DANISH MARITIME AUTHORITY

Danish Maritime Accident Investigation Board

MARINE ACCIDENT REPORT

MAERSK TENDER
Fatal diving accident on 24 July 2010

Division for Investigation of Maritime Accidents,
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The report has been issued on: 19 October 2011.

Case: 201008713

This report is a revised edition of the report on the same subject issued on 11 October 2011. The review is based on new information received from an involved party after the report was issued on 11 October 2011.

The casualty report is available on our homepage:
http://www.dmaib.com/Sider/Home.aspx

The Division for Investigation of Maritime Accidents/Danish Maritime Accident Investigation Board
The Division for Investigation of Maritime Accidents was responsible for investigating accidents and serious occupational accidents on Danish merchant and fishing vessels. The Division also investigated accidents at sea on foreign ships in Danish waters.

On 15 June 2011 the Division for Investigation of Maritime Accidents was abolished and the Danish Maritime Accident Investigation Board was established as an independent institution to replace the Division for Investigation of Maritime Accidents.

When the Division for Investigation of Maritime Accidents was abolished on 15 June 2011, the investigation of this accident was in process, and the preparation of this report is completed by the Maritime Accident Investigation Commission, in agreement with the Danish Maritime Authority.

The report is drawn up in accordance with the rules, methods and recommendations for accident investigations, which were applicable guidelines for the Division for Investigation of Maritime Accidents.

Purpose
The purpose of the investigation is to clarify the actual sequence of events leading to the accident. With this information in hand, others can take measures to prevent similar accidents in the future.

The aim of the investigations is not to establish legal or economic liability.

The Division's work is separated from other functions and activities of the Danish Maritime Authority.

As per 15 June 2011 The Division for Investigation of Maritime Accidents has been abolished and its obligations have been taken over by The Danish Maritime Accident Investigations Board.

This report has been finalized by The Danish Maritime Accident Investigation Board.

Contents

1 Summary

On 24 July 2010, a fatal accident occurred when a diver, 27 years of age, was diving at approximately 41 metres, and his air supply was cut off due to an unintended squeezing of his umbilical.

The diving operation was carried out from the anchor handling tug supply ship MAERSK TENDER, which was chartered as a platform for diving operations by a Swedish diving company.

The diving company was contracted to prepare cable instalment works on a transformer platform for the 'BARD 1' offshore wind farm in the German Bight around 50 nm northwest of the island of Borkum.

The task was to remove bottom material from the seabed at a depth of 40 metres in front of so-called "J-tubes" to draw cables from the wind turbines into the transformer platform. To do so a "dredger pipe", a 20-metre long iron tube, was being positioned on the seabed by a diver - a job whose execution deviated from the method statement in which it is described it should be done by ROV (remote operated vehicle).

When operating on the seabed, the dredger pipe would be hanging from the ship's crane that was operated by one of the ship's crew members.

Two 140 mm H-girders were fitted to the dredger pipe. This was made simply and primitively by shackling the girders to triangle shaped lifting eyes on the dredger pipe. When hanging in the ship's crane, the distance (gap) between the girders and the dredger pipe was approximately 6-7 cm.

The diving operations were carried out as surface supplied air dives by one diver deployed and one diver as a standby diver on the ship's deck, while the ship was dynamically positioned.

The diver had three emergency air supply options, however none of which he was able to use when in distress.

When positioning the dredger pipe, the diver's umbilical got trapped between the dredger pipe and two H-girders fitted to the pipe. The umbilical created a loop, the air hose became squeezed and the air supply to the diver was cut off. The diver was not able to use any of his emergency air supplies. The standby diver was sent down to assist the distressed diver, but the long time passing before the standby diver arrived at the distressed diver and a wide range of verbal misunderstandings between the standby diver and the diving supervisor contributed to the fact that the distressed diver was not rescued despite very hard efforts by the standby diver.

The verbal misunderstandings between the standby diver and the diving supervisor were caused by wrongly connected microphone and earphones in the standby diver's helmet.

A long range of conditions mentioned in this report either caused and/or contributed to the fatal accident and the failed rescue attempt.

The accident, the rescue attempt and everything else dealt with in this report mainly refer to facts and circumstances that exist in the diving industry. Therefore, the report contents may be best understood by people with insight in this industry.

2 Conclusions

2.1 Immediate causes of the accident

Unsafe actions

The Investigation Division assesses that

- *because a risk assessment had not been properly made for this particular task carried out by diver, it was not realized that the diving operation might have been performed more safely, e.g. by more than one diver at the seabed or as a wet bell diving (6.1);*

- *because a risk assessment of this particular task had not been properly made, it was not realized that the diver's umbilical could be trapped between the H-girders and the dredger pipe. Thus, no initiatives were taken to avoid that (6.1);*

- *the diver's umbilical came near the gap between the dredger pipe and the H-girders when the diver passed under the dredger pipe. It is a general rule not to stand or pass under a suspended load. Therefore, this should have been avoided by directing the diver to pass the dredger pipe at a greater distance instead of passing under it and by ensuring that there was a second diver at hand to tend the umbilical (6.1);*

- *the umbilical was trapped and created a loop when the dredger pipe was lowered after the diver had passed under it on his way back to the diving basket. The umbilical's buoyancy may have been a contributing factor (6.1);*

- *the umbilical loop became so very tight and locked between the dredger pipe and the H-girders not only because of the diver's own force in his attempt to haul it back, but also because of movements/lowering of the dredger pipe and because even minor relative movements between the ship and the dredger pipe would have a significant effect on the tension of the umbilical that was already tightened up by the diver and kept tight by the crew on deck (6.1)*;

- *the diver's increase of breaths after having passed the dredger pipe on his way back to the diving basket was caused by an emerging shortage of air supply which in turn was caused by the squeezed umbilical (6.1).*

Unsafe environments/conditions

The Investigation Division assesses that

- *the diver was under the influence of nitrogen narcosis while at the seabed and thus his reactions could not be expected to be rational (6.1);*

- *the divers' safety had not been addressed well during the planning of the diving operation and through the diving method used (6.1);*

- *there was a need for another diver at the seabed to tend the umbilical for the diver in action. Because the diver was not able to tend his own umbilical, he could not prevent it from being trapped and entangled by the dredger pipe and the H-girders (6.1).*

2.2 Contributory causes of the accident

Unsafe actions

The Investigation Division assesses that

- *the use of atmospheric air as a respiratory medium was a contributory cause for the diver not being able to act rationally when in distress and thus a contributory cause for him, for example, passing under the dredger pipe (6.2).*

2.3 Immediate causes of the result of the accident

Unsafe actions

The Investigation Division assesses that

- *the air pressure at the outlet from the diving control station panel was at the minimum needed for safe diving under the given circumstances (6.3);*

- *the diver had no more air available in his bailout bottle when he came into trouble with his umbilical despite it is not seen on the DVR-record that he opened the bailout. The brief air flow from his helmet at 16:15:46 may have been free flow with the very last air in his bailout bottle (6.3);*

- *the relatively low air pressure at the outlet from the diving control station panel may have caused or contributed to the diver using air from his bailout which meant that he had no more bailout air available when needed for his rescue (6.3);*

- *a technical malfunction at the diving control station air distribution panel not identified by the Investigation Division caused a periodically inadequate air supply for the divers (6.3);*

- *an inadequate air supply may have caused or contributed to the diver using his bailout to supplement his air supply, as did the standby diver for the same reason during his rescue attempt, or the diver may have opened his bailout instead of free flow as a mistake because he was under the influence of nitrogen narcosis. In this connection, it should be remembered that the knob for opening the bailout and the knob for opening the free flow are situated very close to each other on the so-called side block on the right side of the helmet (6.3);*

- *the relatively low air pressure at the outlet from the diving control station panel caused serious troubles, even a risk of life, for the standby diver during his attempt to rescue his distressed colleague (6.3);*

- *it cannot be determined whether the inadequate air supply for the standby diver had any delaying and/or decisive effect on his attempt to rescue the distressed diver;*

- *the diver had no more air available in his bailout because he had used it while he had trouble with his umbilical or because he inadvertently and under the influence of nitrogen narcosis had opened one of the valves on the helmet's side block; thus he was unable to use his bailout when needed (6.3);*

