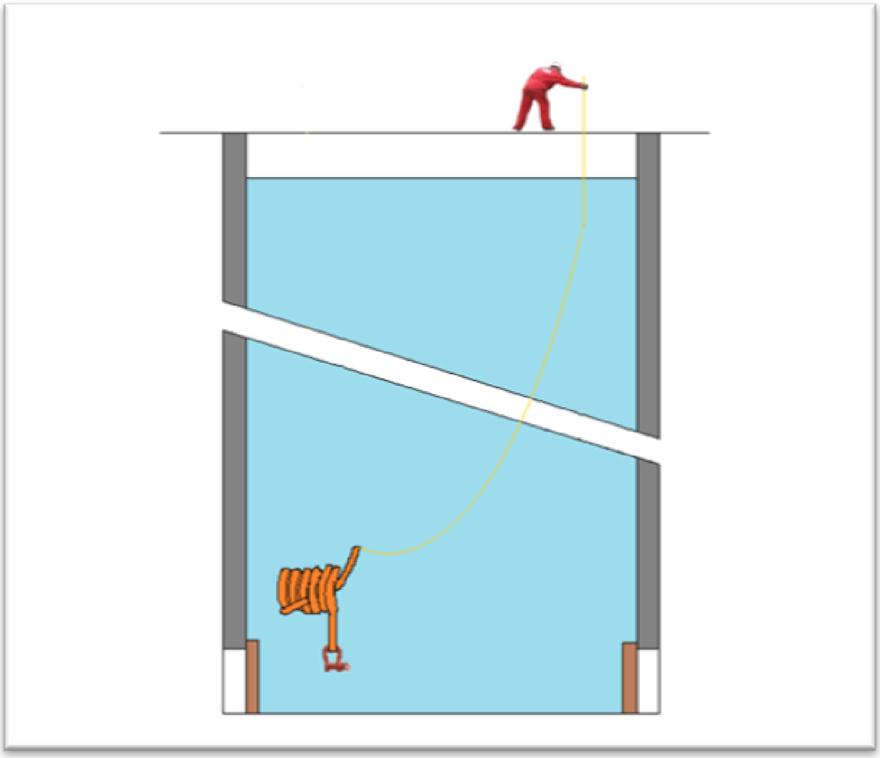


Fig. n° 16: Illustration of the blocking of the hawser



WARNING! All the processes described above are only temporary sealing means that will tend to be eliminated in a more or less rapid time and therefore should not be used for long-term sealing.

Setting up protection

There are certain situations where it will be necessary to dive in an area where the current is high and may push the diver to a water intake or the sucking opening. Various means of protection can be employed to avoid being caught by delta P.

The protective box

When the flow is not very important, it is possible to use a method derived from AODC 055 published by IMCA, which consists in installing a box around a water intake that will allow the diver(s) to work near the suction while remaining in the safety zone where the current does not exceed 0.5 m / sec (1.64 ft.).

In order to stay out of the danger zone, the cage must have a minimum total area that can be calculated as follows:

$$A = Q / 0.5 \times cf$$

Or

$$A = Q / 1.64 \times cf$$

Where

A = total area of the box (m^2) (ft^2)
Q = flow (m^3/sec) (ft^3/sec)
0.5 = current velocity not to exceed (m/sec) (1.64 ft. /sec)
cf = configuration factor

To this area, it is still necessary to add that developed by one or even two divers as well as that of the construction material.
Example: To allow a diver to work safely, what should be the total minimum dimension of a box that has to be installed in a wall around a 0.4 x 0.4 m (16” x 16”) water intake where the pump has a flow rate of 1.2 m^3 / sec (42.37 ft^3 / sec)?

$$1.2 / 0.5 \times 1 = 2.4 \text{ m}^2$$

Or

$$42.37 / 1.64 \times 1 = 25.83 \text{ ft}^2$$

It is considered that the area developed by an equipped diver is about 1 m^2 (10.76 ft^2) and the material used for construction here will be about 0.1 m^2 (1 ft^2).

The minimum total area of the box must therefore be:

$$2.4 + 1 + 0.1 = 3.5 \text{ m}^2$$

Or

$$25.83 + 10.76 + 1 = 37.59 \text{ ft}^2$$

And so each face will have an area of:

$$3.5 / 5 = 0.7 \text{ m}^2$$

Or

$$37.59 / 5 = 7.52 \text{ ft}^2$$

This represents a square of:

$$\sqrt{0.7} = 0.84 \text{ m}$$

Or

$$\sqrt{7.52} = 2.74 \text{ ft}$$

To avoid that the umbilical passes through the mesh, it must not exceed 20 x 20 cm (8” x 8”) or 28 x 14 cm (11” x 6”).
Now imagine that for lack of space the cage can only have a side of 0.7 m (2.3 ft.) that is to say a total area of $0.7^2 \times 5 = 2.45$ m^2 ($2.3^2 \times 5 = 26.45$ ft^2).
This means that if the diver is just in front of the cage, he would be in the danger zone because the current would be greater than 0.5 m / sec (1.64 ft. / sec).

So in this case if we want to allow him to stay at this location it is then necessary to reduce the flow of the pump and therefore we can use the following formula:

$$Qr = (A – Ad – Am) \times 0.5$$

Or

$$Qr = (A – Ad – Am) \times 1.64$$

Where

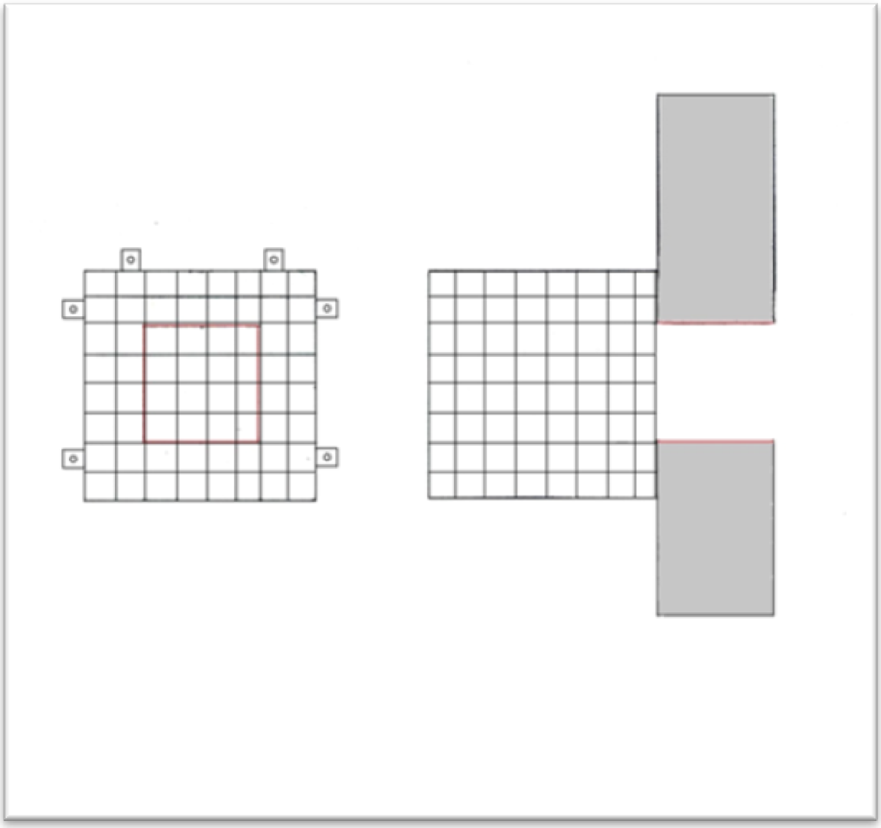
Qr = reduced flow (m^3/sec) (ft^3/sec)
A = total area of the cage (m^2) (ft^2)
Ad = diver's area (m^2) (ft^2)
Am = material area (m^2) (ft^2)

$$Qr = (2.45 – 1 – 0.1) \times 0.5 = 0.67 \ m^3/ sec$$

Or

$$Qr = (26.45 - 10.76 – 1) \times 1.64 = 24 \ ft^3 / sec$$

Fig. n° 17: Example of a protective box



The protective chamber

When the flow is important and the suction is relatively high, a good protection way is to let the diver work inside a chamber that will isolate him from the ambient current (suction or discharge).
To avoid any risk of accidental movement, the caisson must be quite heavy and be held correctly in position.

Fig. n° 18: Illustration of a dive job with a protective chamber

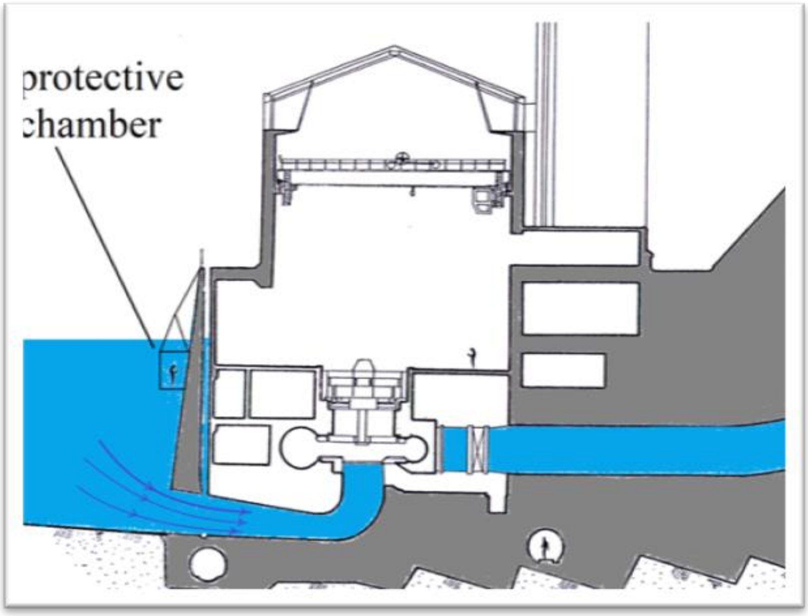


Photo n° 17: Setting of the protective chamber

Photo n° 18: Lowering of the protective chamber

Photo n° 19: Detail of the fixing system

Current deflection system

When none of the methods presented above can be used to control a delta P, we can still try to deflect it by setting up a deflector.

To illustrate this, let us take the example of a diving job realized in a pumping station equipped with 4 pumps whose flow of each one is of 12,000 m³ / h (423776 ft³ / h).

These centrifugal pumps are installed in a room and are fed through 60 cm (24”) diameter openings, each equipped with a segment valve placed through a concrete wall located at the end of a tunnel of 60 meters (197 ft.) in length of 6 meters (20 ft.) wide and 3.5 meters (11.5 ft.) high.

The work consisted of:

1) Inspect the side walls, the bottom and the ceiling of the supply tunnel.
2) Place a watertight cofferdam around the number 1 segment valve for the purpose of replacing it.

For technical and cooling reasons, the pumping flow could not be less than 24,000 m³ / h (847552 ft³ / h), which meant that two of the pumps needed to stay in service.

