IMCA Safety Flashes summarise key safety matters and incidents, allowing lessons to be more easily learnt for the benefit of all. The effectiveness of the IMCA Safety Flash system depends on members sharing information and so avoiding repeat incidents. Please consider adding **safetyreports@imca-int.com** to your internal distribution list for safety alerts or manually submitting information on incidents you consider may be relevant. All information is anonymised or sanitised, as appropriate.

1 Compressed air rather than oxygen supplied to divers

Applicable Life Saving Rule(s): Bypassing Safety Controls; Work Authorisation

What happened

Several divers were affected and two divers became ill when compressed air rather than oxygen was supplied to them by mistake on their BIBS (Built in Breathing System). The error caused two lymphatic/skin decompression illnesses and incorrect decompression profile for several other divers.

What went right?

- Dive and project team reacted appropriately when decompression illness was suspected;
- All emergency procedures were followed;
- Once the root cause was identified and understood all work stopped and investigation and controls were conducted, and the dive and project team took the correct and required actions.

What went wrong

- The gas supplier's agent did not have sufficient control:
  - The wrong kind of gas was delivered – there was no check of the gas quad before it was dispatched;
  - The gas quad had incorrect labelling and colour code and was similar to the other 100% oxygen quads stored at the mobilization site;
  - The threads on the quad piping system containing compressed air were compatible with the approved medical oxygen regulator.
- The oxygen fraction (FO_2) of the third-party gas quad was not checked by the diving contractor upon delivery to site;
- The gas quad fixed pressure manometer (pressure reading) was checked at the site of the quad on 92 occasions by 21 individuals, but no one noticed the difference of the air quad from an oxygen quad;
- The dive system had online gas analysers on all gas types and delivery systems except for the BIBS gas supply line to chamber;
- The team investigating the first incident did not consider the possibility of inappropriate breathing gas. This failed to identify the underlying cause and allowed a second incident to occur.

Lessons and actions

- Better control of supplied diving gases;
- More thorough auditing of diving gas supply chain;
- Improve competence and training in two areas: dive technicians' labelling of gas, and management site investigation;
- Ensure diving gas supply and analysis equipment is fit for purpose;

- Company added new verification requirements, based on the incident, including:
  - Can the BIBS supply be analysed on the chamber panel;
  - Does the competence scheme capture technical know-how of gas management and verification?
  - Do investigation lead/ technical advisors hold formal training in investigation?
  - Ensure regular and thorough audit of third party gas suppliers;
  - Ensure company procedures and routines comply with IMCA guidance on gas management and control

Members may wish to refer to:

- Failure to follow gas quad procedure
- Substandard nitrogen quads delivered to shipyard
- Helium gas quad – gas variances across quadrants
- High potential near-miss: Poor O_2 content in supplied air – diver temporarily lost consciousness

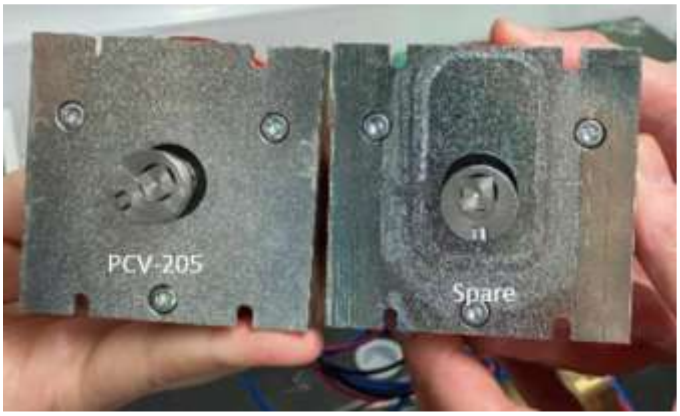
2 Failure of proportional valve in saturation chamber control

What happened

There was a failure during saturation diving operations. There were no injuries to personnel nor damage to equipment, but time was lost. The automatic control system for the hyperbaric chamber detected that there was a proportional valve command/feedback discrepancy and stopped pressure control of the hyperbaric chamber. The valve malfunction forced an abort of diving operations and lost time.

What went right

- The PLC detected the discrepancy, isolated the line, alerted the operator in the control room and handed over control to the manual valve.
- The safety system designed to recover from the first failure worked effectively.
- The diving contractor involved, correctly decided to stop the diving activity, alerted the authorities, and started investigation sharing information with the saturation chamber suppliers and the valve manufacturer;
- The valve was correctly selected for the application, and had correct SIL2 certification.