- *the malfunctioning communication system caused by wrongly connected microphone/earphones was not identified and rectified because of an inadequate test procedure. (6.3);*

- *the malfunctioning communication system caused delay in the standby diver's efforts to rescue his distressed colleague;*

- *it cannot be determined what impact the delay caused by the malfunctioning communication system had on the distressed diver's possibility of survival;*

- *the time spent getting the standby diver available for any assistance at the sea-bed was far beyond the time needed to be of any efficient life saving assistance for the distressed diver (6.3);*

- *the diving method with one diver in action at the seabed and one standby diver on the ship's deck was a causal factor that the distressed diver achieved no efficient assistance in due time when needed (6.3);*

- *the distressed diver may have opened the valve for free flow as a mistake while opening the valve for emergency air supply from his bailout, because he was under the influence of nitrogen narcosis and/or otherwise not acting rationally because of his emergency situation (6.3);*

- *the standby diver ought to have been directed straight to the distressed diver when he arrived at the seabed in order to possibly re-establish an emergency air supply by the use of the distressed diver's own bailout or his pneumo, though it was revealed later that the distressed diver had no more air available in his bailout (6.3);*

- *it cannot be determined whether the rescue attempt would have led to a positive outcome if the standby diver had been directed straight to the distressed diver instead of working with re-establishing the air supply by loosening the umbilical (6.3);*

- *because the diver was lifeless and thus not able to keep his head upright and his respiratory tract free, the differential pressure in his lungs could not be equalized during his way upwards to the surface and therefore he sustained lung overexpansion injuries (6.3);*

- *the diving method used implied that the standby diver was not able to render maximum assistance and support to the distressed diver (6.3).*

2.4 Contributory causes of the result of the accident

Unsafe actions

The Investigation Division assesses that

- *the diver may have become under the influence of carbon dioxide poisoning when the umbilical became squeezed because of a lack of air. This may have contributed to him not managing to act rationally or to follow the diving supervisor's instructions.*

2.5 The safety system

The Investigation Division assesses that

- *lack of proper checklists, lack of proper planning, lack of knowledge of relevant legislation, inadequate procedures on the diving site were contributory factors that led to the operation being performed by means of a non-secure method which led to the fatal accident.*

3 Recommendations and actions taken

According to the diving company, the operations were not conducted in accordance with what was planned.

- *The Investigation Division recommends that the diving company's management and procedures are developed further to ensure that operations planned and described from the head office are correctly planned, risk assessed and executed on site.*

The malfunctioning communication system was caused by wrongly conducted repair work on dive helmets and an inadequate test procedure.

- *The Investigation Division recommends that the diving company's Planned Maintenance System is set up in such a way that it can easily be accessed from the worksite in order to be able to share information between the office and the worksite.*

Lack of knowledge of legislation was a contributory factor that led to the operation being performed by means of a non secure method.

- *The Investigation Division recommends that the diving company develops a system and a database to ensure that national rules applying to diving operations conducted from ships, regardless of flag or register, are known.*

The shipping company has informed that they have learned from this incident to focus on and verify other parties involved in the operation, such as the diving company on this occasion, and their compliance with relevant legislations for their part of the operation.

4 The investigation

The Investigation Division embarked the ship on 26 July 2010 and received statements from the ship's master, relevant officers and crewmembers, the diving supervisor, the standby diver and other relevant persons related to the diving company.

The Investigation Division received a DVD, without audio, of the record of the fatal dive.

The Investigation Division received a DVD with a section of the record of the standby diver's rescue attempts.

The Investigation Division attended to the diving company at the company head quarter in Sweden and received information about the company and the diving project at BARD1.

The Investigation Division examined the diving equipment on board the ship except the deceased diver's umbilical, dive helmet and the DVR (black box) that were taken into custody by the German Water Police, Emden, upon the ship's arrival at Emden. This had an impact on the Investigation Division's investigation and examination of the diving control station's piping and valves.

The Investigation Division has received the diver's helmet, a sample piece of the umbilical and the DVR (black box) from the German Water Police in February 2011 and then visually examined these items.

The Investigation Division has received a copy of records from the perished diver's diving log.

The Investigation Division received investigation material from the Public Prosecutor in Aurich, Germany.

The Investigation Division received information about the perished diver from his next of kin.

The Investigation Division received the diving company's "black box" (LG Professional 4 ch stand alone DVR-secu station LE2104D).

The Investigation Division has been assisted by the Danish Police, National High Tech Crime Centre, in synchronizing the sound tracks from the DVR records of the fatal dive and the standby diver's rescue attempt.

The Investigation Division has scrutinized the DVR records of the fatal dive and the standby diver's rescue attempt.

The Investigation Division has been assisted by instructors at the Diving School of the Royal Danish Navy in the interpretation of the DVR records of the fatal dive and the standby diver's rescue attempt – in particular the divers' breaths.

The Investigation Division has requested a brief description from the operator BARD of the overall sequence related to the diving operations in question, including any "near misses" or occurrences that might have caused serious problems for the divers. BARD informed they had no experience on any sea bed diving activities until NDE joint the project. Surface dives in the slash zone have been carried out with own divers. No diving incidences occurred.

The Investigation Division has, as a standard procedure, forwarded a draft investigation report to persons and parties involved to hear whether they had any further comments to the draft report. On that occasion the shipping company has informed about lessons learned from this incident, and the diving company has forwarded a large range of additional documentation and made a review report with comments to the draft.

The Investigation Division has scrutinized the review report to identify any possible new information. Where such new information has been identified, the Investigation Division has re-edited the investigation report accordingly. In a number of instances the diving company and the Investigation Division have a different approach to the accident. In these cases the Investigation Division has not made any changes in the original text.

The Investigation Division received no comments to the draft report from the operator BARD. However, after the release of the final report, BARD submitted new information which caused a review and a revised edition of the report.

5 Factual Information

5.1 Accident data

Type of accident (the incident in details)	Fatal diving accident
Time and date of the accident	24 July 2010, 16:16
Position of the accident	54°22.5' N – 005°56.5' E
Area of accident	German Bight
Injured persons	One person (diver) perished
IMO Casualty Class	Very serious accident

5.2 Navigation data

Stage of navigation	Dynamically positioned

5.3 Ship data

Name	MAERSK TENDER
Home port	Ringkøbing
Call sign	OYGS2
IMO no.	9388651
IMO Company no.	1045146
Owner	Maersk Supply Service A/S
ISM responsible operator/owner	Maersk Supply Service A/S
Register	Danish International Ships Register
Flag State	Denmark
Construction year	2009
Type of ship	Anchor handling tug supply (DP2 ship)
Tonnage	4,678 GT
Classification	Det Norske Veritas +1A1, SUPPLY VESSEL, TUG, EO, DYNPOS AUT, BIS, TMON CLEAN DESIGN, COMF-(2)c(2)
Length o.a.	73.20 meters
Engine power	10,200 kW
Area served	International trade within the limitations of statutory and Class certificate

5.4 Weather data

Wind – direction and speed	NW, 9 m/sec.
Sea water temperature	22°C at surface, 15°C at 40 metres depth
Light/dark	Daylight
Current	At depths 0-12 metres: 3-4 knots At seabed: 0-2 knots

5.5 The ship's crew

Number of crewmembers	15
Number of crewmembers certified to act as bridge watch	4
Minimum Safe Manning	8

5.6 The site of the accident

Image: Google Earth

5.7 Narratives

The task and the dredger pipe

MAERSK TENDER was chartered as a platform for diving operations by the diving company Nordic Dive Enterprise AB, Sweden. The ship is constructed and equipped for dynamically positioning Class 2 (DP2).

Nordic Dive Enterprise AB was contracted to prepare cable instalment works on a transformer platform for the 'BARD 1' offshore wind farm in the German Bight around 50 nm northwest of the island of Borkum.