For the inspection it was therefore necessary at first to calculate the speed of the current in the tunnel and check if it could be done with the 4 pumps running.

$$Q = 48{,}000 / 3{,}600 = 13.33 \text{ m}^3/\text{sec}$$

$$A = 6 \times 3.5 = 21 \text{ m}^2$$

$$V = 13.33 / 21 = 0.63 \text{ m/sec}$$

Or

$$Q = 1695104 / 3{,}600 = 471 \text{ ft}^3/\text{sec}$$

$$A = 20 \times 11.5 = 230 \text{ ft}^2$$

$$V = 471 / 230 = 2 \text{ ft. /sec}$$

It can be seen that this was above the recommended 0.5 m / sec (1.64 ft. / sec)

Let's repeat the same calculation with 2 pumps running.

$$V = 6.66 / 21 = 0.31 \text{ m/sec}$$

Or

$$V = 235.5 / 230 = 1 \text{ ft. /sec}$$

This time the speed of the current was not excessive but for the comfort of the diver it was nevertheless necessary to provide a handrail system on which he could hold.

Then the limit of the danger zone in which the diver could not enter was calculated. As the tunnel consisted of 4 faces we applied a configuration factor (fc) of 4.

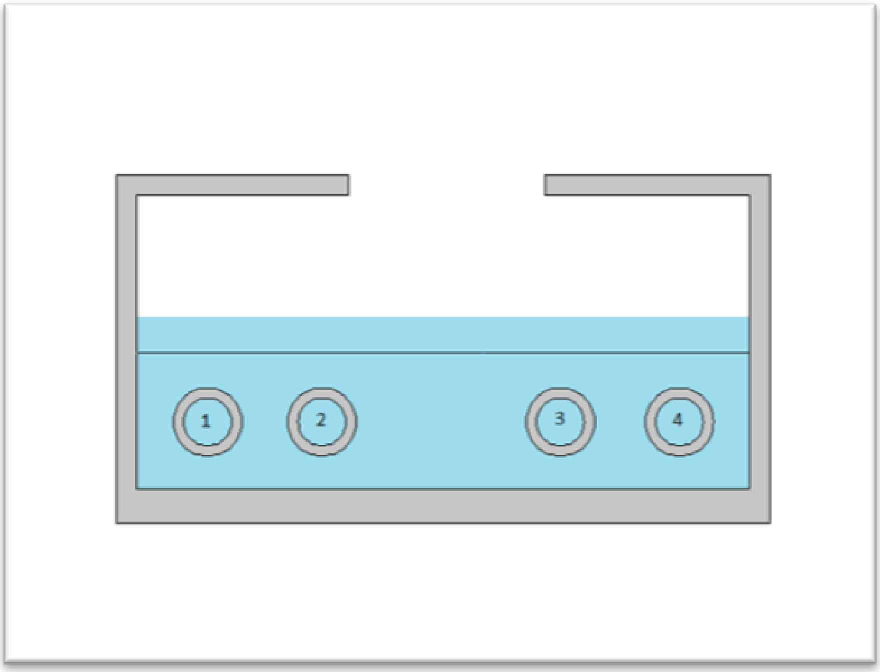
$$DZ = 4 \sqrt{6.6 / (3.1416 \times 1)} = 5.79 \text{ m}$$

Or

$$DZ = 4 \sqrt{235.5 / (3.1416 \times 3.28)} = 19.10 \text{ ft.}$$

As the diver had to travel far enough from his entry point into the water, the DZ was extended to 15 meters (50 ft.) and the umbilical was accurately marked and held correctly on the surface so as not to exceed this distance.
Regarding the second work which consisted to install the cofferdam around the valve no.1, we can see by looking at the figure n°. 19 that even when stopping the pump no. 2 the diver would still evolve in the risky area of pumps n° 3 and n° 4 which would represent a mortal danger because the current would aspire him immediately against the entrance of the pump no. 3.

Fig. n° 19: Front view of the 4 pump inlets



If this was the case, the pressure on the diver's body would not only depend on the height of water above the entrance, but also on the ability of the pump to evacuate the water in the tube before cavitation, which in this case corresponded to a theoretical water depth of 5 and 8 meters.

We use again the formula found on page 11

$$F = 3 + 8 \times (0.6^2 \times 3.1416 / 4) \times 1 \times 1{,}000 = 3{,}108 \text{ kg}$$

Or

$$F = 10 + 26 \times (2^2 \times 3.1416 / 4) \times 62 = 7012 \text{ lb.}$$

As can be seen with such pressure, the diver would be killed instantly even before being crushed by the pump. So to avoid this risk we set up a deflector that would allow divers to work in relative safety if all other rules were respected. This was indeed the case and thanks to it the dives for the installation of the watertight cofferdam as well as the replacement of the segment valve were done without problem.

Photo n° 20: Used deflector

Photo n° 21: Installation of the deflector

Fig. n° 20: Front view of the deflector installation

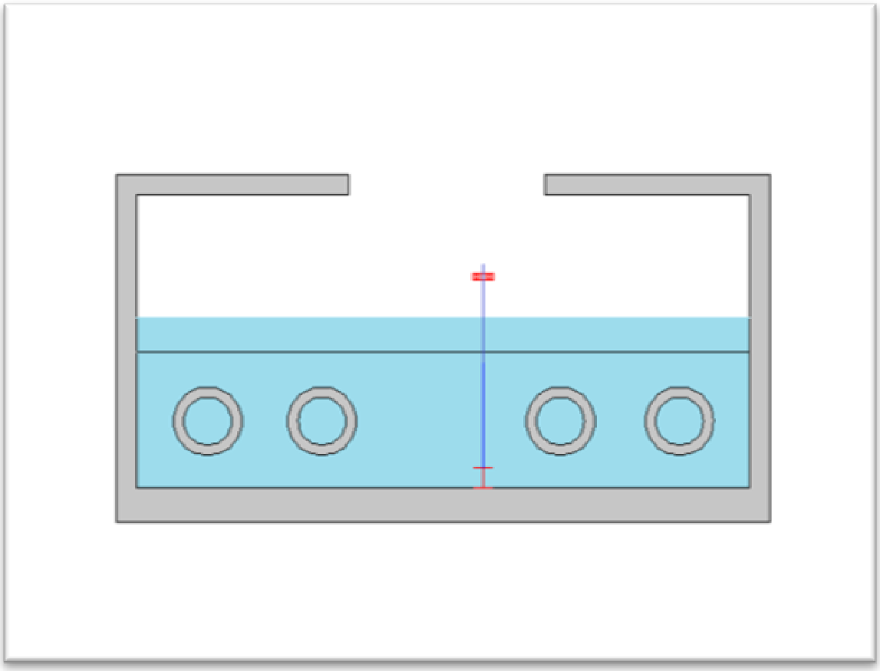


Fig. n° 21: Side view of the deflector installation

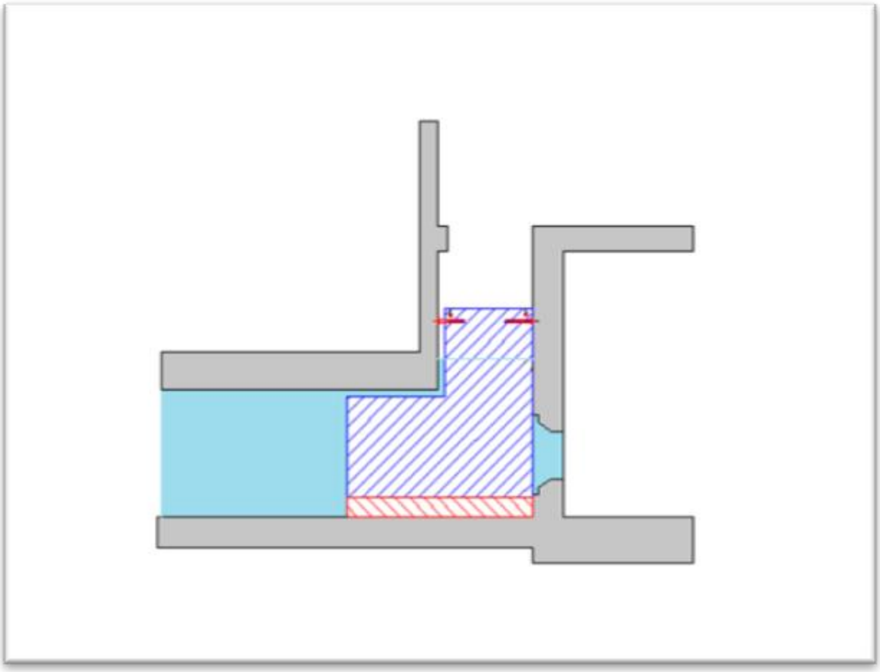


Photo n° 22: Detail safety measures for the tender

Photo n° 23: Diving at the shelter of the deflector

Photo n° 24: Installation of the cofferdam

Photo n° 25: Segment valve to be replaced

Protection by restraint

The last method that can be used is to voluntarily limit the distance of movement of the diver so as to ensure that he cannot reach the danger zone. For this we can either limit the length of the umbilical that will be deployed, or limit the movement of the diver through a line of restraint.

Limitation of umbilical length

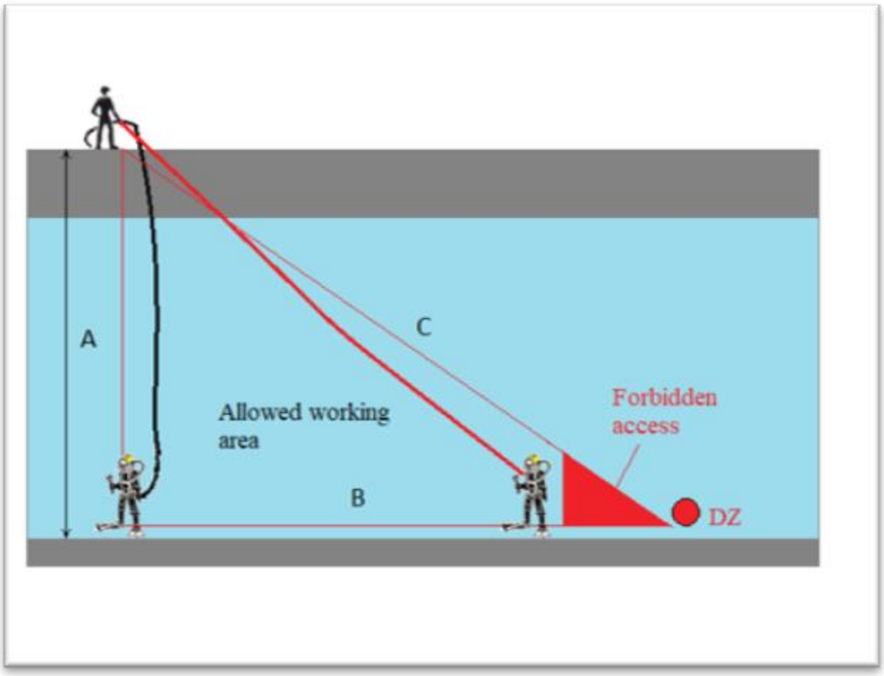
For the first method, we can use the method suggested by the CANADIAN ASSOCIATION OF DIVING CONTRACTORS (CADC) which uses the Pythagorean Theorem to calculate the limit length of an umbilical.

$$A^2 + B^2 = C^2$$

Where

A = total height (depth of water + part above water) (m or ft.)
B = diver distance to the nearest danger (m or ft.)
C = maximum length to deploy (m or ft.)

Fig. n° 22: Umbilical deployment limitation



Example:
A diver must work 10 meters deep. At 25 m from his working place there is a water intake. What is the maximum umbilical length that the tender can give from its current point so that the diver does not arrive in the hazardous area of the pump?