What went wrong

- The valve feedback did not respond correctly, the potentiometer was found defective;
- The diving contractor's personnel had dismantled the valve (although this was prohibited by the manufacturer) in an attempt to solve the problem. It had to be reassembled 180° upside down because the drive shaft was out of alignment with its 'set' zero point. This made it impossible to understand if the potentiometer was damaged by wear of time or by wrong disassembly/assembly;
- Investigation found debris in the valve seat, which could have led to more serious problems (see second image).

Lessons

- Manufacturers recommended maintenance should be followed. If operational experience falls outside this, the OEM should always be consulted with a view to ensuring manuals are updated and knowledge shared;
- Work with manufacturers and suppliers to ensure there are up-to-date maintenance procedures;

- Follow an equipment supplier's recommendation for critical spares;
- Ensure personnel are properly trained to operate safety critical equipment in all circumstances.

Actions

- Share incident with operators of similar saturation systems equipped with that specific equipment;
- Ensure there is a stock of spares considered critical by the saturation system supplier;
- Amend planned maintenance system to include appropriate testing, maintenance or planned replacement of critical parts;

The supplier of the saturation system further recommended:

- Checking pipe cleaning status and filtering throughout the system;
- Ship all dismantled valves to the manufacturer for further examination;
- Perform appropriate tests before returning to dive operations.

Members may wish to refer to:

- Uncontrolled movement of A-frame *[failure of proportional valve driver]*
- Loss of redundancy in diving bell launch and recovery (LARS) PLC system

3 Case study: saturation diver fatality due to hydrogen sulphide

This is a very brief summary of a 2021 case report on the much earlier death of a saturation diver in the Bombay High oilfield, which occurred as a result of hydrogen sulphide poisoning. It is included as a reminder of the danger of hydrogen sulphide and as a means to facilitate discussion. The full case study, prepared by Dr Ajit C Kulkarni, of Hyperbaric Solutions, Mumbai, India, can be found here.

Hydrogen Sulphide

The permissible exposure limit of H_2S is 15 parts per million (ppm) for 15 min at normal temperature and pressure.

At 10 ppm it has a 'rotten egg' smell but at concentrations above 200 ppm, the olfactory nerve becomes paralysed immediately.

At concentrations above 500 ppm often the sense of equilibrium is lost and the affected person can become unconscious.

Beyond 1000 ppm death is almost instantaneous.

What happened

The incident happened on board a vessel operating in an offshore oil field, on a long charter for carrying out inspection, maintenance and repair duties. An oil leak was discovered in one of the main 36-inch (91cm) diameter subsea lines carrying sour crude. The vessel was directed to proceed to the site and carry out pipeline repairs on an emergency basis at 74 msw depth.

A diver was deployed from the bell at 65m depth, a short distance away from the pipeline, not directly above it. On reaching the seabed, the diver approached the leaking pipeline to locate the rupture and conduct a close survey of the leak area and the pipeline. The seabed all around the trench was covered with oil sludge. After getting preliminary details, he returned to the bell.

Shortly after he had returned to the bell, first the bellman, then the diver himself, collapsed. Not having secured the safety harness, the diver fell into the water and was carried away by the current, and drowned. A bell-to-bell rescue of the bellman was arranged with equipment and divers from another nearby vessel. Following medical treatment, he made a full recovery and was diving a month later. The lost diver's body was recovered the following day.

What was the cause

The presence of hydrogen sulphide (H_2S) in the bell was the root cause.

The diver, while working near the pipeline, had dislodged oil sludge which resulted in release of dissolved H_2S. Although the diving bell was not directly above the leak, there is a possibility that some H_2S entered the diving bell. At that time, an electronic continuous gas monitoring system was not fitted in the diving bell nor was a handheld detection unit carried in the bell. The diving supervisor would not have had any indication of H_2S in bell.

Another possibility is that there was a considerable amount of oil was on the diver's suit. His umbilical was also covered with oil sludge. Rising from the seabed to the bell, the pressure decreased by almost 100 kPa (one bar), reducing the solubility of H_2S in oil, and excess gas was released from solution and entered the bell, causing the bellman and diver to collapse.

Lessons

The case study notes that, ideally, a remotely operated vehicle (ROV) could have carried out a pipeline survey at zero risk. When this accident happened, ROVs were not routinely available. Today, work ROVs are present on MSVs and carry out pipeline surveys, marine growth removal, etc. Divers continue to work on pipelines but a similar accident has not recurred.

4 Case study: confined space fatalities due to Hydrogen Sulphide

This is a brief summary of a recent case report on confined space fatalities on board an oil rig during work involving gas sampling/monitoring inside the "spud cans" of the rig.