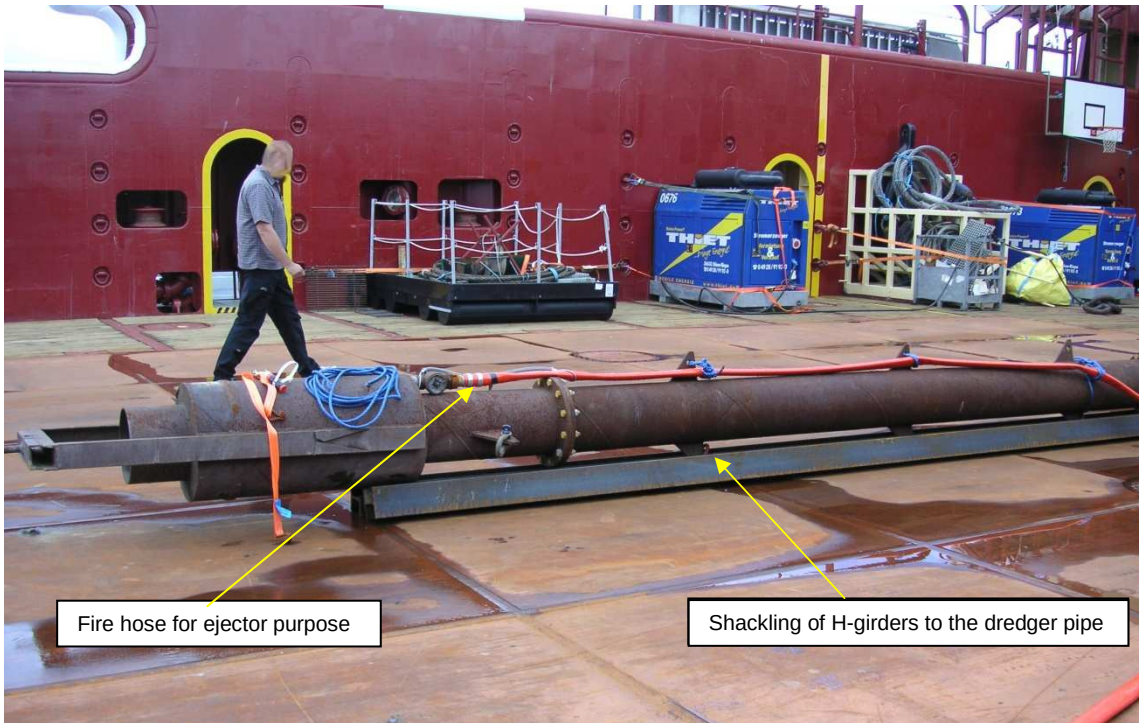
On 24 July 2010, the task was to remove bottom material from the seabed at a depth of 40 metres in front of so-called "J-tubes" to draw cables from the wind turbines into the transformer platform.

To do so a "dredger pipe" had to be positioned on the seabed. Although it was intended that this should be performed with ROV (Remote Operated Vehicle), it was decided to be carried out by a diver. No new method statement and risk assessment was made.

The dredger pipe was a 20-metre long iron tube consisting of four tube segments assembled by flanges. At the lower end of the dredger pipe, a fire hose was connected to make the dredger pipe operate as an ejector for moving seabed materials.

When operating on the seabed, the dredger pipe would be hanging from the ship's crane at an angle of 45-60°. The crane was operated by one of the ship's crew members following the directions from the diving supervisor.

The dredger pipe on the ship's deck, viewed from the top end of the pipe Photo: The Investigation Division



The dredger pipe with H-girders on the ship's deck Photo: The Investigation Division

Dredger pipe and H-girders

Photo: The Investigation Division

To regulate the dredger pipe's balance and angle to the seabed, two 140 mm H-girders were fitted to the dredger pipe. The fitting was made simply and primitively by shackling the girders to triangle shaped lifting eyes on the dredger pipe (see pictures). When hanging in the ship's crane, the distance (gap) between the girders and the dredger pipe was approximately 6-7 cm.

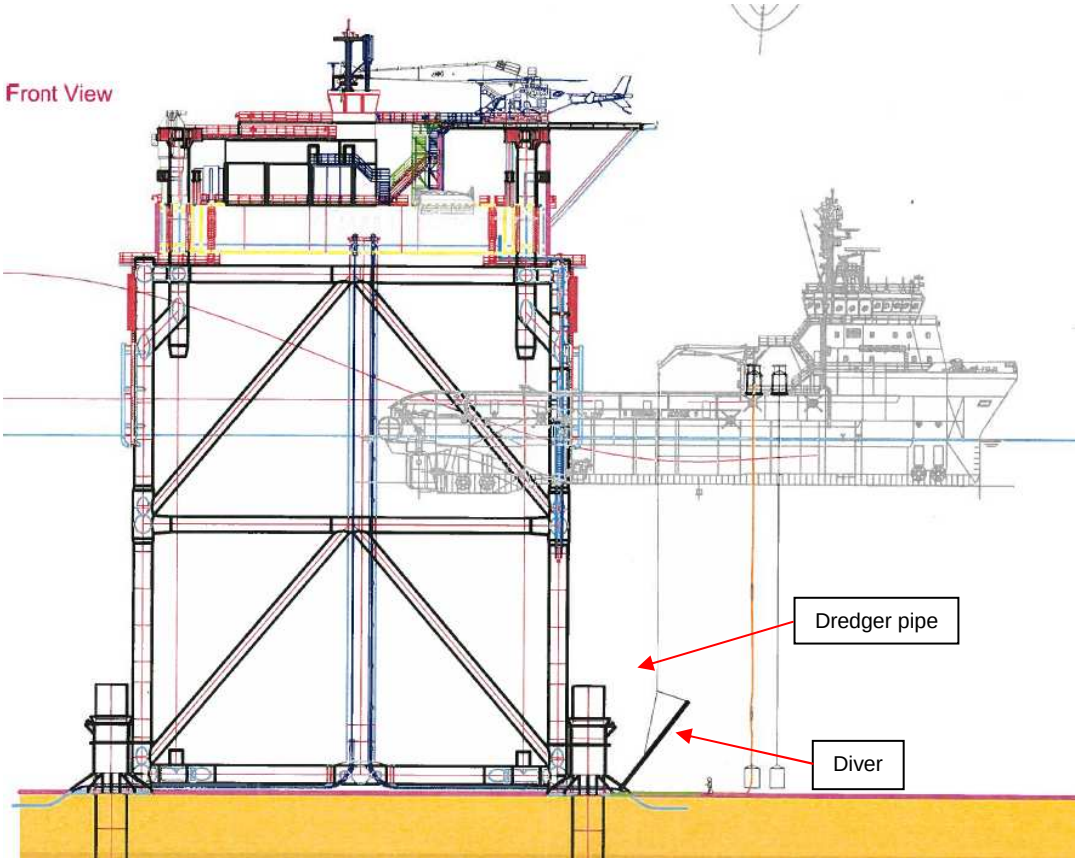
At the lower end of the dredger pipe, a fire hose was connected to make the dredger pipe operate as an ejector for moving seabed materials.

5.8 Diving method

According to the diving company it was the company's preference to use nitrox as a respiratory medium. However, upon the request of BARD (the client) it was stated in the contract that diving operations were carried out as surface supplied air dives by one diver deployed and one diver as a standby diver on the ship's deck while the ship was dynamically positioned.

Bard has stated that since BARD had no sea bed diving experience at 40 m water depth, especially outside the 12 miles zone, it was ensured that only a professional IMCA certified diving company with own equipment and procedures shall carry out the work. The diving method was only chosen by the sub contractor without any influence from BARD.

Due to the usage of a "DP 2" vessel, with running thrusters to maintain position, it was agreed between BARD and the diving company to use two diving baskets that had to be operated on the vessel. The diving method had been predetermined by the diving company and could not be altered by the diving supervisor.



The diving company's layout of the operation (This image shows two diving baskets deployed. During the accident, only the forward basket was deployed, and the aft basket was on the ship's deck for the purpose of standby diver)

5.9 The diver's air supply

Main air supply

The diver was supplied with atmospheric air via an umbilical from an air bottle bank consisting of nine air bottles of 50 litres at 200 bar in the diving station on the ship's deck. From the air bottles the air pressure was reduced by reducing valves to the pressure desired by the diving supervisor who also governed the air flow by the use of a throttle valve.

