Differential pressure hazards in diving

HSE information sheet

Diving Information Sheet No 13

Introduction

This diving information sheet is part of a series of information sheets providing guidance on diving at work.

It provides information on the nature of differential pressure hazards in diving and highlights the considerable risks associated with this hazard. It also provides guidance on methods to use to assess, prevent, control and mitigate pressure differential risks to working divers.

Differential pressure hazards – understanding the problem

The Health and Safety Executive has funded research[1] into the unique and deadly hazard that differential pressure presents to divers. Differential pressure hazards occur where water moves from an area of high pressure to one of low pressure. It presents no risk when there is no water flow. However, once flow starts, the forces generated can be considerable. Water flow may be a consequence of the movement of water under its own weight, or it may be an active process involving machinery. It could occur, for example, as a result of structural failure, the opening of a valve, a diver cutting into a void, or a pump starting. When the flow passes through an opening, any diver approaching the high pressure (or upstream) side may be drawn in and trapped. Serious or fatal injuries frequently occur under such circumstances.

The force generated between two bodies of water at different levels is dependent on the difference in height between the water levels and the size of any opening in the barrier. Where the water levels are significantly different on either side of a barrier considerable forces are likely to be generated, even through small openings. However, what is often not recognised is that very significant suction forces can also be created when a modest difference in water levels is combined with a relatively large opening. Divers have been killed in depths as shallow as 3 metres.

Types of differential pressure hazards

Differential pressure hazards commonly occur in, but are not limited to, the following:

- dams, canals, locks, weirs, sluices, water tanks, swimming pools and drains;
- around ships, pipelines and other hollow structures; and
- at power, desalination and other plant intakes.

Differential pressure hazard situations can be divided into four types:

- when water levels vary either side of a boundary (eg at dams and lock gates);
- when a submerged or partially submerged hollow structure contains gas at a higher or lower pressure than the surrounding water (eg at submarine pipelines and other underwater structures with hollow components and also around ships);
- when water is mechanically drawn through intakes (eg at cooling or fire water intakes in onshore and offshore installations, or sea chests on ships); and
- when water is mechanically drawn towards propellers, or other types of thrusters, on vessels.

Incidents caused by propellers or thrusters on vessels are almost invariably fatal. However, the injury is significantly different to that caused by suction and does not involve being trapped or injured by the differential pressure. This Diving Information Sheet does not address these hazards. Industry guidance on controlling the hazards associated with diving on ship hulls can be found in the ADC document; ADC-GP-001[2]

Characteristics of differential pressure hazards

- Differential pressure hazards are found in virtually all water depths.

- Incidents involving energised pumps can occur at any depth of water, with the pump itself providing the suction force (eg, in a swimming pool).
- Submerged divers can rarely detect a pressure differential hazard in time to avoid it.
- Once encountered, it is very difficult for divers to escape from the suction forces. Equalization of the pressure difference is usually required before divers can be freed.
- Differential pressure hazards are frequently fatal with no opportunity for effective intervention from rescuers. Attempts by rescuers at the surface to use force to free a diver, prior to the equalisation of pressure, frequently result in further injuries to the trapped diver.
- Other divers who enter the water to try to free a trapped diver are themselves often injured or killed during attempted rescues.

Risk assessment

Diving contractors are responsible for ensuring that a suitable and sufficient risk assessment is carried out before the start of any diving project and a diving project plan prepared. The risk assessment must assume differential pressure hazards are present where:

- water levels between adjoining areas vary;
- water is adjacent to gaseous voids;
- water can be mechanically drawn through intakes; and
- water can be mechanically drawn towards propulsors or other types of thrusters on ships.

The risk assessment should be completed in conjunction with competent staff fully familiar with the dive site (eg, client company engineers) and reviewed regularly.

Some differential pressure hazards may only arise following a structural failure. In this case the risk assessment should include an assessment of the integrity of the structures in or around which diving is to take place. Particular care must be taken before assuming the continued integrity of temporary or damaged structures.

The area of fast moving water around a hazard which may place the diver at risk from water flow, suction or turbulence (whether brought about naturally or produced by the operation or failure of plant and machinery) is termed the Differential Pressure Danger Zone (DPDZ). Simple methods of estimating the size of a DPDZ and the magnitude of the potential forces involved are provided at Annex F of the HSE research report[1].

The considerable uncertainties associated with applying these calculations to diverse real life situations indicate they should be used with caution. They should not be used in an attempt to demonstrate that the differential pressure hazard is trivial and requires no further control.

Prevention and control of differential pressure hazards

Engineering controls to minimise differential pressure hazards should be considered at the design stage of ‘new-build’ projects. For example, these might include design features that:

- allow pressures to be equalised;
- only require diver intervention from the low pressure side;
- provide relevant valves with double redundancy
- prevent diver encroachment into a DPDZ.

When suitable and sufficient controls are in place it is possible for divers to work safely in the vicinity of differential pressure hazards. Engineering control measures (‘hardware’ measures) are considered inherently more reliable than procedural and behavioural control measures (‘software’ measures). Reasonably practicable hardware measures should therefore be instituted ahead of software measures. Software measures should not be used to justify the absence of reasonably practicable hardware measures. Both types of risk control measures are likely to be required for the effective elimination or control of differential pressure hazards and risks during diving operations.