A = 10 m

B = 25 m

$$(10 \times 10) + (25 \times 25) = C^2$$

$$100 + 625 = 725$$

$$\sqrt{725} = 26.90 \text{ m}$$

At this length (C) it will be necessary to remove 5 m for safety measure and therefore the maximum length that the tender may give will be:

$$26.90 - 5 = 21.9 \text{ m}$$

Restraint line

To illustrate the second method that involves the use of a restraint line, we can rely on figure 23, where the work consisted to make a video inspection and thickness measurements on a few pipes located in the upper part of a cooling into which a discharge pipe Ø 1.5 m (4.9 ft.) with a flow of about 20 m^3/sec (706 ft^3/sec) was present.
With such a high flow rate it was estimated that the danger zone around this down tube was about:

$$DZ = \sqrt{Q / (\pi \times C)}$$

$$DZ = \sqrt{20 / (3.1416 \times 1)} = 2.52 \text{ m}$$

Or

$$DZ = \sqrt{706 / (3.1416 \times 3.28)} = 8.28 \text{ ft.}$$

To restrict the movements of the diver and ensure that he did not move towards the centre of the well, a line with a weight of a 30 kg (66 lb.) was each time set up just beside the tube that had to be controlled and onto which the diver was connected via a sliding whip of two meters (6 ft.) long.
Since the surface of the tank was quite large (176.7 m^2) (1902 ft^2), the speed of the current at the tubes level was relatively low (+/- 0.11 m / sec) (0.36 ft. / sec), despite the strong turbulence generated by all the discharges tubes.
On the other hand thanks to the excellent visibility reigning in the tank, one could note the presence of an important vortex above the central well.

Fig. n° 23: Example of a restraint protection system

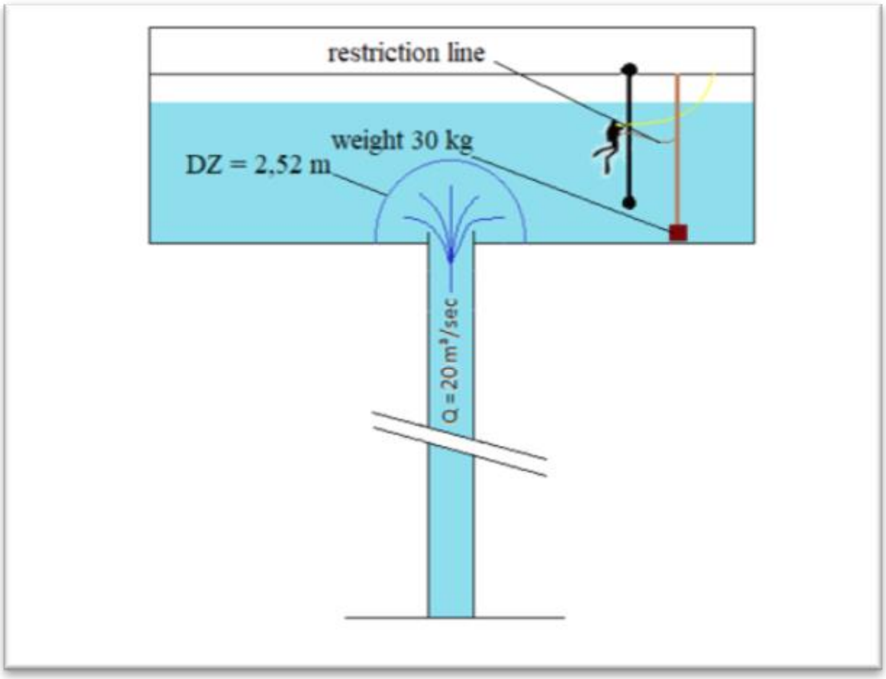
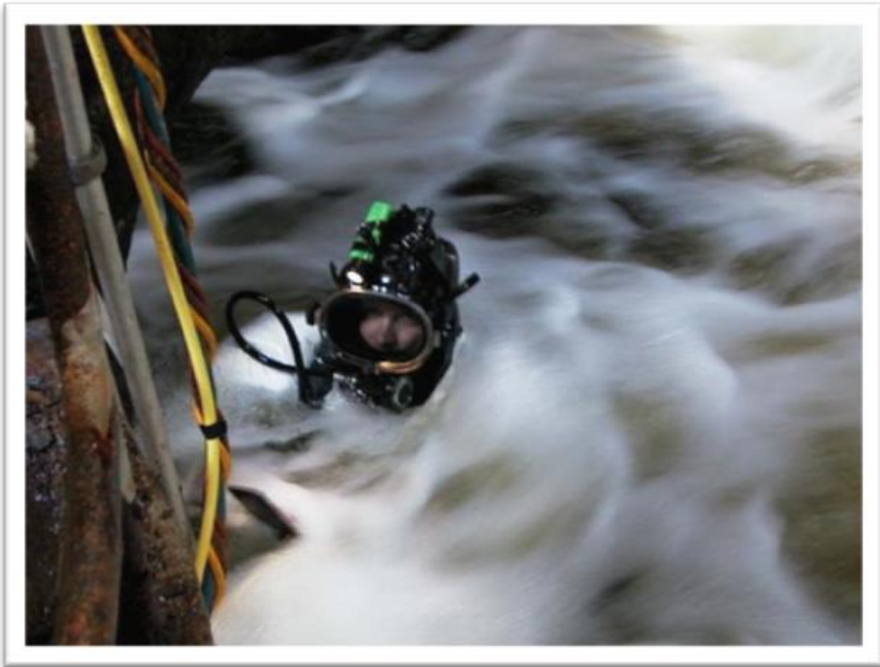


Photo n° 26: Dive in the cooling tower (doc. Thierry Vanden Eynde)



Projects where the risk is greatest

As we have seen previously, delta P can occur only where there is a difference in height of water or pressure between two sides of a wall, gate, valve or barrier and these risk zones are mainly found on:

- Locks.
- Hydroelectric dams.
- Weirs on rivers.
- Storage tanks.
- Factories equipped with cooling circuit and other easements.
- Vessels.
- Pumping equipment.
- Pipelines.
- Shutters.

Locks

Photo n° 27: Lock with winged doors (doc. Internet)

Locks are hydraulic structures that allow ships to navigate despite differences in water level over the course of the waterway. They are equipped with two swinging, guillotine or sliding gates which seal off the lock chamber from the upper and lower ponds. The water is drained into or out of the lock by gate paddles or via culverts sluices. Various types of work can be done in a lock, for example:

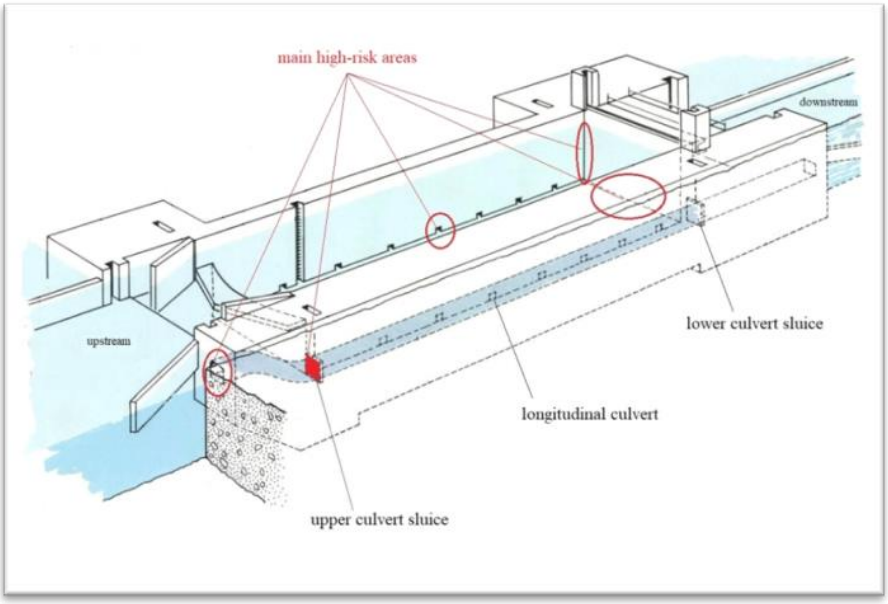
- Release of the sluice valves.
- Release of the gates.
- Repair of the sills.

- Repair on the gates.
- Search for and recovery of lost objects.
- Various inspections.
- Setting a cofferdam.
- Removal of silt.

In a lock the main high-risk areas are:

- Door sluices.
- Upstream culvert sluice gates.
- Filling, longitudinal and discharge culverts.
- Door seals (wood or rubber lining).
- Cofferdams.

Fig. n° 24: Illustration of the high-risk areas in a lock



Culvert sluice gates

The valves used to fill and empty the lock chamber are positioned upstream and downstream of a culvert. They can be manoeuvred manually via a jack, either electrically or hydraulically from the control cabin. Their closing is sometimes hampered by various objects, especially when no grid or trash rack protects the entrance of the culvert. The hazardous areas for the divers are on the upstream side at the gate obstruction and / or in the immediate vicinity of the culvert entrance.

Photo n° 28: Upstream culvert sluices inlets (doc. Internet)

Photo n° 29: Upstream culvert inlet with protection grid (doc. Internet)

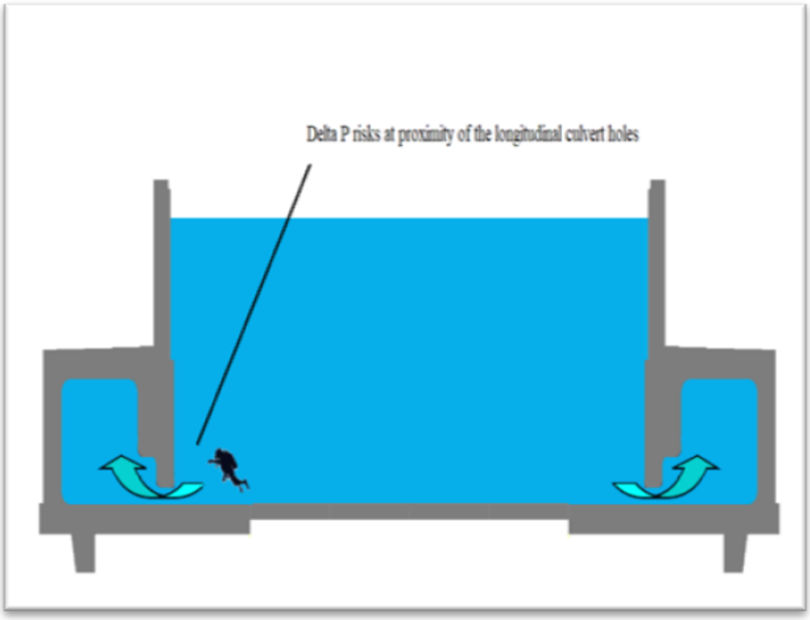
Photo n° 30: Electrical sluice (doc. Internet)

Longitudinal culverts

These small tunnels connect with the lock chamber via a series of holes situated at the bottom of the lock walls. They are intended to bring the water of the upper pond into the chamber, or to empty the chamber by sending the water to the lower pond.
The danger zones for the divers are located close to the openings when emptying the chamber.

Photo n° 31: External view of the communicating holes with the longitudinal culvert (doc. Internet)

Fig. n° 25: Illustration of delta P risks due to longitudinal culvert



Door's sluices

A door sluice is a small valve that slides in a frame on a door. It is manoeuvred by a jack or by hydraulic or electric power. The danger zone for the divers is on the upstream side in the immediate vicinity of the doors.