The air was supplied at a pressure of 12-14 bar at the outlet from the diving control station panel.

The atmospheric air was filled into the air bottles of the air bank by the diving company's own compressors on board the ship.

After the accident, the Investigation Division carried out an analysis of the air from bottles randomly picked out. The analysis revealed no nonconforming threshold limiting values.

It has been stated that because of noise caused by the diver's breathing, vibration of pressure gauges, pipes with small diameters and high air flows, etc., the diving supervisor used to throttle the air supply in order to better understand what the diver said.

It has been stated that the high noise in the panel arose because something was wrongly connected in the panel.

Diving control station air bottle bank Photo: German Water Police

It has also been stated that something was wrong with the panel so the diving supervisor had to constantly regulate the pressure manually on the controller because otherwise the pressure went down to below 10 bar.

The Investigation Division has requested the diving company to perform a calculation of the pressure needed, based on the given conditions:

• Depth	41 metres, sea water
• Length of umbilical	152 metres in one length
• Air hose part of umbilical	Cortland Fibron BX type FBL08G
• Air hose bore	½" (12.7 mm)
• Fittings at both ends	FPBSF/M/08-08JIC
• Helmet	KM 37
• Regulator	SuperFlow 350
• Air supply	High pressure regulated source
• Work rate, estimated	Moderate to heavy work

The diving company has stated:

"The company does not carry out calculations on flow losses and pressure drop in the umbilical.

The company is referring both to the manufacturers' recommendations and their assurances that diving control panels etc. shall be made for the purpose to provide the diver with a sufficient amount of gas/air.

The company is further stating that a calculation of the flow loss is also an almost impossible task because it depends on whether the umbilical is completely straight or not.

However, the company chose to use the ½" (12.5 mm) umbilical instead of the usual one of 3/8" (9 mm) diameter to increase the flow of air to the diver, thus compensating for flow losses.

As regards the set pressure of the panel, the company considers this the supervisor's responsibility as the regulator can be adjusted from 0 Bar to over 20 Bar pressure. The controllers at the diving control panels are not predefined and therefore nobody but the supervisor can know exactly what pressure is set at a specific moment.

The diving company can only recommend the supervisor what the pressure should be and that is according to Kirby Morgan's recommendations on the depth 11.2 to 13.6 Bar which gives a pressure at the surface between 15.2 and 17.6 Bar. Furthermore it says that a Kirby Morgan 37 has an operating pressure between 8.8 and 16 Bar.

The calculated consumption of air for a diver is, according to IMCA, 35 litres per minute. At very hard work this should be 60 litres per minute. This amount at 5 Bar makes 300 litres per minute.

The diving system is designed to deliver well over 1000 litres per minute which means there is no need to make a specific estimate whether the system is able to deliver the amount of air. However, one might argue that there should be a physical flow test before beginning a diving. This is not a requirement of any organization and therefore no practice in the industry."

Emergency air supply
As a primary emergency air supply the diver carried a 10-litre air bottle of atmospheric air at 260 bar, colloquially called “the bailout”. When used, depending on the diver’s air consumption, the bailout would enable him to breathe for 5-10 minutes.

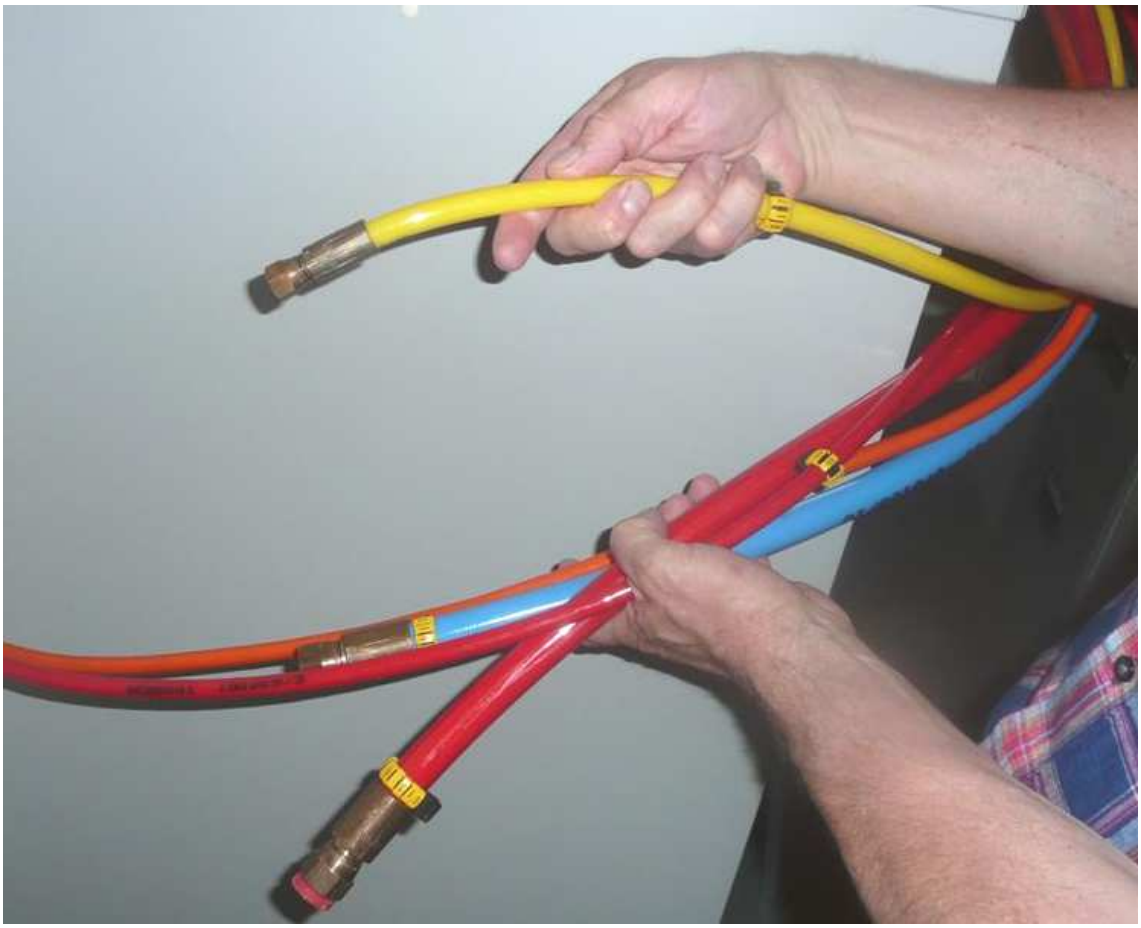
The bailout bottle valve was opened as usual during the dive. To use the bailout the diver had to open a valve on the right side of the helmet, a standard training procedure.

As a secondary emergency air supply the diver had in his umbilical an air hose, the pneumofathometer hose, colloquially known as the “pneumo”.

The pneumo is primarily supposed for gauging the diver’s depth on the bottom and for decompression control during ascent and it can be used for other purposes. It has an outside diameter of ½” (12.7 mm) and a bore of 1/4” (6.4 mm).

The pneumo can be put in between the neck dam and the diver’s neck. The neck dam is a neoprene sealing connected to a steel ring which the diver has around his neck to prevent the water from entering into the helmet and locking the helmet to the diver’s head.

To use the pneumo as an emergency air supply the diver had to put the hose into his helmet via the neck dam, and the diving supervisor should open fully for the air supply through this hose. This is in no way an easy task, especially if the diver is under the influence of e.g. nitrogen narcosis, carbon dioxide poisoning, panic, etc., and the usage of a pneumo hose is not considered a reliable or valuable emergency air supply for diving with a demand mode helmet.



Yellow hose: The pneumo Photo: The Investigation Division

As a third emergency air supply the diver had a 50-litre air bottle of 200 bar in his diving basket. To use this emergency air supply the diver had to be in the basket and to put the air hose from the 50-litre bottle into his helmet via the neck dam like the pneumo.

Diving operation and accident

On 24 July 2010 at 06:35, MAERSK TENDER was positioned on DP alongside BARD 1, about 15 metres from the east side of the platform, heading 180°.

