APPENDIX V3.04

ENVIRONMENTAL MEASURES FOR THE WRECK OF U-864

Use of divers to raise the mercury – Assessment of mercury exposure

DNV GL AS

http://www.caldive.com/diving-support.html
http://www.blue-bubbles.com/com_diving.html
Project name: Environmental measures for the wreck of U-864
Report title: Use of divers to raise the mercury – Assessment of mercury exposure

DNV GL AS
Project Management & Technical Services Program
P.O.Box 300
1322 Høvik
Norway
Tel: +47 67 57 99 00

Prepared by: Jens Laugesen (DNV GL AS)
Verified by: Carl Erik Høy-Petersen (DNV GL AS)

Dato: 12.5.2014

Gjengivelse av deler av dette vedleggsdokument som kan føre til mistolkning er ikke tillatt
TABLE OF CONTENTS

1. INTRODUCTION
2. DESCRIPTION OF THE OPERATION
3. ABOUT SATURATION DIVING
4. NORWEGIAN GUIDELINES FOR MERCURY IN THE OIL AND GAS SECTOR
5. HAZARDS WHEN DIVING IN CONTAMINATED WATERS
6. SPECIFIC CRITICAL OPERATIONS FOR THE DIVERS WHEN WORKING WITH MERCURY AND MERCURY CONTAMINATED SEDIMENTS AT U-864
7. AVERTING MEASURES FOR DIVERS WORKING WITH MERCURY AND MERCURY CONTAMINATED SEDIMENTS AT U-864
8. CONCLUSION
9. REFERENCES
1 INTRODUCTION
The German submarine U-864 was sunk by the British submarine Venturer on 9 February 1945, approximately 2 nautical miles west of the island Fedje in Hordaland, Norway. The submarine was on its way from Germany via Norway to Japan with war material and according to historical documents; U-864 was carrying about 67 metric ton of metallic (liquid) mercury, stored in 1 857 steel canisters in the keel (Figure 1). The U-864, which was broken into two main parts as a result of the torpedo hit, was found at 150-175 m depth by the Royal Norwegian Navy in March 2003. The Norwegian Costal Administration (NCA) has, on behalf of the Ministry of Fisheries and Coastal Affairs, been performing several studies on how the risk that the mercury load constitutes to the environment can be handled. In 2001 six different alternatives were studied for environmental measures at the wreck of U-864 on behalf of the Norwegian Government. In 2012 the Norwegian Government decided to continue with design and quality assurance for two of the alternatives; raising the cargo (mercury) (Alternative 3) and capping the wreck site (Alternative 1).

This memo presents an assessment on possible exposure to mercury if divers are used to raise the mercury cargo from U-864 (Alternative 3).

Figure 1: Mercury canister from U-864. Photo: Norwegian Coastal Administration
2 DESCRIPTION OF THE OPERATION

The alternative to raise the cargo is limited to bringing the mercury containers to the surface, while the remaining wreckage remains. After the cargo of mercury is raised, the wreck and contaminated sediments will be capped with clean sand/gravel. After the project is completed the situation in the area will be followed up with environmental monitoring.

Use of divers may be relevant in the following parts of the operation:

- Remove the steel plates on the sides of the keel to get the mercury canisters out (Figure 2).
- Place the mercury canisters in baskets (or similar) on the seabed before lifting them to the surface (Figure 3).

Figure 2: Photo showing a part of the keel of the U-534 submarine that is exhibited in Liverpool. U-534 is a type IXC/40 submarine very similar to U-864. The steel plate to the left is covering a keel compartment and to the right the steel plates covering the keel compartments have been removed. In U-864 the compartments in the keel were used for storing the ballast. The mercury containers were used as such ballast. Photo: DNV GL.
ABOUT SATURATION DIVING

Saturation diving involves divers at very large depths for a sustained duration. This results in a point in which no more gas, in particular nitrogen, is able to be dissolved into the tissues of the diver. This is where the term ‘saturation’ is derived. After the saturation point is reached the decompression time to rid the body of excess nitrogen is the maximum time needed. Therefore the diver can stay at large depths for a much longer period of time with the same decompression time needed. Typically, the commercial deep diving executed around the Norwegian coast involves working at depths around 100 – 150 meters. At these depths the total pressure that a diver can be subject to may be towards 1600 kPa (HSE).