Examples of failures in the control of these hazards highlight the necessity of:

- assessing the effectiveness of control measures prior to the diver entering the water;
- the use of robust physical barriers to the operation of valves/intakes; and
- the separation of divers from a DPDZ.

Prevention

- Identify any possible differential pressure hazards in conjunction with the appropriate competent people (eg, client company engineers familiar with the site).
- Evaluate the risks arising from any possible differential pressure hazards.
- Avoid the risk. Do not allow a diver to enter an active or latent DPDZ (especially on the high

pressure side). Question if the work needs to be done using a diver.
- Use engineering controls to eliminate the existence of any active DPDZ, or the chance of a DPDZ developing which could impact on the safety of the diver. Wherever possible, equalise any pressure differentials prior to the commencement of diving operations.

Control

If it is physically impossible to eliminate the risk from pressure differential situations and there is no way of avoiding the use of a diver to carry out the work, then control the risk as follows:

- Use engineering controls to make the differential pressure as small as possible.
- Do not dive on the high pressure side; dive from the low pressure side.
- Consider conducting a remotely operated vehicle pre-dive survey.
- If diving work on the high pressure side is absolutely unavoidable, carry out a thorough risk assessment and produce a detailed (procedural) safe system of work (SSW) in conjunction with the relevant competent people (eg, client company engineers familiar with the site).
- As part of the SSW use a Permit-to-Dive system, incorporating lock-off isolation of any necessary plant/machinery to ensure that unsafe reconnection/operation is not possible.
- Check any valves that must be closed are indeed fully closed and not leaking. Do so from the low pressure side. Check that all submarine structures, machinery and seals are fit for purpose and safe to use prior to diving. Prove the efficacy of any isolations necessary to safeguard the diver.
- When a closed valve(s) represents the main defence against exposure to an active pressure differential situation, where possible, use more than one valve.
- Estimate the size of any active or latent DPDZ. Use the tables in reference 1, Annex F. Consider if there are foreseeable circumstances where the size of a DPDZ might suddenly increase or exceed anticipated values. For example, marine growth partially blocking a water intake will significantly increase the water flow velocity. Where practicable carry out accurate flow velocity measurements at appropriate locations immediately prior to diving.
- Where practicable, prevent divers from entering a DPDZ by limiting the length of umbilicals, constructing adequate guards/screens, or by designing valves to minimise entrapment risks. Alternatively, establish a standard exclusion zone which incorporates a suitable safety margin around a DPDZ.
- If divers are unavoidably required to enter a latent DPDZ do not allow them to interfere with seals or other engineering barriers to water flow (especially when working from the high pressure side).
- Provide divers and support staff with all necessary information and instructions to work safely prior to commencing diving operations.
- Only use surface supplied diving equipment (SSDE) on diving projects where pressure differential hazards have been identified.

References

1 *Differential pressure hazards in diving.* HSE Research Report 761.

2 *Diving From, On or in Close Proximity to Merchant Vessels*, Association of Diving Contractors (ADC) Guidance Procedure ADC-GP-001. Available from the ADC website at: http://www.adc-uk.info/

Further reading

The Professional Diver's Handbook, Second Edition 2005, John Bevan, Submex Ltd, ISBN: 0 9508242 2 4
Differential Pressure Heads, Association of Diving Contractors (ADC) Information Note 03/05

Guidelines for Isolations and Intervention: Diver Access to Subsea Systems, International Marine Contractors Association, IMCA D 044, October 2009

Diving Operations in the Vicinity of Pipelines, International Marine Contractors Association, IMCA D 006 Rev. 2, April 1999

Protection of water intake points for diver safety, Association of Offshore Diving Contractors, AODC 055, February 1991

Effects of underwater currents on divers' performance & safety, Association of Offshore Diving Contractors, AODC 047, July 1987

The Hazards of Working in "Delta P" Work Environments (video/CD Rom), Association of Diving Contractors International (ADCI). Available from ADCI website at http://www.adc-int.org/products.php

Commercial diving projects offshore. The Diving at Work Regulations 1997. Approved Code of Practice L103 HSE Books 1998 ISBN 0 7176 1494 8

Commercial diving projects inland/inshore. The Diving at Work Regulations 1997. Approved Code of Practice L104 HSE Books 1998 ISBN 0 7176 1495 6.

Recreational diving projects. The Diving at Work Regulations 1997. Approved Code of Practice L105 HSE Books 1998 ISBN 0 7176 1496 4

Media diving projects. The Diving at Work Regulations 1997. Approved Code of Practice L106 HSE Books 1998 ISBN 0 7176 1497 2

Scientific and archaeological diving projects. The Diving at Work Regulations 1997. Approved Code of Practice L107 HSE Books 1998 ISBN 0 7176 1498 0

The Diving at Work Regulations 1997 SI 1997/2776 The Stationery Office 1997 ISBN 0 11 065170 7

IMCA/AODC guidance notes are available from: International Marine Contractors Association, 52 Grosvenor Gardens, London, SW1W 0AU. Tel: +44 (0) 20 7824 5520. Email: publications@imca-int.com.

Further Information

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This document contains notes on good practice which are not compulsory but which you may find helpful in considering what you need to do.

This document is available at: www.hse.gov.uk/pubns/dvis13.pdf.