The forward diving basket positioned in its A-frame on the ship's boat deck. Photo: The Investigation Division

The diving operation was carried out from the ship's starboard side as surface supplied air diving by one diver in action on the seabed and one standby diver on the ship's deck, supervised and directed by the diving supervisor from the diving control station situated in a container on the ship's boat deck. Each dive was meant to last 30 minutes as bottom time and 30 minutes for decompression.

When diving, a diver was deployed by one of two diving baskets situated on the ship's starboard side. The lowering and hoisting of the baskets was fully controlled and carried out on deck by crew from the diving company following the directions of the diving supervisor.

At 10:50, the dredger pipe was deployed hanging in the ship's starboard crane.

At 14:08, a diver was deployed by the forward diving basket to position the dredger pipe on the seabed. However, the diver was not able to locate the dredger pipe and thus he had to be taken on board without having carried out the task. The visibility at the seabed was approximately two metres. This diver was back on the ship at 14:53.

At 15:49, another diver (the later distressed diver) was deployed by the forward diving basket. The diver had approximately 30 metres of umbilical at his disposal on the seabed. All standard checks and preparations had been carried out, including the diver's own check of bailout function and pressure.

The diving supervisor was in direct verbal contact with the diver via an intercom system, and he was able to watch the diver's operations on a monitor in the diving control station via a camera on the diver's helmet.

Diving baskets, their A-frames and hoisting devices viewed from the deck above Photo: The Investigation Division

A standby diver was placed on the ship's deck. He had donned his diving suit and neck dam. The helmet, the harness and umbilical were placed on the deck at the diving basket, prepared, tested and ready for quick use.

Information from the recordings in the dive recorder ("black box"):
(Quotations are translated from Swedish by the Investigation Division).

> The diving basket passed the water surface at 15:50:22, and the diver left the basket at 37 metres depth at 15:53:00. He opened a shackle from a guiding wire at the ballast weight below the basket. The shackle was attached to one end of a rope of which the other end was shackled to the dredger pipe. This rope was later used by the diver to draw and position the lower end of the dredger pipe.
>
> At 15:55:15, the diver switched on his headlamp on request from the diving supervisor, and he worked with positioning the dredger pipe on the seabed by means of the rope in accordance with the diving supervisor's instructions.
>
> At 16:03:03, the diver passed over some wire debris on the seabed according to the diving supervisor's instructions.
>
> Between 16:03:03 and 16:07:51, the diver worked with positioning the dredger pipe in accordance with instructions from the diving supervisor. There was a good and clear communication between the diver and the diving supervisor.
>
> At 16:07:51, the diver ended a sentence by asking for a little more air.
>
> Again at 16:08:06, the diver asked for a little more air and the diving supervisor said he would get that.
>
> At 16:09:09, the diver was at the lower end of the dredger pipe. There was still precise and detailed communication between the diver and the diving supervisor about the positioning of the dredger pipe.
>
> At 16:09:28, the diving supervisor instructed the diver to loosen the rope from the dredger pipe and return to his basket, and the diver tried in vain to open the shackle. He said to the diving supervisor that he could not open the shackle.
>
> The diving supervisor then instructed the diver to cut the rope and the diver cut the rope at the dredger pipe with his diver's knife.
>
> At 16:10:10, the diving supervisor asked the diver about the dredger's direction on the seabed and the diver answered the question.
>
> At 16:10:23, the diving supervisor instructed the diver to return to his diving basket bringing the rope with him. The communication was still good.
>
> At 16:10:46, the diver coiled some of the rope in his left hand. He and the diving supervisor spoke together. The diving supervisor asked if the diver was OK. They joked a little about the diver being in a jolly mood because of the nitrogen narcosis, and the diving supervisor laughed and praised the diver for a job well done.

At 16:10:55, the diving supervisor instructed the diver to follow his umbilical back to his basket, and the diver began following the umbilical. He coiled the rest of the rope in his left hand, and at 16:12:03 he began dragging himself rather fast along the umbilical.

At 16:12:21, the diver reached the dredger pipe and passed above it. When he was at the opposite side of the dredger pipe, his umbilical was leading below the dredger pipe just at the upper end of the H-girders. In agreement with the diving supervisor, he passed under the dredger pipe following his umbilical.

At 16.13.19, the diver reached his basket and entered it at 16:13:50.

At 16:14:05, the diver closed the door of the basket, and the diving supervisor said that they would now begin to haul up the diver's umbilical.

Then at 16:14:14, the diving supervisor instructed the diver to remove the locking pin that was stuck through the bundle of hoses in the umbilical ensuring that the diver had 30 metres of umbilical at his disposal and to prevent this from being unintentionally hauled upwards through a fairlead in the top of the basket. (The locking pin is shown on the picture below – on the top side of the fairlead the umbilical is secured in a similar way by two locking, pins not visible on this picture, to prevent the diver from getting more than 30 metres umbilical at his disposal).

The diver released the locking pin and the umbilical was hauled upwards guided and assisted by the diver hauling the slack umbilical from outside the basket.

At 16:14:40, the umbilical began providing resistance to being hauled towards the basket and the diver pulled hard at it, still holding the locking pin in his hand.

The locking pin in the umbilical before being removed by the diver Photo: screen shot from the DVR recorder

Umbilical trapped and squeezed between dredger pipe and H-girders. Photo: screen shot from DVR recorder

At 16:15:00, the diver expressed an annoying sound whereupon the diving supervisor asked whether the umbilical was stuck by something and instructed the diver to hurry back and let go of the pin in his hand.

The diver left his basket and followed the umbilical and the diving supervisor instructed him to hurry. The diver answered agreeing.

He followed the umbilical 10-12 metres for approximately 10 seconds until he reached the dredger pipe. At the dredger pipe, he found the umbilical entangled making a loop between the dredger pipe and the upper end of the two H-girders hanging in shackles below the dredger pipe (see picture above).

At 16:15:18, the diver approached the dredger pipe. The umbilical proved to be entangled in the gap between the dredger pipe and the H-girders.

At 16:15:30, the diver was at the dredger pipe, holding on to the entangled umbilical with his left hand and still holding the pin in his right hand. It was clearly visible that the umbilical had entangled.

At 16:15:36, the diver was at the dredger pipe. He was gasping for air, and during the following seconds he gasped and said weakly: *"Air".*

A few seconds later, air bubbles were streaming out from the diver's helmet and the sound of streaming air like free flow was audible.

The diving supervisor said that the diver had air, and the diver answered weakly: *"Thanks – no bailout".*

At 16:16:07, somebody on the ship's deck said: *"He gets no air".*

During the following seconds, the diver weakly repeated on the diving supervisor's questioning that he had no air and needed air. The diving supervisor instructed the diver to go on bailout, and the diver holding his left hand on the dredger pipe answered weakly: "*Yes bailout*".

At 16:16:19, the diver, still at the dredger pipe and holding the pin in his right hand, said weakly: *"I get no air".*

The diving supervisor told the diver that he had air but the umbilical was stuck and said repeatedly that the diver had to go to the other side of the dredger pipe and loosen his umbilical.

The diver, still holding the pin in his right hand, agreed weakly and moved along the dredger pipe and the entangled umbilical, held his left hand to the dredger pipe and moved, following the instructions of the diving supervisor, downwards under the dredger pipe.

At 16:16:54, the diving supervisor asked: *"All right?"*

The diver answered weakly: *"All right"* – faced away from the dredger pipe, showed no more controlled movements and said no more.

At 16:17:00, the standby diver's helmet lying on the ship's deck was being moved which indicated that the standby diver was preparing for being deployed.

For the next 32 seconds, the diving supervisor repeatedly, 11 times, instructed the distressed diver to follow his umbilical and to use his "pneumo". By this the diving supervisor directed the diver to use an air hose in the umbilical connected to the diver and supposed to gauge the water depth – colloquially known as the "pneumo" – as an emergency air supply.

Until 16:19:56, the diving supervisor continuously spoke to the distressed diver calmly and yet instructing him to draw the umbilical and breathe calmly. Then the diver supervisor's communication became mainly directed to the standby diver.

Rescue attempt

When the distressed diver began breathing heavily, it was immediately clearly heard via the external loudspeakers that he was struggling to breathe air that was not available to him.