The diving system used in saturation diving is composed of four main chambers known as the deck decompression chamber (DDC) or living chamber, the personal transfer chamber bell (PTC) or submersible decompression chamber (SDC), the recompression chamber (RC) and the transfer chamber (DTC). Attached to the DTC is the supply lock (SL), see Figure 4. Divers enter the environment through the PTC and when the work is completed the worker re-enters the PTC which is subsequently attached to the DDC via the DTC. Within the DDC the diver can start to decompress.
Use of divers to raise the mercury – Assessment of mercury exposure

Figure 4: Simplified schematic plan of saturation dive system showing compartments used by saturation divers. Schematic plan of a simple saturation system showing the main pressure vessels for human occupation. DDC - Living chamber, DTC - Transfer chamber, PTC - Personnel transfer chamber (bell), RC - Recompression chamber, SL - Supply lock. (From Wikipedia).
4 NORWEGIAN GUIDELINES FOR MERCURY IN THE OIL AND GAS SECTOR

In Norway the Norwegian Oil and Gas Association (Norsk olje & gass) have issued a guideline with recommendations for handling mercury in the oil and gas sector.

The uptake of mercury in human beings can take place through inhalation, skin contact and by swallowing. The main uptake is through inhalation (75-80 %). For persons working in an area with mercury the administrative norm (recommended target value) is 0.02 mg/m\(^3\) in air and for a 12 hour shift (exposure) it is 0.014 mg/m\(^3\).

The guideline has no specific recommendations for diving in mercury contaminated areas.

In the guideline the level of risk control is divided into three levels depending on the amount of mercury. For installations with more than 100 ppb mercury concentration the highest level of risk control (level red) is required. Red level includes frequent measurements of mercury concentrations in the working atmosphere, personal air measurement devices and personal protection devices (mask, special clothing, gloves and shoes).

5 HAZARDS WHEN DIVING IN CONTAMINATED WATERS

IMCA (The International Marine Contractors Association) have issued the *International Code of Practice for Offshore Diving* (IMCA, 2007). In chapter 7.4.1.3 *Pollutants* the following is stated concerning diving in polluted areas:

"The presence of man-made and natural petroleum products around oil fields can cloud optical lenses and may damage plastic materials. Equally, gas can affect visibility, block sound transmission and cause sudden loss of buoyancy. Special precautions should be taken to protect the divers if pollutants are present and prevent these pollutants from entering the diving bell, as well as protecting personnel who may handle the divers or their equipment during launch/recovery and during maintenance ".

IMCA has also released a report that specifically concerns diving in polluted areas; *Diving in Contaminated Waters* (IMCA, 2004). The report identifies the following hazards that need to be considered when diving when there may be contamination in the water or on the seabed or because the diver is recovering contaminated materials:

- direct contamination of the diver while working in the water;
- contamination of the diver’s equipment causing hazards to the surface personnel or others that are required to handle it;
- contamination of the atmosphere of the diving bell or deck decompression chamber (DDC) either by the contaminant entering directly or else on the equipment of the diver after he returns.

Concerning heavy metals the report concludes:

"Heavy metal contamination is normally encountered as a result of past industrial activity. Examples of such substances that may be encountered are mercury, cadmium and arsenic although other substances may also be found."
Use of divers to raise the mercury – Assessment of mercury exposure

Heavy metals do not normally have acute (that is sudden) effects but tend toward chronic (that is long term) health effects. Skin contact will normally have to be repeated and prolonged to become a serious hazard and there usually be little or no toxic vapours given off that may contaminate, for example, the inside of a bell. The main risk is if the heavy metals are ingested which means that the risk to divers from heavy metals on their own is often relatively small”.