It is included as a reminder of the danger of Hydrogen Sulphide and as a means to facilitate discussion. The full case study, prepared by Dr Ajit C Kulkarni, of Hyperbaric Solutions, Mumbai, India, can be found here.

What happened

The legs of a jack-up rig were fully retracted and the "spud cans" or feet of the legs were above the water and accessible for man entry. They were dewatered and forced ventilated for two days. A "Gas free", i.e. no H_2S present, "safe to enter" certificate had to be generated before a marine surveyor could enter for inspection. The onboard diving team (three divers and a diving supervisor) were tasked to enter the "spud can" and obtain gas samples. A diver using SCUBA (self-contained underwater breathing apparatus) equipment and a life-line, climbed down a 5m ladder and went into various corners. He was attended by another diver at the bottom of the ladder, also wearing B.A. This diver was visible to the supervisor above. The third diver was a "stand by" diver dressed and ready to intervene – but not yet wearing B.A.

Jack-up rig leg "spud can" removed for maintenance (Image for illustrative purposes only)

Shortly after starting the operation, the dive supervisor saw the attendant at the bottom of the ladder collapse. On seeing this, the supervisor impulsively climbed down the ladder to assist, *without wearing a B.A set*. Before he could reach the attendant, he too collapsed. The alarm was raised and the ventilation rate was increased to drive out the "sour gas" from inside the spud can. As soon as this was done, a large quantity of gas emerged out of the narrow opening of the spud can and the "stand by" person was affected and collapsed.

All three persons who entered the spud can died; the "stand by" person" was resuscitated, evacuated and admitted to intensive care at hospital.

What went wrong

- Cause of death as determined by the Coroner as asphyxia. Circumstantial evidence pointed to inhalation of H_2S anticipated in the spud can. Spud can is almost 5 m in height and because of its typical internal construction, has numerous poorly ventilated nooks and corners;
- In addition, there were puddles of mud sludge which contain dissolved H_2S. The first person who went inside the spud can stirred up the collected H_2S in low areas and also the sludge containing dissolved H_2S. Being exposed to this, he became unconscious and collapsed;
- Ventilation exhaust could escape through a single opening only. The attendant who was at the bottom of the ladder was affected by the toxic gas produced and collapsed;
- The supervisor entered the spud can without B.A and collapsed immediately;
- The "Stand by" person, not wearing B.A, was affected by the gush of gas coming out of the opening due to forced ventilation but being in the open, quantity of gas inhaled was much less and this person survived.

Hydrogen Sulphide is a highly toxic, colourless, combustible gas. It has the unmistakable odour of rotten eggs at low concentration. However, the sense of smell is not a reliable warning because exposure to this gas results in paresis of the olfactory nerve very quickly. It being heavier than air, tends to settle down in low lying areas. It is soluble in water and oil, and its presence in the workplace is a serious environmental hazard.

What was the cause

- Incorrect Breathing Apparatus (B.A) – SCUBA diving equipment - was being used;
  - This is entirely - and in this case lethally so - inappropriate for use other than underwater. For enclosed space entry, SCBA (self-contained breathing apparatus) should be used; the face mask is gas tight, preventing entry of toxic gas, fumes etc. from entering.
  - The face mask used in SCUBA underwater breathing apparatus is not tight fitting and some water gets inside and equalizes pressure under the mask. If the mask was tight fitting, as the diver descends in water and there is an increase in ambient pressure, the mask will squeeze the face.
  - The two kinds of face mask look similar but are fundamentally different. [IMCA notes: there is a human factors lesson there for us all]
- The team doing the job were not trained for the job and had no idea of the risks involved;
- There was no risk analysis of the job, no tool box meeting was held, no contingency plan prepared;
- The team doing the job were third-party contractors and were not inspected, audited or checked when they arrived on the rig.

Possible solutions identified by author

- Proper planning and appropriate training for enclosed/confined space entry, particularly for third-party contractors;
- Such training should include:
  - Active monitoring for H_2S gas, including both personal and area monitoring;
  - Understanding of the dangers of H_2S and how it behaves;
  - Where to wear personal detection monitors, preferably over the chest pocket or on the collar, i.e. as close as possible to the nose;
  - Proper use of correct breathing apparatus;
  - Use of the "buddy" system;
  - Training and drilling of emergency response team;
  - Proper use of Permit to Work system and safe systems of work;

Members may wish to refer to:

- Hydrogen Sulphide detected in a bilge tank
- Crew member fainted after working in water ballast tank
- Confined space entry: person overcome by fumes and rendered unconscious