The standby diver was standing outside the diving control station when he heard his colleague struggling to breathe. He began immediately, and was also instructed by the diving supervisor, to don his gloves, helmet and harness and prepared to assist the distressed diver on the seabed.

During the rescue attempt, the communication between the standby diver and the diving supervisor proved to be problematic because the communication line had been connected incorrectly in the standby diver's helmet. Thus, the sound to the standby diver was heard by him in his microphone and the sound from him was transmitted via his earphones in the helmet.

Another diver from the team on board the ship assisted the diving supervisor in “interpreting” what the standby diver said. He also forwarded orders from the diving supervisor to dive tenders, the crane driver and winch operators, etc. and prepared the decompression chamber.

Information from the recordings in the dive recorder (“black box”):
Quotations have been translated from Swedish by the Investigation Division.

> At 16:17:00, the standby diver had begun to prepare for diving, and at 16:20:00 he entered the aft diving basket.
>
> At 16:20:50, the deploying of the standby diver’s basket began.
>
> At 16:21:35, the basket was passing the water surface. At between 0 and 12 metres’ depth, there was a very strong current. At every 10-15 metres the diving tender had to secure his umbilical to the basket’s hoisting wire by shackles to prevent the umbilical from being entangled with the ship’s thrusters.
>
> At 16:24:43, the standby diver reached the seabed, and the diving supervisor instructed him to go out and locate the distressed diver.
>
> The standby diver was taking his umbilical out from the basket until he left the basket at 16:25:26 and moved forward.

The air hose of the umbilical squeezed between dredger pipe and H-girders. Photos: screen shot from DVR recorder

At 16:25:45, the standby diver approached the dredger pipe. The distressed diver who lay lifeless on the seabed became visible. (The standby diver noticed that it did not look right. The dredger pipe was almost lying down, which it was not supposed to do, and he saw that his colleague's umbilical was jammed). The diving supervisor instructed the standby diver to get the distressed diver's umbilical loose.

At 16:25:57, the standby diver reached and grabbed the umbilical that was entangled between the dredger pipe and H-girders. He tried to loosen the umbilical by hand and shouted repeatedly during the following 20 seconds to the diving supervisor to lift the dredger pipe.

Because of the poor communication line, the diving supervisor apparently misunderstood him and replied that the standby diver had air.

The standby diver slowly and clearly repeated his request to have the dredger pipe lifted. It was clear and obvious that the distressed diver's umbilical was stuck and squeezed in a loop between the dredger pipe and the H-girders.

At 16:26:44, the dredger pipe was being lifted, and the standby diver repeatedly requested so until 16:27:24 when he shouted: *"Stop stop stop stop stop".*

At 16:27:41, the standby diver left the dredger pipe and followed his distressed colleague's umbilical and approached the colleague's diving basket.

The standby diver requested his distressed colleague's basket to be lifted. This was, however, misunderstood by the diving supervisor who ordered the dredger pipe to be lifted. When the dredger pipe was lifted, the distressed diver's umbilical between the dredger pipe and his basket became tightened. Thus the hoisting wire for the distressed diver's basket became slack and the basket was hanging in the umbilical.

However, the standby diver still needed the distressed diver's umbilical to be slackened in order to loosen the entanglement, and he repeatedly requested the distressed diver's umbilical to be slackened. And he held his right hand on this umbilical to make this clear.

At 16:28:06, the diving supervisor repeatedly said they were hauling the distressed diver's umbilical. This went on until 16:28:27, while on the other hand the standby diver repeatedly requested the same umbilical to be slackened.

This went on until 16:28:43, when the diving supervisor said they would give more umbilical for the standby diver, and the standby diver refused and said it was needed for the distressed colleague while he shook this umbilical with his right hand and pointed at the slack hoisting wire.

At 16:28:58, the diving supervisor said they would give more umbilical for the distressed diver.

Until 16:30:18, the standby diver made repeated requests in despair and attempted to express himself slowly while emphasizing the need for more umbilical for the distressed diver, while on the other hand the diving supervisor simultaneously repeated that the umbilical was stuck somewhere and that the standby diver needed to go and see and loosen it.

The standby diver still shook the distressed diver's umbilical and in despair requested more of this umbilical, whereupon the diving supervisor finally said he could not get more umbilical, there was no more umbilical available; he had plenty, but it was stuck somewhere and the standby diver had to go and get it loose.

At 16:30:28, the standby diver requested the distressed diver's basket to be lifted and within some seconds this basket was lifted by its hoisting wire and the distressed diver's umbilical became slack.

At 16:30:50, the distressed diver's umbilical was slack and the standby diver followed it quickly till he reached the dredger pipe from above, and the diving supervisor instructed him to loosen the umbilical from the entanglement.

At 16:31:30, the standby diver came to the side of the dredger pipe from where the distressed diver's umbilical was leading to and from, he gasped weakly and his communication to the diving supervisor was rather incomprehensible. He remained on the same side of the dredger pipe. The distressed diver's umbilical was still entangled, while the diving supervisor repeatedly said they would lower the dredger pipe.

At 16:32:44, the diving supervisor asked whether the standby diver was able to draw the umbilical loose.

At 16:33:00, the standby diver requested the distressed diver's umbilical to be hauled upwards, which was understood by the diving supervisor.

At 16:33:26, the standby diver passed under the dredger pipe while saying: *"I get no air".* The diving supervisor replied that the standby diver had plenty of air to which the standby diver angrily answered. *"No!"*

At 16:33:33 and during the following seconds, the standby diver said something incomprehensible about bailout and air.

At 16:33:46, the diving supervisor asked whether the standby diver was able to loosen the entangled umbilical, and the standby diver, now at the top of the dredger pipe, answered: *"I get no air".*

At 16:34:10, the diving supervisor asked the standby diver if everything was all right, and the standby diver confirmed. A few seconds later he requested that his distressed colleague's umbilical was hauled upwards.

At 16:34:30, the diving supervisor said the umbilical was tight and the standby diver angrily replied: *"I get no air",* and some seconds later a lot of air bubbles were streaming from his helmet.

At 16:34:52, the standby diver requested the umbilical to be hauled upwards which was confirmed by the diving supervisor.

At 16:34:54, the standby diver again said something incomprehensible about bailout. The diving supervisor asked again whether everything was all right. The standby diver confirmed and followed his distressed colleague's umbilical that was tight.

At 16:35:18, the diving supervisor instructed the standby diver to continue following the distressed diver's umbilical, because it was stuck somewhere. The standby diver replied something incomprehensible including: *"Air",* and at 16:35:24 he shouted like in despair for more air, still following the umbilical towards his distressed colleague.

At 16:35:50, the standby diver reached the distressed diver who was lying lifeless on the seabed facing upwards. He grabbed the distressed diver's leg with his right hand, reached with his left hand for the distressed diver's helmet and opened the free flow, while the diving supervisor instructed him to do so. However, free flow air bubbles were already streaming out from the distressed diver's helmet before the standby diver touched it, indicating that the distressed diver had opened for free flow by himself and that the air flow through the umbilical had been re-established. The distressed diver remained lifeless.

At 16:36:11 while at the distressed diver, the standby diver said loudly and clearly that he got no air and a few seconds later he resignedly repeated the same words.

At 16:36:18, the diving supervisor advised the standby diver to return to his basket if he had opened for his bailout.

The standby diver again resignedly said that he got no air. *"Do you hear what I am saying?"* he said. The diving supervisor obviously did not hear or understand what the standby diver said, and the standby diver resignedly said that he could not continue.

At 16:36:38, the diving supervisor again asked whether the distressed diver had become free from the dredger pipe and when the standby diver confirmed so, the diving supervisor repeated that the distressed diver's umbilical was still stuck somewhere and instructed the standby diver to follow it.

The standby diver followed the umbilical and arrived again at his distressed colleague.

Air bubbles were continuously streaming out from the distressed diver's free flow (the free flow provides an additional flow of air into the helmet, not demanded by the diver's actual breath need and originally purposed for ventilation and defogging of the helmet).

At 16:37:22, the standby diver requested the distressed diver's umbilical to be hauled upwards which was confirmed by the diving supervisor, but a few seconds later the diving supervisor repeated that the umbilical was stuck and instructed the standby diver to follow it and investigate. The standby diver followed the umbilical that was tight.