Photo n° 32: Mechanism of the door sluices (doc. Internet)

Photo n° 33: Flow through the door sluices (doc. Internet)

Lock gates

The lock gates can be of several kinds: flap, mitre or sector gates and each of them has a different sealing arrangement. It's always at the upstream side of these sealing that a danger zone can be present for the diver if a leak is present.

Photo n° 34: Danger associated with worn seals (doc. Internet)

Photo n° 35: Flap rolling door (doc. Internet)

Cofferdams

Cofferdams are used to set a lock or part of a lock installation dry. They may consist of metal beams superposed on each other, or on the contrary be floated and sink on site.
Hazardous zones for the divers are located on the upstream side of the cofferdam at the contact areas with the bottom if it is damaged or not properly cleaned and in the vertical grooves if the broad stones, metal or concrete are damaged.
Small aspirations can also be observed between the various elements of a stacked cofferdam.

Photo n° 36: Risk related to the setting of a cofferdam (doc. Internet)

On cofferdams intended to put a door chamber dry, besides the sealing problems encountered on the vertical and horizontal parts, the greatest danger for the divers is generally situated at the level of the rolling rails.

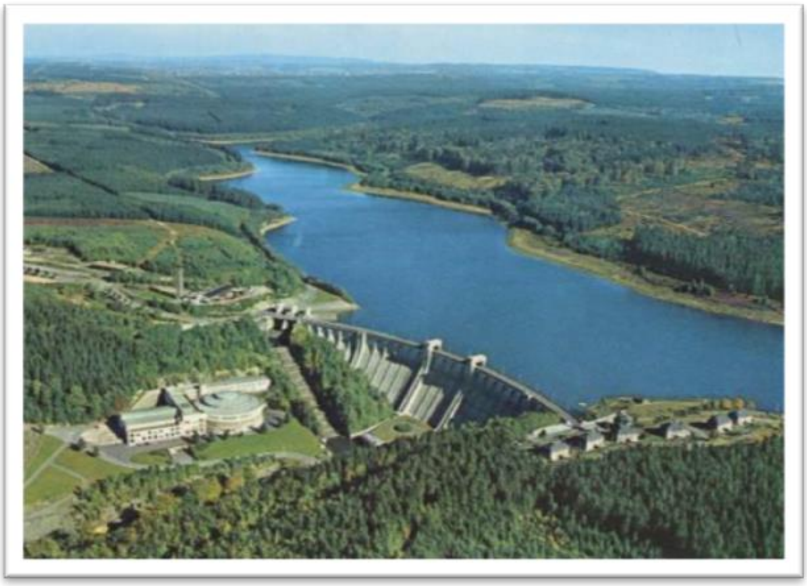
Photo n° 37: Setting of a door chamber cofferdam (doc. Internet)

ΔP safety rules to be applied during lock diving operations

- Inform the lockmaster about your presence and tell him what you are going to do.
- Install a dive warning display in the control room.
- If necessary ask for the lockout of certain elements and check that it has been done.
- Inform the lockmaster via radio or smart phone of the start and end of the dive.
- Check the lockmaster’s behaviour subtly to see if he is under the influence of alcohol or drugs.
- Install the alpha flag so that it is clearly visible from far away.
- When diving upstream of a lock, calculate the length of the danger zone (DZ) at the entrance of the culverts and / or the gate sluices.
- If divers are working upstream near these danger zones, they must be come out of the water before the closing of the lock downstream door(s).
- When releasing the upstream culvert sluice gate, keep the water in the chamber lock high and leave the upstream lock gate open.
- When working upstream close to a mitre gate, survey the umbilical so that it is not sucked in between the door and the hollow coin.
- When working on the bottom of a filled chamber lock, the downstream culvert sluice gates must be locked to prevent accidental suctioning into the longitudinal culvert.
- Before installing a cofferdam check that all the seats and grooves are clean.
- Start sealing a cofferdam at the beginning of the pumping so as not to have too much flow at the level of any leaks.

Hydraulic dams

Photo n° 38: Bank side reservoir (doc. Internet)



The first series of dams that concern us are the structures built of concrete. They can have as function:

- The production of motive power (turbine) and electricity (called a hydro-electric dam).
- To be a reserve of drinking water.
- The creation of artificial lakes or reservoirs.

Three types of construction are generally used for these structures:

- Gravity dams which are structures relatively thick and whose mass is sufficient to oppose the pressure exerted by the water.
- Arch dams that are usually built in narrow valleys where there is a good rock foundation. This type of structure is built using an arched concrete wall where the pressure of the water is transferred to the abutments of the valley.
- Buttress or hollow dam are reinforced concrete dams generally built in wide valleys were solid rock is rare. This type of dam is composed of a series of buttresses and supports which prevent the dam from falling over, and transmits the thrust of water to the foundations of the structure.

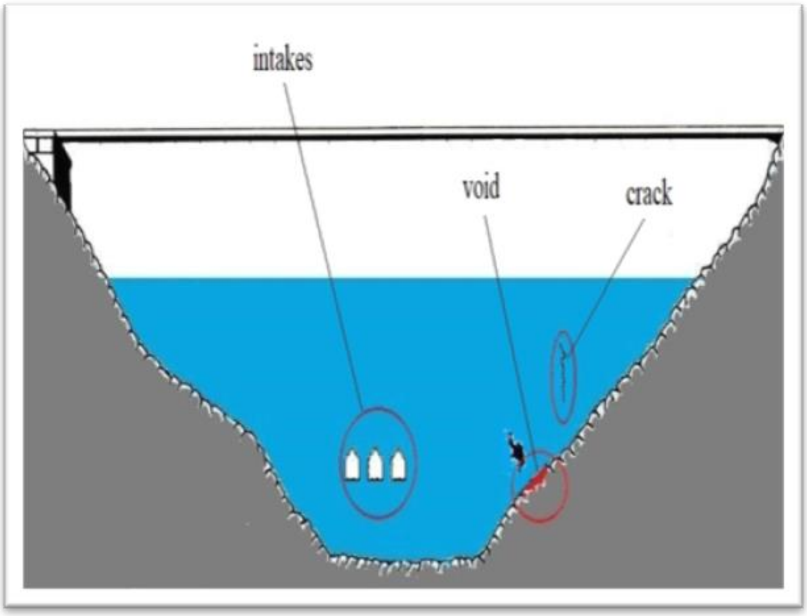
Various types of work can be done on a dam, for example:

- Inspection of dam faces to check for leaks.
- Installation / removal of cofferdams.
- The removal of obstructions / debris.
- Repair of the dam face.
- Maintenance works.
- The removal of silt around the intakes.
- Etc.

On such structures, the main high-risk areas are:

- The water intakes.
- Damage in the dam face.
- Leaks linked to interstitial pressure between the base of the structure and the natural terrain.

Fig. n° 26: Illustration of the high-risk areas on the upstream side of a dam.



<u>ΔP safety rules to be applied when diving on a dam</u>

- Inform the person in charge of the dams you are working on well ahead of time.
- The day of the dive, inform the person in charge of your presence and tell him what you intend to do.
- On an unknown installation consult the plans of the structure and ask the technical staff to indicate the areas at risk.
- Install a dive warning display of in the control room.
- Request a lockout of the concerned elements and verify that it has been carried out.
- Install the alpha flag so that it is clearly visible.
- If necessary, explain the meaning of the alpha flag to the dam personnel.
- Check at the downstream side if no suspicious eddy is visible.
- Do not dive on the upstream face unless the turbines are stopped or that all valves are closed, if not, apply a safety factor of 10 to the DZ and use a displacement restraint system.
- Keep the person in charge of the dam informed via radio or smart phone of the beginnings and ends of the dive.
- Check subtly the behaviour of the person in charge of the lockout to see if he is not under the influence of alcohol or drugs.

River barrages

The other types of structure on which divers are likely to intervene are mobile dams and spillways on rivers or downstream parts of some rivers.

Photo n° 39: Barrage on a river (doc. Internet)

These barrages essentially consist of gates located between piles placed parallel to the axis of the river.
A concrete foundation raft protects the river bed against scouring that could occur especially during the passage of high speeds floods.

Shutting members may consist of:

- Radial gate that allow the passage of water through a rotational movement around the axis.
- Flap gate on the floor and which is lowered to let the flood.
- Flat gate which move vertically and which may consist of several parts allowing the water to pass over or under it.
- Inflatable rubber dams.

Photo n° 40: Radial gate (doc. Internet)

Photo n° 41: Flap gate (doc. Internet)

Photo n° 42: Flat gate (doc. Internet)

Photo n° 43: Inflatable rubber dams (doc. T. Vanden Eynde)

Various types of work can be done there, for example:

- Various types of inspections.
- Installation / removal of cofferdams.
- Maintenance works.
- Removal of sill.
- Removal of obstructions / debris.
- Searches for objects (or victims).

In these types of structures, the main risk areas are:

- The immediate proximity of the gate.
- Gate leaks.
- Cascades downstream of the gates.

Cascades are not delta P’s, but the eddies they generate can pose a significant risk.
The gates of these types of dam are often managed remotely.

ΔP safety rules to be applied when diving on river barrages

- Inform the barrage manager and / or the waterways department in advance of your intervention.
- The day of the dive, inform the person in charge of your presence and what you will do.
- On unknown installations, consult the plans of the site and ask to the technical staff of the site to indicate the risk areas.

- Install a dive warning signal in the control room.
- Request the lockout of the concerned items and check that it has been carried out properly.
- Install the alpha flag so that it is clearly visible from far away.
- Subtly check the behaviour of the person in charge of the lockout to see if he or she is under the influence of alcohol or drugs.
- Check downstream if no suspicious eddy is visible.
- In case of doubt about the possible presence of a delta P (leak, partially open gate or valve, etc.) it is necessary to practice a control from the surface before diving.
- Inform the manager via radio or smart phone of the beginning and end of the dive.
- Dive from a vessel or a pontoon.

Pumping stations

Photo n° 44: Entry of a pumping station (doc. Internet)

Many plants located near a waterway have pumping station (s) to cool down their installation or for other servitude.

These are usually installed at the end of a supply channel and are equipped with submerged pumps whose capacity can range from a few tens to several thousand cubic meters per hour.

Photo n° 45: Inside view of a pumping station (doc. Internet)

Various types of work can be carried out underwater, for example:

- Silt removal or cleaning of the intake canal.
- Cleaning / replacing pump strainers.
- Work on sectioning valves.
- Cleaning of grids.
- Release of the trash rakes.
- Construction / demolition work.

In this type of installation, the main risk areas are:

- The current velocity in the supply channel.
- Submerged pumps.
- The wall or pipe inlets of the pumps.
- The trash rakes.

In a pumping station, the calculation of the danger zone (DZ), which we recall is dependent on the flow, is this time not calculated according to the surface of the opening and the height of water above it, but only in relation to the characteristics of the pumps.

ΔP safety rules to be applied when diving in a pumping station

- Inform the technical manager of the site of your presence.
- Learn about the characteristics of the pumps on which or around which you need to intervene.
- Install a dive warning signal in the control room.
- Depending on the flow rates of the pumps, if necessary ask to lockout the one on which you have to work.
- When working on a trash rake, have the screen lockout and check that it has been made.
- Subtly check the behaviour of the person in charge of the lockout to see if he or she is under the influence of alcohol or drugs.
- At the beginning of a dive in a pumping room, check before you start to work that all the pump strainers are in place.
- Keep the technical personal informed of the beginnings and ends of the dive.