The control measures for heavy metals are:

"levels of risks should normally be considered low/medium;

- for lowest level risks, normal diving equipment with precautions such as those for drilling muds;
- for medium level risks, closed suits with fitted helmet may need to be used;
- particular care is needed that divers are not exposed to risk of ingestion;
- surface teams with adequate PPE1 disinfecting/rinsing by washing down, showers, etc.”

6 SPECIFIC CRITICAL OPERATIONS FOR THE DIVERS WHEN WORKING WITH MERCURY AND MERCURY CONTAMINATED SEDIMENTS AT U-864

For divers working with the mercury canisters and mercury contaminated sediments on the seabed at U-864 there would be specific critical operations like:

- The divers have to stand on the seabed close to the wreck when working. Investigations have shown that there is pure mercury (droplets) in the sediments close to the wreck. The diving suit can be polluted by the mercury.
- When the divers have removed the steel plates and are going to remove the mercury canisters there could be free mercury in the keel compartment from broken/corroded canisters. Their gloves and diving suit could then be polluted by mercury.
- When the divers are moving the mercury canisters from the keel over to the baskets (or similar) to lift them to the vessel the canisters can leak or break and pollute the diving suit.
- When the diver after working on the seabed enters the diving bell mercury on the divers suit can enter the diving bell and can evaporate and go further into the pressure chamber system. The diver could then risk inhaling the mercury vapour in the diving bell.

1 PPE = Personal Protective Equipment
7 AVERTING MEASURES FOR DIVERS WORKING WITH MERCURY AND MERCURY CONTAMINATED SEDIMENTS AT U-864

In the previous chapter different specific critical operations were identified for divers working with the mercury canisters and mercury contaminated sediments on the seabed at U-864.

The IMCA report *Diving in Contaminated Waters* (IMCA, 2004) has recommendations for measures to reduce the risk for divers working in polluted areas that are relevant for the U-864 mercury case.

The most important recommendation is that when the hazard cannot be controlled by elimination the next best option is substitution. In this case it would be possible to substitute the need for divers by using one or several ROVs (remotely operated vehicle) to do the work.

In cases when the hazard is limited, engineering control can be used. In this case it could be measures like:

- The divers could be equipped with a protective extra suit outside of the regular diving suit. This protective suit would be taken off before the diver enters the diving bell and remain on the outside of the diving bell. The protective suit is taken up separately and taken care of by the surface crew. The divers will wear a new clean protective suit for each dive they are doing.
- Fitting covers (similar to a hot water shroud) to the second stage of the helmet to help prevent ingress of mud/mercury through the demand valve.
- As mercury contaminated sediments could be brought back into the bell on the diver's umbilical, mainly in the twisted lay of the hoses, some form of cleaning brush could be fitted to the bell clump weight.
- Protecting the first (say) 40 metres of umbilical with some form of rubber (latex) sock. This would be easier to clean or remove by the divers in the water prior to entering the bell.
- When the diver comes into the bell there could be installed a washing facility in the transfer chamber to remove any mercury that has attached to the body.

8 CONCLUSION

In this case it is assessed that the use of divers to raise the mercury could constitute a substantial risk. Raising mercury by divers at 150 m depth in the North Sea has never been done before. The operation has parts that are a risk for the diver's health and safety where they can be exposed to mercury in very high concentrations.

It is possible to substitute the divers with unmanned ROVs and thereby not needing to use the divers.

For this operation it is therefore recommended to use ROVs and not divers.

---

2 With elimination is meant that the hazardous activity is not performed. In this case it would mean not to dive.
3 With engineering control is meant that the hazard is controlled or limited, normally by mechanical or physical means.
9 REFERENCES


/6/ Hansen, Arnfinn at DNV GL, Principal Engineer at the department for Offshore Equipment and Diving (MOANO374).
ABOUT DNV GL
Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.