At 16:37:35, the standby diver said: *"I go on bailout now",* and the diving supervisor said: *"No ... bailout, you have air".*

Again at 16:37:45, the diving supervisor said: *"You have air"* and the standby diver, still following the distressed diver's umbilical again said: *"No".* Then the diving supervisor repeated that the standby diver had full supply of air.

At 16:38:08, the standby diver arrived at the distressed diver's basket and requested the umbilical to be hauled upwards, but again the diving supervisor stated that the umbilical was stuck somewhere. During the following approximately 20 seconds, the standby diver repeatedly requested the umbilical to be taken home and still the diving supervisor stated it was stuck somewhere.

At 16:38:10, the distressed diver's umbilical began passing upwards through the fairlead at the top of the basket guided by the standby diver, and thus the distressed diver was lifted by his umbilical towards his basket.

At 16:40:00, the distressed diver came to his basket and the standby diver eased him inside, closed the door and requested the basket to be hoisted up.

At 16:41:00, the distressed diver's basket was hoisted up, passed the water surface at 16:42:20 and arrived at the ship's boat deck at 16:43:30.

Because of the weight of the diving helmet and because of his lifeless condition, the distressed diver was not able to keep his head upright and his respiratory tract free when in the diving basket. Thus the differential pressure in his lungs could not be equalized during his way upwards to the surface. The standby diver was not able to assist the distressed and lifeless diver on the way up because his own umbilical was lead through his own diving basket and because he had to make decompression stops.

When back on the ship's deck, the diver was not breathing or moving. He had white/pink foam and blood flowing from his mouth and nose and was immediately taken from his basket, divested of his diving suit and taken into the diving company's decompression chamber on board the ship together with another diver who immediately rendered first aid/cardiac massage.

> At 16:41:00, when the distressed diver's basket was being hoisted, the standby diver was instructed by the diving supervisor to go back to his own basket. The diving supervisor praised him for a job well done and said they would make decompression stops for him on his way upwards.
>
> At 16:45:17, the standby diver was inside his own basket and, after due decompression stops on his way to the surface, he was back on the ship's deck at 17:38.

When the standby diver arrived to the ship, his bailout emergency air supply that was initially 10 litres of 220 bar had decreased to 160 bar. Thus the standby diver had used 10 x 60 litres of air from his primary emergency air supply source during his attempt to rescue his distressed colleague.

Operations on board the ship

A man from the ship's crew acted as the diving team's crane operator. The crane operator on duty at the time of the accident took over his duty at 16:00. He had not participated in the toolbox meeting prior to the diving operations.

When the crane operator took over his duty, the dredger pipe was hanging rather far out and low. After some minutes, he was ordered to lower it a little, which he did. Then he was ordered to heave up which he did. The crane operator demanded to receive orders from only one particular person in order not to create dangerous situations.

At a point in time, the crane operator was ordered to lower down completely – and further down – but he could not lower any further down.

Later, as the standby diver was instructed to assist the distressed diver, the diving supervisor called the ship's bridge and informed the chief officer on duty that the diver on the seabed had problems and that the standby diver would go down for assistance/ rescue. The chief officer called the master who arrived on the bridge shortly after.

The crane operator called the bridge and asked for assistance to help with the umbilical for the standby diver, and a cadet was sent to assist.

At 16:30, the diving supervisor called the bridge and said that a rescue helicopter was needed. The chief officer immediately called the BARD 1 traffic control and requested a rescue helicopter. The BARD 1 traffic control immediately relayed the request to MRCC.

At 16:37, it was confirmed that a rescue helicopter had scrambled and was on its way from Bremen. In the meantime, the 1st officer was sent to the ship's hospital to get the first aid kit and automated external defibrillator ready for use. The master ordered all deck crew to stand by on deck for assistance.

When the injured diver was back on deck, some of the ship's crew members assisted the diving team in taking off his helmet and other equipment and putting him inside the decompression chamber together with another diver.

At 17:38, when the standby diver had returned to the ship, the ship was moved to port in order to recover the dredger pipe, and when the dredger pipe had been recovered, the ship was taken out of the dynamical positioned mode.

At 18:15, the ship departed from the site heading for Emden. It was agreed with the MRCC that the helicopter would meet the ship en route to Emden.

At 19:00, the helicopter had arrived, and an emergency physician was lowered from the helicopter. After being presented to the facts about the accident and the injured diver, the emergency physician agreed that there was no possible rescue for the diver. The physician did not enter the decompression chamber, but observed through a porthole, and at 19:21, the emergency physician was hoisted back into the helicopter. Thereafter the ship proceeded for Emden and arrived at 01:15.

5.10 The diver

The diver, a 27-year-old Swedish citizen, held a valid certificate of medical fitness endorsed "fit to dive", issued in Stockholm and dated 7 October 2009.

The diver was educated as a construction diver in 2007, and he held certificates for surface supplied air diving to a maximum depth of 50 metres.

After having left the diving school, the diver had been employed by carrying out multifarious subsea tasks, among these construction and inspection tasks, in Scandinavia and the Arabian Peninsula.

The diver was employed as a construction diver by the diving company NDE on 28 November 2008. However, from the middle of January 2009 to the middle of September 2009, he was employed as a construction diver by another diving company.

His latest dive before this diving operation on 24 July 2010 was for NDE on 26 May 2010 at 13.5 metres' depth in Balha, Yemen.

The diving on 24 July 2010 was the diver's first

- diving from a ship in the dynamically positioned mode;
- diving for more than a year at a depth of more than 30 metres;
- diving with this diving team;
- diving from this ship.

The diving supervisor did not consider the diver an experienced diver.

The diver fulfilled the Danish requirements for the diving operation in question.

5.11 The standby diver

The standby diver was a 51-year-old Swedish citizen at the time of the accident. He was educated as a professional diver and as a construction diver in 1983 and as a rescue diver in 1999.

The standby diver is a highly experienced construction diver. He fulfilled the Danish requirements for the diving operation in question.

5.12 The diving supervisor

The diving supervisor was a 39-year-old Swedish citizen at the time of the accident. He was educated as a professional diver in 1997, including saturation diving, surface supplied air diving and closed bell diving. He is also certified as a diver's paramedic.

The diving supervisor had served as a diving supervisor for approximately 1½ year at the time of the accident.

The diving supervisor was not employed by the diving company NDE. He was working freelance and was hired as a diving supervisor by NDE for some operations in the Baltic Sea for a couple of months in 2010 and later on for this particular job on BARD 1 on 18 July 2010, estimated to last for approximately one year.

The diving supervisor fulfilled the Danish requirements for a diving supervisor at the diving operation in question.

5.13 The diving company

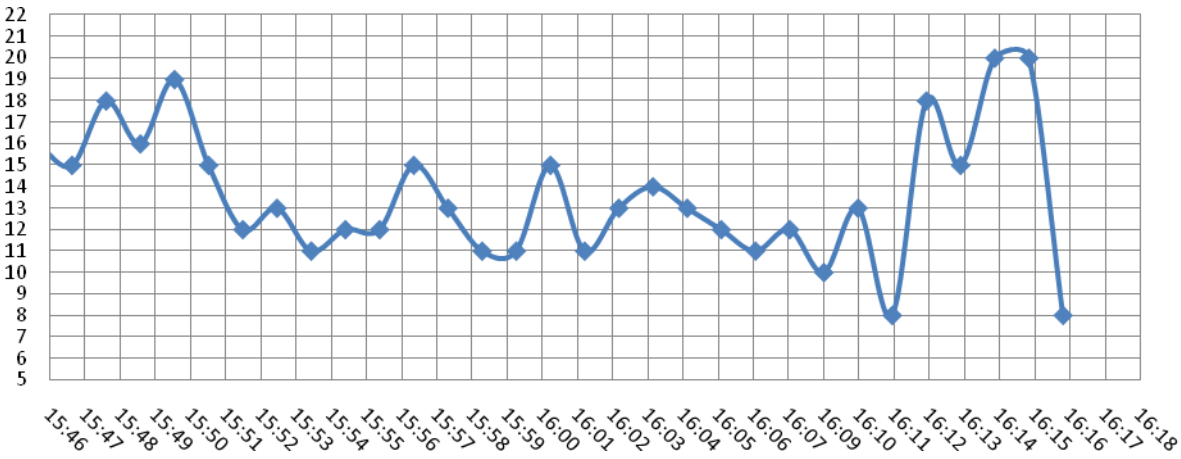
The diving company Nordic Dive Enterprise AB, Sweden, founded in 1995, is an international subsea contractor with its main office in Stockholm operating in three main business areas:

- Renewable energy, installation/maintenance of wind power installations, wave energy and tidal energy;
- the oil and gas industry, near and offshore work during construction and inspection, repair and maintenance work;
- ROV (remote operated vehicle), operation of light and medium ROVs for inspection work and assistance during diving operations.