Storage tanks

Photo n° 46: Intervention in a storage tank

Most factories have cisterns for storing fire water.
Depending on the size of the company, these tanks may be more or less important and to avoid having to empty them, their maintenance requires from time to time the intervention of commercial divers.

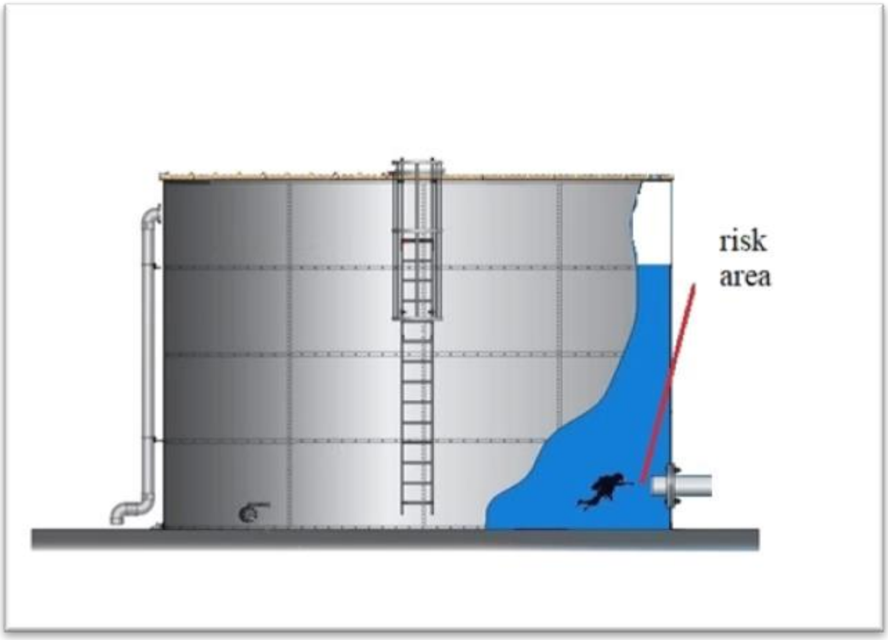
Various types of work can be carried out underwater, for example:

- The removal of sill from the bottom.
- Brushing or cleaning of the walls.
- Measurement of wall thickness.
- Underwater corrosion protection by paint treatment.
- The placement of an inflatable shutter for valve change.

Virtually all tanks are equipped in their lower part with a flange connected to a pipe leading to a control room which in case of fire dispatches the water to the burning areas.
These pumps are often programmed to start automatically in the event of a disaster and here too the DZ will have to be determined according to the capacity of the pump.
In this type of structure, the main risk areas are:

- The immediate proximity of the flange.
- The interface between the access hole and the surface of the water (the water level can go down very quickly if the pumps are switched on).
- The ambient air (confined space with less of 20% oxygen).

Fig. n° 27: Illustration of the risk area (extract doc. internet)



ΔP safety rules to be applied when diving in a storage tank

- Inform the technical manager of the site of your presence.
- Learn about the characteristics of the pump on which or around which you need to intervene.
- Calculate the danger zone (DZ) in front of the flange.
- Install a dive warning display (s) in the control room.
- Have the pump interlock system locked out and check that it has been done correctly.
- If a lockout is not possible due to automatic starting, work well outside the DZ and provide a restraint system or set up of a protective cage.
- Plan a quick recovery system (crane, electric winch) of the diver if the pumps are started.
- If an inflatable shutter is installed in the flange nozzle, make sure that the residual thickness of the tube at downstream of the plugging is still sufficient to avoid the crushing (implosion) of the pipe during emptying.
- Inform the technical personnel of the beginning and end of the dive.

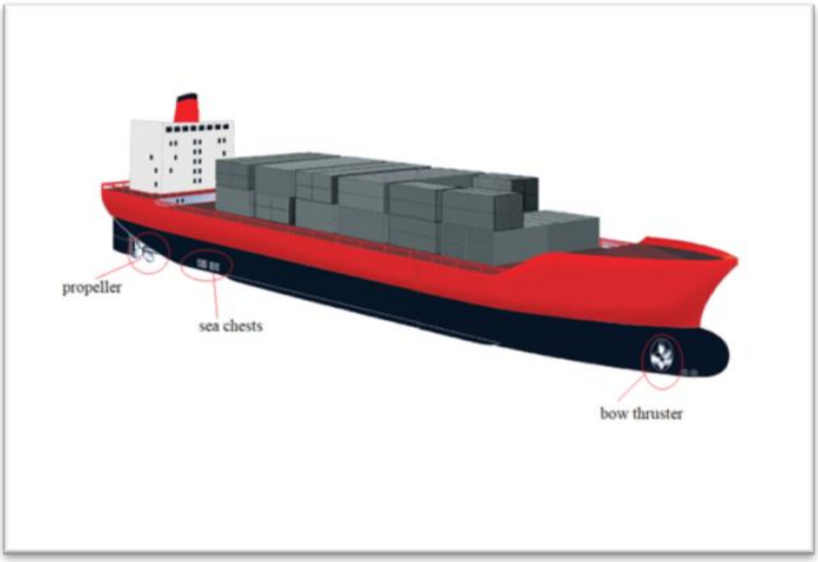
Vessels

Photo n° 47: Diving Support Vessel (doc. Internet)

Various types of work can be carried out underwater, for example:

- Various inspections.
- Anode replacement.
- Hull scrubbing.
- Polishing the propeller.
- Probe replacement.
- Damage repairs.
- Cleaning of the protection grids of the water intakes.
- Work on the rudder.
- Work on propellers and bow thruster.

Fig. n° 28: Illustration of the risk areas (extract doc. internet)



Under a boat the main risk areas are:

- Water intakes.
- Bow thruster (s).
- The propeller (s).
- Hull damage.

Photo n° 48: Sea chest (doc. Internet)

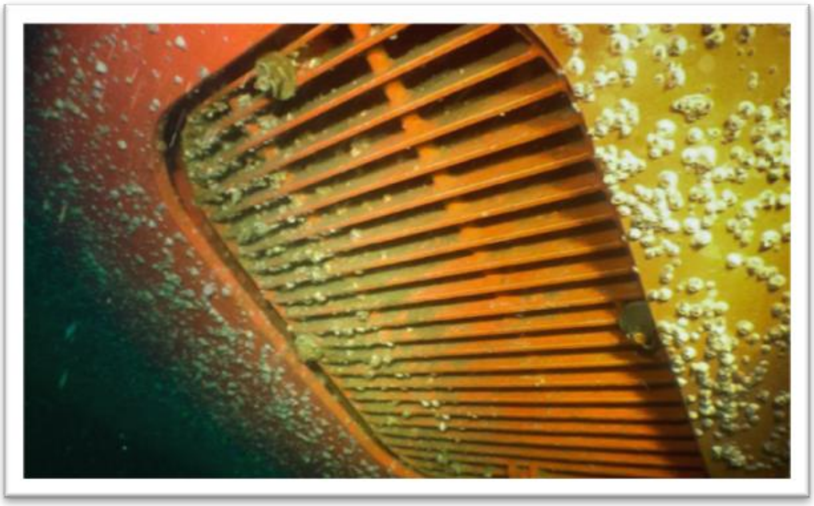


Photo n° 49: Bow thruster (doc. Internet)

To determine the DZ under the hull of a boat, it is here also necessary to take into account the capacity of the pumps to calculate the flow of water. In practice, some as the US Navy recommends to keep a safe distance of at least 15 meters (50 ft.) when a pump has a flow equal to or greater than 0,189 m^3 / sec (6,7 ft^3 / sec).

Concerning the accidents due to the propellers, they are not strictly speaking accidents related to a delta P, but as it is in spite of all the current generated by the rotation of the propeller which attracts the diver, one can classify them in this category.

ΔP safety rules to be applied when diving under a vessel

Fig. n° 29: Example of a predive checklist (doc. ADC - GP - 001 Aug 09*)

<table>
<tr><th colspan="6">Diving operations – Vessels Checklist
To be completed by the Diving Supervisor
A remplir par le COH</th></tr>
<tr><td colspan="2">Vessel Name:</td><td colspan="2"></td><td>Vessel Type:</td><td></td></tr>
<tr><td colspan="2">Master Name:</td><td colspan="2"></td><td>Duty Engineer Name:</td><td></td></tr>
<tr><td>Date:</td><td></td><td>Time:</td><td></td><td>Location:</td><td></td></tr>
<tr><td>1</td><td colspan="3">Has the Vessel Master (or his official deputy if the Master is off-shift and asleep) approved the diving operations?
Le capitaine (ou son second si le capitaine n’est pas de quart) a-t-il approuvé les opérations de plongée?</td><td>confirmed</td><td>Not confirmed</td></tr>
<tr><td>2</td><td colspan="3">Has the Chief Engineer (or his official deputy if the Chief Engineer is off-shift and asleep) approved the diving operations?
Le chef mécanicien (ou son adjoint si le chef mécanicien n’est pas de quart) at-il approuvé les opérations de plongée?</td><td></td><td></td></tr>
<tr><td>3</td><td colspan="3">Are all bridge staff aware of the diving operations?
Tout le personnel du pont est-il au courant des opérations de plongée?</td><td></td><td></td></tr>
<tr><td>4</td><td colspan="3">Are all engine room staff aware of the diving operations?
Le personnel de la salle des machines est-il au courant des opérations de plongée?</td><td></td><td></td></tr>
<tr><td>5</td><td colspan="3">Has a suitably competent Duty Officer been allocated to coordinate the isolation of operating machinery onboard?
Un officier de service compétent at-il été chargé de coordonner l'isolement des machines en service à bord?</td><td></td><td></td></tr>
<tr><td>6</td><td colspan="3">Will the Duty Officer remain available throughout the period of the diving operations?
L'officier de service demeurera-t-il disponible pendant toute la durée des opérations de plongée?</td><td></td><td></td></tr>
<tr><td>7</td><td colspan="3">If a shift change is expected while diving operations are ongoing, are arrangements in place so that when replacement staff arrives on shift they will know that diving operations are underway and that all necessary risk control measures must remain in force?
Si un changement de quart doit se faire pendant que les opérations de plongée sont en cours, des dispositions sont-elles en place pour que, lorsque le personnel de remplacement prend son poste, ils sauront que les opérations de plongée sont en cours et que toutes les mesures de contrôle des risques doivent rester en vigueur?</td><td></td><td></td></tr>
<tr><td>8</td><td colspan="3">Have all necessary steps been taken to isolate securely all machinery hazardous to the divers by applying appropriate preventive measures on the bridge, in the engine room or at any other relevant locations?
Est-ce que toutes les mesures nécessaires ont été prises pour isoler en toute sécurité toutes les machines présentant un risque pour les plongeurs en appliquant des mesures préventives appropriées sur le pont, dans la</td><td></td><td></td></tr>
</table>

	salle des machines ou tous autres endroits appropriés?		
9	Can you confirm that no additional safety precautions are required to achieve the required isolation over and above that proposed by the Duty Officer/vessel crew? Pouvez-vous confirmer qu'aucune mesure de sécurité supplémentaire n'est nécessaire pour obtenir l'isolement requis au-delà de celui proposé par l'officier de quart / l'équipage du navire?		
10	Are you satisfied that the proposed isolation control actions do fully shutdown / lock-off any possible movement or harmful action that could occur in the vicinity of the diving operation? Êtes-vous convaincu que les mesures de contrôle d'isolement proposées bloquent ou verrouillent complètement tout mouvement ou toute action dangereuse qui pourrait se produire à proximité de la zone de plongée?		
11	Have warning signs been placed at strategic locations alerting crew members, other than those on the bridge or control room, that the indicated equipment has been isolated for safety reasons? Des panneaux d'avertissement ont-ils été placés à des emplacements stratégiques alertant les membres de l'équipage, autres que ceux sur le pont ou dans la salle de contrôle, que l'équipement concerné a été isolé pour des raisons de sécurité?		
12	Have lock-off isolation procedures been used so as to minimize the chances of inadvertent or inappropriate reactivation of plant during diving operations conducted within danger zones? OR If it has proven impossible to institute lock-off isolation procedures, have dive team members been posted as sentries for the specific purpose of preventing inadvertent or inappropriate start-up of dangerous machinery by other persons while diving operations are underway? Des procédures de blocage ont-elles été mise en place afin de réduire les risques de réactivation accidentelle ou inappropriée de l'installation pendant que des opérations de plongée sont effectuées dans des zones dangereuses? OU S’il s'est avéré impossible de mettre en place des procédures de blocage, les membres de l'équipe de plongée ont-ils été affectés comme sentinelles pour empêcher le démarrage involontaire ou inapproprié de machines par d'autres personnes dangereuses pendant les opérations de plongée?		
13	Is the vessel is displaying the appropriate diving signal(s)? Flag Alpha Ball – Diamond – Ball Red – White – Red (Lights) Le navire affiche-t-il le ou les signaux de plongée appropriés? Drapeau Alpha / + signaux de capacité de manœuvre restreinte		
14	Has a VHF radio broadcast been made to alert: Harbour Authority / Port Control / VTS; and all other nearby vessels, informing all those in the vicinity that diving operations are approved and about to commence? Une émission de radio VHF a-t-elle été faite pour alerter les autorités portuaires et tous les autres navires à proximité que des opérations de plongée sont approuvées et sur le point de commencer?		
15	No other controls or warnings are required. If they are, summarize here and then confirm:		

	Aucun autre contrôle ou avertissement n'est requis. Si tel est le cas, résumez ici et confirmez:		

Confirmation Signature Box :		
	Name	Signature
Vessel Master: (or official deputy)		
Chief Engineer: (or official deputy)		
Diving Supervisor:		
If any of the above checklist items are NOT CONFIRMED, additional control actions will be required before diving operations can commence. Si l'un des éléments de la liste de contrôle ci-dessus n'est PAS CONFIRMÉ, des contrôles supplémentaires seront nécessaires avant que les opérations de plongée ne commencent.		

- Before starting a dive on or in the immediate vicinity of any vessel, all relevant personnel aboard must be informed.
- Relevant personnel means: the master, the officer of the watch, the chief engineer, the deckhands or any other person who unintentionally could put the life of the diver(s) in danger.
- Dive Warning Information Boards should be placed at all strategic points where a machine could be started.
- A lockout of all pumps and machines must be put in place.
- A work permit system such as the one proposed by ADC - GP - 001 (Aug 09) must be completed and signed by the concerned parties (see figure n ° 29).
- The keys of the locks must be kept by the diving supervisor.
- Keep all concerned personnel informed of the beginning and end of the dive.

Offshore

Various types of work can be carried out underwater in offshore, but the one with a ΔP risk are:

- The pipelines, flexibles, risers.
- The removal silt work (will be discussed in the next chapter).

Pipelines

Working on submerged pipelines or hoses may present a risk of delta P because they are often set up empty with an internal pressure equal to atmospheric pressure.
The risks of accidents related to a delta P are particularly present when:

- The pipeline is flooded via the pulling head valve.
- Flange protectors are removed from a spool piece or a hose.
- The pipeline is cut.

Photo n° 50: View of a pipeline pulling head (doc. Internet)

ΔP safety rules to be applied when diving to flood a pipe

- Make sure that the filling tube placed on the pulling head, ends with a T-section or that the opening valve is at least at one meter from the end.
- Never stand in front of the water intake.
- Never feel with your hand to see if the opening sucks.

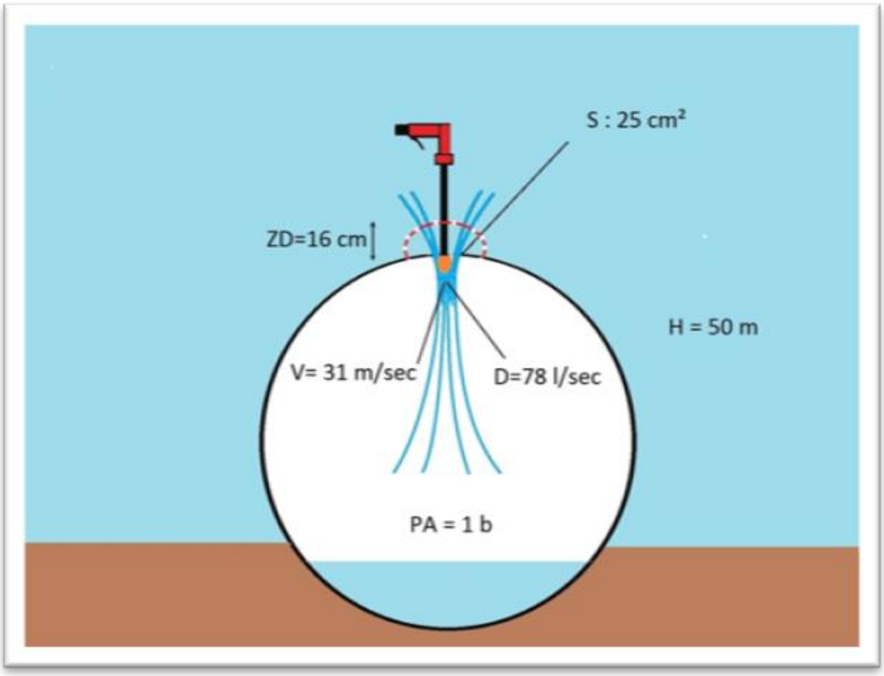
Photo n° 51: Illustration of a bad flange protection (extract photo doc. Terence Elding)

Photo n° 52: Illustration of a correct flange protection (extract photo doc. Terence Elding)

<u>ΔP safety rules to be applied when removing flange protectors</u>

- Make sure that this type of protection has holes or sufficient spacing to fill the spool piece (or hose) during the descent.
- Never break the protection until the tube is completely filled.

Fig. n° 30: Illustration of the initial piercing



ΔP safety rules to be applied when cutting a pipeline

- During the initial piercing for making a venting window, never assume that the pipe is completely full of water.
- Use a new collet and tighten the electrode as far as possible to prevent it from being sucked out of the torch head.
- When first starting, first use a maximum length rod.
- Hold both hands at the level of the torch.
- Wait until the pipe is completely filled with water before continuing cutting.

If a depression exists in the pipeline, the delta P will immediately be materialized by a shrill noise as well as the more or less violent suction of the melting steel into the kerf.
In this case, never use the electrode entirely and leave a butt long enough to keep your hands out of the danger zone.

Example:

Suppose the cutting at sea of a pipeline at 50 meters (165 ft.) depth.
Cutting method: oxy-arc or thermic rods.
The work must begin with the initial completion of a small 5 x 5 cm (0.0025 m^2) (2" x 2") (0.027 ft^2) vent window.
Upon initiation of the arc, the diver will be surprised by the powerful suction that will tend to suck the electric arc and molten metal into the pipe.

As can be read in Figure 30, after completion of this window the flow entering the pipe will be about:

$$Q = 4.43 \times 0.0025 \sqrt{50} = 0.078 \ m^3 / sec$$

Or

$$Q = 8.02 \times 0.027 \times \sqrt{165} = 2.78 \ ft^3/sec$$

This will generate a rather shrill hissing noise that will be caused by the entry at high speed of water into the pipeline.

$$V = 0.078 / 0.0025 = 31.32 \ m / sec$$

Or

$$V = 2.78 / 0.027 = 103 \ ft. / sec$$

It can be estimated that the danger zone (DZ) above the hole will be approximately:

$$DZ = \sqrt{0.078 / (3.1416 \times 1)} = 0.157 \ m$$

Or

$$DZ = \sqrt{2.78 / (3.1416 \times 3.28)} = 0.52 \ ft.$$

To avoid getting your hands sucked into the opening, the diver will have to keep his free hand at the top of the torch during the first piercing and consume a maximum of 10 to 15 cm (0.5 ft.) from the electrode because if unfortunately his hand was caught, the pressure would then be:

$$F = 50 \times 0.0025 \times 1.025 \times 1000 = 128.12 \ kg$$

Or

$$F = 165 \times 0.027 \times 64 = 285.12 \ lb.$$

This pressure will leave no hope to the diver because the concerned member would be quickly dissected by suction.
As can be clearly seen in the following video, the risk of accident is high so avoid it - it is preferable to use remote mechanical cutting and only the local fauna will be at risk.

Photo n° 53: Crab victim of a delta P (doc. Internet)

The inflatable shutter

Shutters are devices intended to close a flow of water in a pipe.
Various types of shutters are available but the two most used types under water are:

- The inflatable shutters.
- The mechanical shutters.

Photo n° 54: Inflatable shutters (doc. Internet)

Photo n° 55: Mechanical shutter (doc. Internet)

ΔP safety rules to be applied when diving to install a shutter

- Before each use, clean the shutter and check if its surface is torn, nicked or damaged.
- Always clean the inside of the pipe correctly and make sure there is no ruggedness in it.
- Choose the correct diameter according to the manufacturer's criteria.
- Observe the loading pressure set by the manufacturer.
- Install a restraint system to prevent the shutter to slide into the pipe in the event of pressure loss.
- Check the pressure regularly.
- At the end of the work, restore the equalization before deflating the shutter.

Loss of tightness due to accidental bursting or deflation of the shutter can have disastrous consequences not only for the diver, but also for personnel working downstream and / or just for the installation that then risks being completely under water.

To avoid this, it is useful to provide a redundancy system that prevents or strongly limits these risks.

Photo n° 56: Inflatable shutter with a redundancy plate

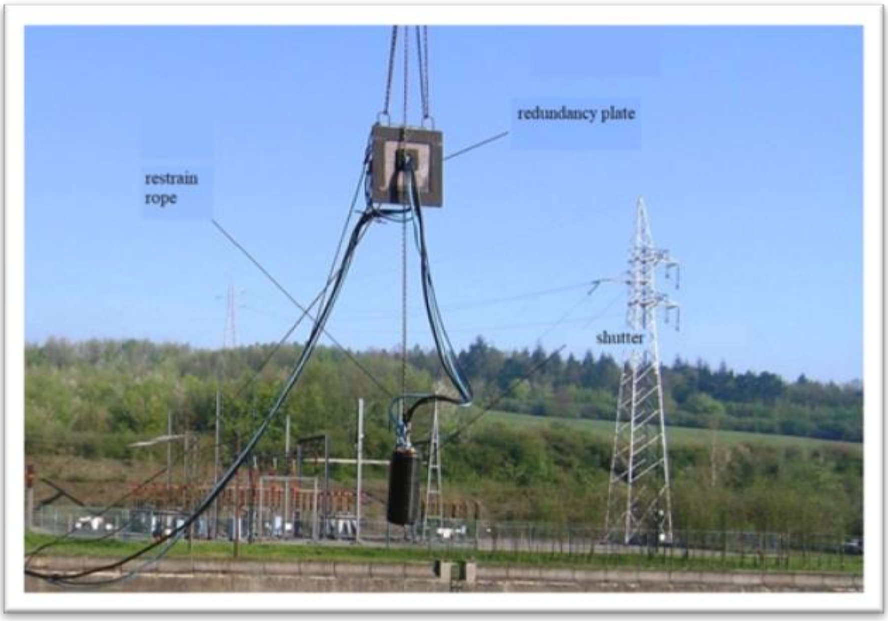


Photo n° 57: Installation of an inflatable shutter

Photo n° 58: Installation of a redundancy plate

Fig. n°31: Illustration of the installation of a shutter and redundancy plate

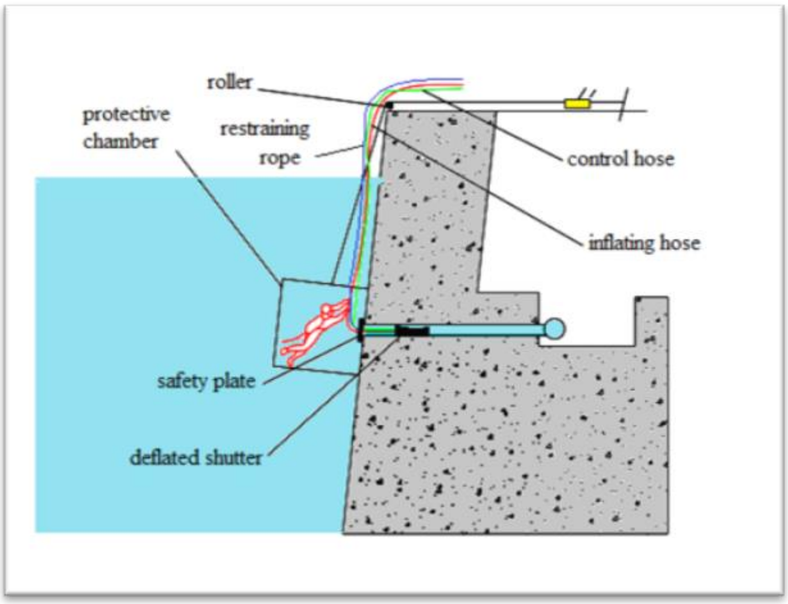
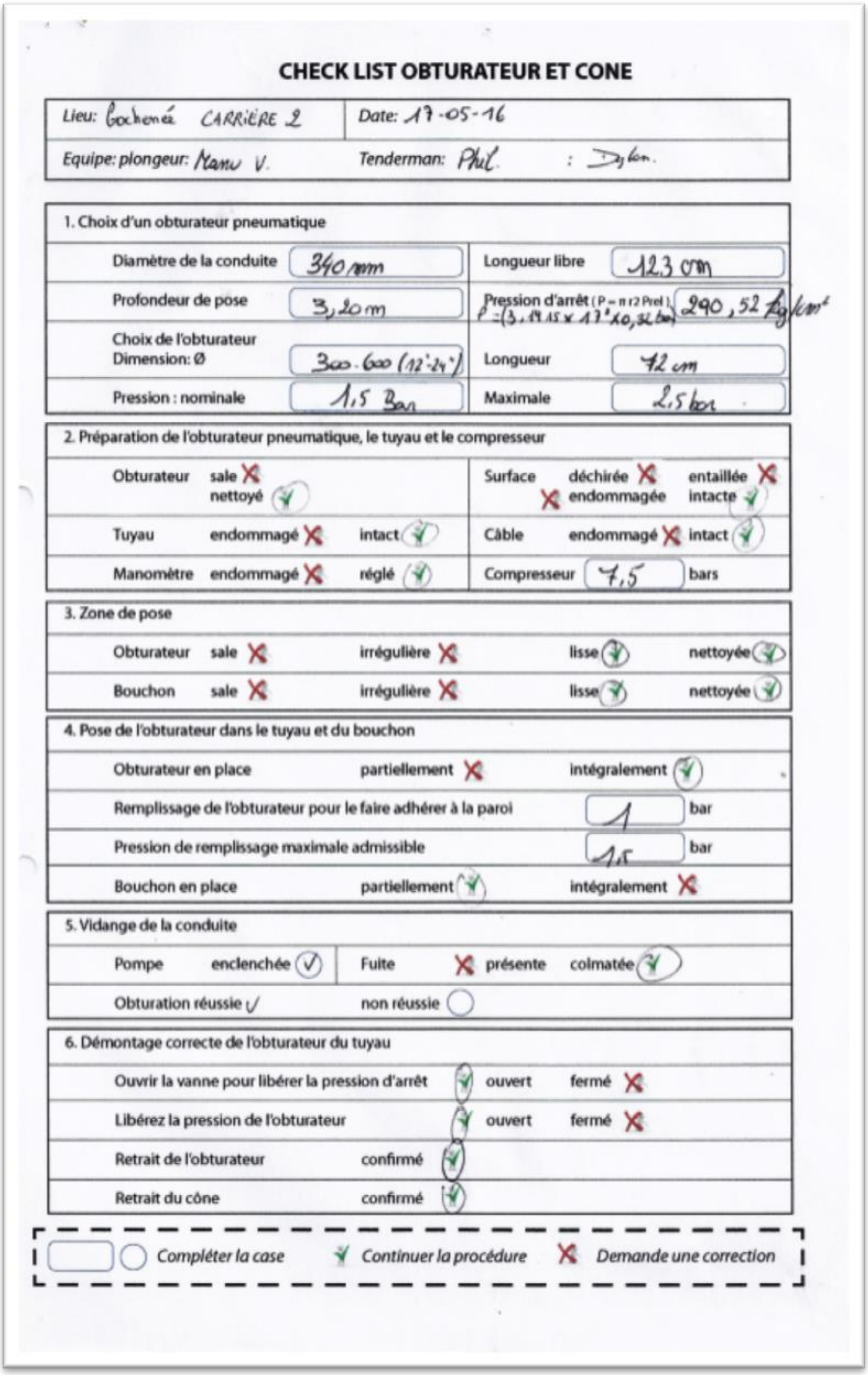


Fig. n°32: Example checklist for a shutter installation (doc.T. Vanden Eynde)



CHECK LIST OBTURATEUR ET CONE

Lieu: Gochenée CARRIÈRE 2	Date: 17-05-16
Equipe: plongeur: Manu V.	Tenderman: Phil. : Dylan.

1. Choix d'un obturateur pneumatique			
Diamètre de la conduite	340 mm	Longueur libre	123 cm
Profondeur de pose	3,20 m	Pression d'arrêt (P = π r2 Prel) P = (3,1415 × 17²×0,32 bar)	290,52 kg/cm²
Choix de l'obturateur Dimension: Ø	300-600 (12"-24")	Longueur	72 cm
Pression : nominale	1,5 Bar	Maximale	2,5 bar

2. Préparation de l'obturateur pneumatique, le tuyau et le compresseur					
Obturateur	sale ✗ nettoyé ✓		Surface	déchirée ✗ ✗ endommagée	entaillée ✗ intacte ✓
Tuyau	endommagé ✗	intact ✓	Câble	endommagé ✗	intact ✓
Manomètre	endommagé ✗	réglé ✓	Compresseur	7,5	bars

3. Zone de pose				
Obturateur	sale ✗	irrégulière ✗	lisse ✓	nettoyée ✓
Bouchon	sale ✗	irrégulière ✗	lisse ✓	nettoyée ✓

4. Pose de l'obturateur dans le tuyau et du bouchon		
Obturateur en place	partiellement ✗	intégralement ✓
Remplissage de l'obturateur pour le faire adhérer à la paroi	1	bar
Pression de remplissage maximale admissible	1,5	bar
Bouchon en place	partiellement ✓	intégralement ✗

5. Vidange de la conduite		
Pompe enclenchée ✓	Fuite ✗ présente	colmatée ✓
Obturation réussie ✓	non réussie ◯	

6. Démontage correcte de l'obturateur du tuyau			
Ouvrir la vanne pour libérer la pression d'arrêt	✓	ouvert	fermé ✗
Libérez la pression de l'obturateur	✓	ouvert	fermé ✗
Retrait de l'obturateur	confirmé ✓		
Retrait du cône	confirmé ✓		

▭ ◯ *Compléter la case* ✓ *Continuer la procédure* ✗ *Demande une correction*

Silt removal tools

Various silt pumping tools can be implemented by divers such as:

- The airlift.
- The vacuum truck pumping.
- The mud pump.

The airlift

Photo n° 59: Airlift (doc. Internet)

This diver’s well-known tool operates by the effect of gravitation thanks to the pressurized air that is injected at the bottom of the tube.
While coming up, this air of lesser density will create a suction at the end of the tube and send the mixture of water and various materials to the surface.
The diameter of the airlifts used underwater by divers generally varies between 5 and 35 cm (2 and 14 inch), but much heavier and large diameter tools can also be implemented when handled by a surface crane.
At shallow depth less than 3 m (10 ft.) this type of tool is very inefficient and therefore the suction it creates is not very important, however, beyond this depth suction will quickly increase and therefore increase risks for the divers.
The accidents most frequently encountered under water, are the brutal suction of the hand inside the tube which besides the trauma it can create can also cause the tearing of the glove, the detachment of the cuff and the setting in depression of the diving suit.
To reduce this risk it is safer to weld a cross on the airlift when diameter is greater than 10 cm (4”). This will at the same time limit the size of the materials entering the tube.

Another consequence related to the use of this tool is due to the fact that in case of total obstruction of the lower part of the tube, the air will rapidly replace the water in the hose.
This can trigger an uncontrolled rise that can pull the diver to the surface with the risk of decompression problems that it entails.
To avoid this, the airlift must be equipped with a quarter-turn valve so that the air supply can be immediately closed by the diver in case of clogging.
The presence of another surface closure valve in the immediate vicinity of the supervisor is also recommended.
Whenever possible, a whip limiting the movement of the airlift must be put in place between the extremity of the tube and a fixed point on the bottom.

Photo n° 60: Silt removal from the surface

In case of use of a large airlift moved by crane, the control of the work may only be done after the suction has been completely stopped.

Vacuum pumping

Photo n° 61: Vacuum truck (doc. Internet)

This type of machine is often used for silt removal in industrial factories when no space is available to store the sludge or when the depth of water is too low to use an airlift.
The operating principle consists to create a vacuum inside the truck tank so as to obtain a pressure practically equal to zero.
At the start of the machine, the pressure difference between the submerged end of the hose and the inside of the tank will create a suction effect in the pipe and send the products to the truck.

Photo n° 62: Improvised grip system

The risks of accident when using this type of tool are mainly to the hands because most of the time the hoses used by the suppliers do not include a holding handle or brace. It happens then that some divers maintain the end of the hose by passing their fingers inside the pipe risking then to crush them if the hose meets a rigid surface. This type of incident is easily avoided by installing a rope handle a few tens of centimetres from the end.

This type of accessory also avoids getting the hand sucked into the tube, this time with far more serious consequences than a simple jamming.

As we have seen, this tool works because of the depression in the tank.

In principle for most vacuum trucks, the maximum suction head of the pump is about 8.8 m (28.9 ft.). We can easily imagine the pressure on the hand of a diver working at 5 meters (16.4 ft.) deep if the palm of his hand is caught against a hose of Ø 150 (6”)in which there is a depression of 500 mb (7.25 psi).

$$F = Ha + Hd \times Area \times D \times 1{,}000$$

Or

$$F = Ha + Hd \times Area \times D$$

Where

F = force in kg (lb.)

Ha = Height of the water above the diver (m) (ft.)

Hd = depression value (m) (ft.)

Area: area (m^2) (ft^2) (here the hand)

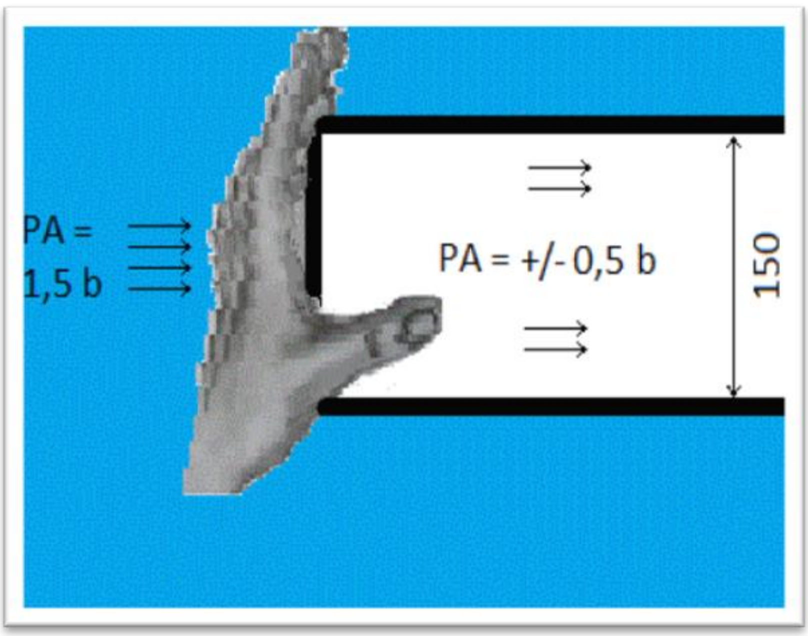
D = density of the liquid (g/cm^3) ($lb./ft^3$)

$$F = 5 + 5 \times 0.017 \times 1 \times 1{,}000 = 170 \text{ kg}$$

Or

$$F = 16.4 + 16.4 \times 0.18 \times 62 = 366 \text{ lb.}$$

Fig. n° 33: Illustration of the pressure / vacuum on the hand



As can be seen, this pressure is more than enough to break the hand and this tool must be handled with the utmost caution. In order to limit the risk of an accident, the diving supervisor must be in direct contact with the truck operator so that the latter can immediately stop pumping if necessary.

Mud pumps

Mud pumps are generally selected when the volume of mud to be removed is important because they have a much higher efficiency ($\geq 360\ m^3 / h$) than other pumping equipment.
Two types of pumps can be used by the divers:

- Submerged pumps.
- Surface pumps.

Submerged pumps

Due to their weight, this type of pump is only moved by a crane and the role of the diver is generally limited to simple inspections.
If the bottom of the pump is not streamlined, the main risk is at the propeller, which can then catch the umbilical or cause extremely serious limb injuries. It is therefore strongly recommended that the pump is shut down when a diver moves in the immediate vicinity of it.

Photo n° 63: Submerged pump (doc. Internet)

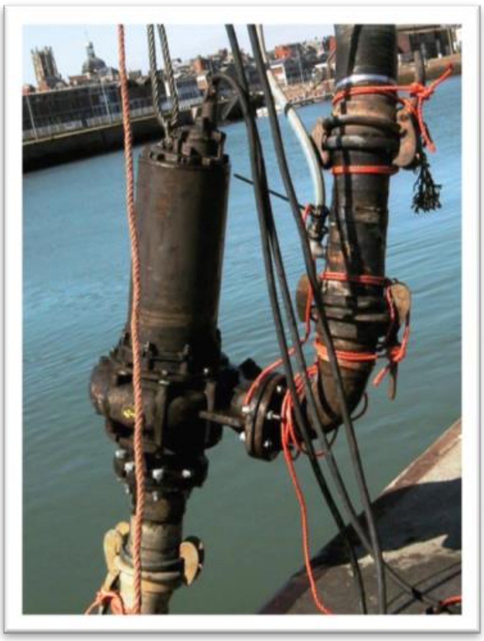
Surface pumps

As its name suggests, this type of pump remains on the surface and pumping is done through a reinforced hose (4 " / 6 ") moved by the diver.

Photo n° 64: Surface pump

With the installation of a special connection, submerged pumps can also be used with a suction hose moved by the diver.

Photo n° 65: Connection for the use of a suction hose (doc. T. Vanden Eynde)



In both cases, the safety rules to follow are identical to those prescribed for vacuum pumping.

Risk Analysis

It is likely that a large number of accidents due to delta P could have been avoided if a correct analysis had been carried out.
Unfortunately this approach is relatively recent and is still far from being applied everywhere, or when done, it is without really taking into account the real risks likely to be encountered on the site.
To be effective, it is preferable that all the involved actors make the risk analysis together and take into account the remarks of the people familiar with the site.
In this type of document, the most important thing is to list the risks likely to be met and indicate the way to avoid them.
As example here is an excerpt from the risk analysis carried out on a diving site in Belgium a few years ago.

Fig. n° 34: Example risk analysis for the cooling tower project (see page 42)

RISK ASSESMENT FORM

Site : Moustier sur Sambre
Date: 23/06/03
Work description: Video inspection and metal thickness measurements on the reject pipes inside the cooling tower
Water temperature: 40° C

	Hazard		Initial risk			Prevention	Final risk		
Job task	Hazard description	Concerns	Severity of hazard	Likelihood of occurrence	Risk rating	List	Severity of hazard	Likelihood of occurrence	Risk rating
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Thickness measures & video	Delta P. Being sucked in the central tube DZ = 2,52 m Current velocity around the reject pipes +/- 0,11 m/sec.	Diver	High	Very likely	High	Setting up of a weighted down line (30kg) beside the pipes to be controlled. Setting up before getting down on the ladder, of a 2 m sliding rope between the diver's harness and the restriction line. Maintain the umbilical straight at the upstream side of the diver.	High	Very unlikely	Low
		Tenders	High	Possible	Medium	Stay behind the railing. Wear a lifejacket.	High	Very unlikely	Low
Thickness measures & video	Hyperthermia	Diver	Moderate	Possible	Medium	Wearing of a Tivex suit with cold water circulation. Limitation of dive time to 15 minutes in case of cooling system problem	Moderate	Very unlikely	Low
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Rules of conduct during dives in a ΔP risk zone

- When preparing the diving project, we must take into account the accessibility of the site so that any rescue team can intervene without difficulty.
- In case of doubt about the possible presence of a delta P (leak, valve partially open, etc.) it is necessary to practice a control before diving.
- Always go down in front of the work area so that the umbilical does not cross a risk zone.
- If this cannot be done from the structure, use a stable vessel or a small pontoon.
- Properly handle the umbilical's slack.
- Never dive in scuba.
- Never dive without communication.
- If necessary, limit the displacement of the diver with a restraint system.
- If there is known delta P, calculate the danger zone (DZ) and extend that distance as much as possible.
- Ensure enough breathing gas to cope with an emergency situation if the diver is stuck.
- Use an umbilical with a breaking load of at least 500 kg (1,100 lb.)(1000 kg (2,200 lb.) recommended by the CADC).
- Wear a solid harness with a breaking load of at least 500 kg (1,100 lb.)(1000 kg (2,200 lb.) recommended by the CADC).
- Attach a rope of +/- Ø 20 mm (tensile load + / _ 8T) to the harness (neck / shoulders) ring(s) used for lifting.
- Provide a pull / lift system to which this rope can be connected.
- Whenever possible, position this pull / lift system so that in case of problem it is possible to pull the diver away from the opening.
- Wear the harness correctly, taking care to also attach the legs straps.
- Ensure that the diver wears enough warm clothing so that he can cope with an emergency situation and delay hypothermia as much as possible in the event that he cannot free himself.
- Whatever the structures to dive on, locate the dangerous places and install a guide line leading directly to the safe area.
- After the lock-out, the hydraulically or the compressed air operated elements must be purged downstream of the isolation point in order to remove the residual pressure.
- Ensure that surface personnel are protected from falling into the water (guardrail, stop-fall) and wear their lifejacket.
- When looking for leaks, using a shackle or clay bag, make sure that the slack of the rope on the surface remains clear so that it do not accidentally pull someone in the water in case the rope is violently sucked into the opening.

What to do if the diver is caught in Delta P

Under water the diver must:

- Try to disengage so that neither the chest nor the head can get caught in the opening.
- If the chest is caught against the opening, try to position yourself laterally to reduce the pressure area.
- If the helmet is caught in the opening, one must open the free flow thoroughly because the pressure difference will cause a depression in the regulator and make inspiration difficult or impossible. Depression may also create a squeeze inside of the helmet or band mask via the exhalation valve.

On the surface the team must:

- Immediately stiffen the umbilical in a position diametrically opposed to the delta P to prevent the diver from engaging more in the opening.
- Depending on the cause of the delta P check if it can be stopped immediately (emergency stop button / balancing / etc.)
- Attempt to recover the diver by pulling him via the safety rope (men or winch) in a direction diametrically opposite to the delta P.
- As a last resort in case of a critical situation and if it is possible, open the element to send the diver to the other side while giving maximum slack to the umbilical.

In Belgium, two rescue attempts using this method took place during this decade.
In the first case the rescue was successful and the diver escaped with some broken ribs.
In the other, it unfortunately failed because the diver was not properly equipped (scuba and small band mask) and drowned.

Conclusions

As a conclusion, it can be written that the chances to survive a delta P depend on the pressure on the diver, but in most cases his chances are relatively slim.
The risks inherent to the pressure differences are not only a danger for the underwater workers, but in the event of an accident also for the stand-by diver or, failing that, the rescue team because if the danger has not been neutralized, it risks then to do other victim (s).
This is, moreover, and unlike other situations, the reason why the supervisor must avoid sending the stand-by diver immediately to assist his colleague.
In many cases, if there is no balancing of the pressures, the help that he can provide will be negligible and will often be limited to setting up an additional means of traction on the diver's harness.
Depending on the forces encountered, attempts to recover via the umbilical are often unsuccessful and can if it is incorrectly rigged transfer the traction (or part of it) on the connection connectors and twist them, or even more serious tear off or break the umbilical if the tensile strength of it is less than the pull required to extract the diver.

Therefore, to avoid the sending of the stand-by diver and in order to ensure the recovery of the casualty, it is recommended as specify in the general safety rules to wear a solid harness correctly and already put in place on the lifting ring (s) a rope of adequate diameter. In order to facilitate its handling, the immersed part of the rope on the diver's side can be roughly taped every meter on the umbilical, while the other part should be kept close to a mechanical lifting device.
Unfortunately, if one is not able to balance the pressures and one has to use a great pulling force to extract a diver from his grip, then it is rare that he gets out without serious traumas which are often fatal.
So to avoid one day being part of the statistics, watch out for yourself, think before diving and as our English-speaking colleagues say:

DIVE SAFE

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