At the time of the accident, the diving company mainly dealt with offshore operations, and the company had no detailed knowledge of Danish diving legislation.

5.14 The diver's breath

While the diver was preparing for diving, from approximately 15:45 until he reached the depth of 28 metres at approximately 15:52, his breath varied from 19 to 12 per minute.



While he was working on the seabed, from approximately 15:52 until approximately 16:11, his breath varied between 10 and 15 per minute. This can be interpreted as a sign of good physical fitness.

When the diver began following his umbilical back to his basket from approximately 16:12, his breath increased remarkably until 16:16 (see graph).

5.15 Nitrogen narcosis

Nitrogen under high pressure can temporally affect the human nervous system and at greater depths cause a condition known as nitrogen narcosis.

Nitrogen narcosis is a reversible alteration in consciousness that occurs while diving on pressurized atmospheric air at depths of 25-30 meters and more and may vary individually from day to day.

The effect is similar to that of being under the influence of alcohol (lost ability to make decisions, loss of focus, impaired judgment, multi-tasking and coordination). The diver may feel invulnerable and disregard normal safe diving practices.

If nitrogen narcosis does occur, the effects disappear almost immediately when ascending to a shallower depth.

Nitrogen narcosis cannot be ignored. It will under the given circumstances occur to any diver, but vary according to the diver’s physique and experience, and even for the same diver nitrogen narcosis may vary from time to time.

The most straightforward way of avoiding nitrogen narcosis is by limiting the depth of dives.

The diver’s communication with the diving supervisor gave clear indications that he was under the influence of nitrogen narcosis.

5.16 Carbon dioxide poisoning

Carbon dioxide poisoning is caused by an excessive level of carbon dioxide in the blood. Carbon dioxide is a gaseous product of the body's metabolism and is normally expelled through the lungs.

Human beings expel carbon dioxide when breathing. Carbon dioxide poisoning often occurs when something interferes with that process. Re-breathing exhaled air is one cause.

Signs of excessive carbon dioxide include rapid pulse and breathing, flushed appearance, elevated blood pressure, muscle spasms and confusion or inability to think. In extreme cases, it may cause convulsions and panic attacks as well as hyperventilation.

The diver’s breath gave indication that he was under the influence of carbon dioxide poisoning.

5.17 The dive helmet

The divers used dive helmets of the brand and type Kirby Morgan Dive Helmet 37, a well-known and recognized dive helmet.

On the right side on the top of the helmet a camera is fitted that transmits live pictures to the diving control station via a cable in the umbilical, and on the left side on the top of the helmet a head lamp is fitted that is powered via another cable in the umbilical.

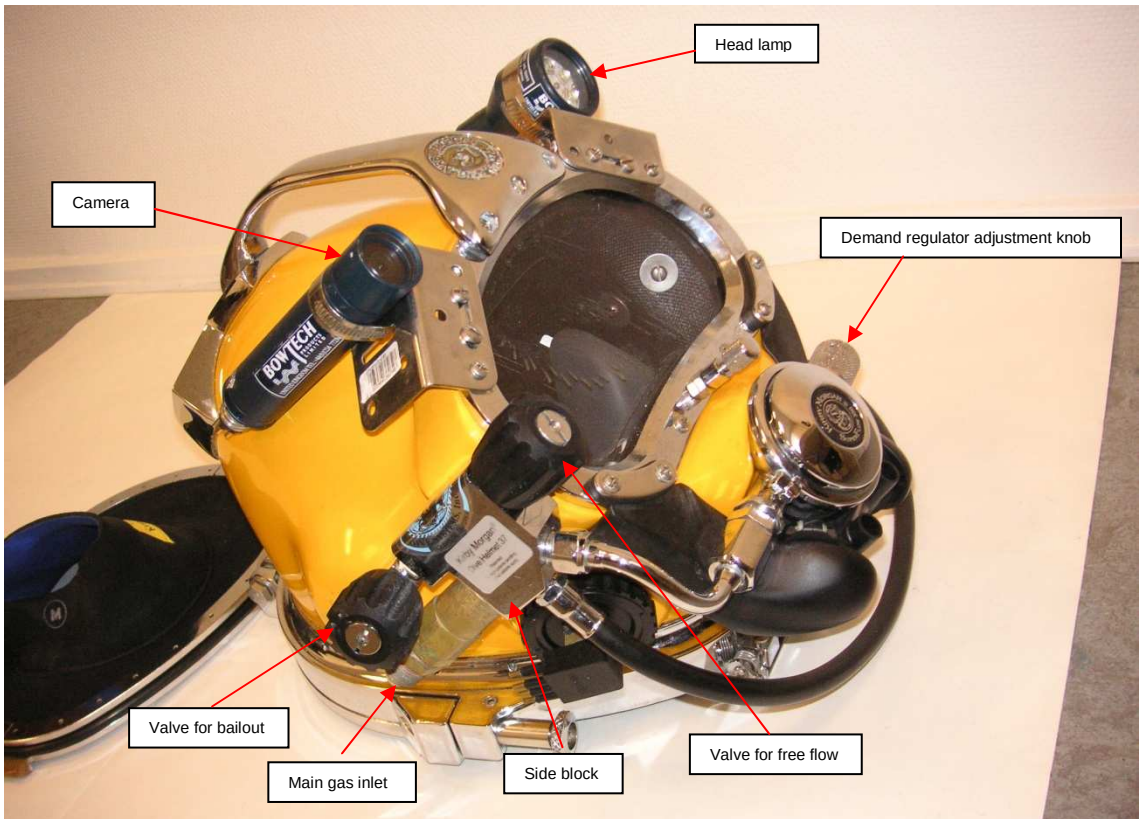
The helmet weighs 14.8 kg. Its shell is made of fibre glass reinforced polyester and the lens is of clear polycarbonate.

On the right side of the helmet, the “side block” with the helmet’s air flow system is situated. The side block has two inlets, one with a non-return valve for the main air supply and one for the emergency air supply (the bailout bottle worn by the diver).

The side block is furnished with two valves, one forward and one on the right side, each with its control knob of polyurethane.

The forward valve is for opening the free flow of air for venting and dehumidification of the helmet. The valve on the block side is for opening the emergency air supply, the bailout, to flow to the regulator.

The dive helmet is supposed for the diver’s demand of air supply and thus furnished with an oral nasal mask inside the helmet. A demand regulator opens for air according to the diver’s inhaling and the setting of the regulator adjustment knob on the front of the helmet. The helmet/regulator needs a certain pressure above the ambient pressure to function satisfactorily. There is no evidence that the diver adjusted his demand regulator during his dive.



The dive helmet. Photo: The Investigation Division

The distressed diver's helmet was taken into custody by the German Water Police immediately after the ship's arrival at Emden. At the request of the German Water Police, the helmet was examined by the Bundeswehr Technical Center for Ships and Naval Weapons, Germany.

The examination revealed no defects in the helmet's air distribution system. When the demand regulator was examined, the regulator adjustment knob was found approximately in the middle position. Six turns on the knob were needed to set it for maximum breath resistance and eight and a half turns were needed to set it for minimum breath resistance. No statements indicate that the setting of the adjustment knob had been touched after the accident.

At the request of the Investigation Division, the dive helmet was examined by the Diving School of the Royal Danish Navy to establish the condition of its communication system. The examination revealed that the microphone and earphone wiring was made of a non-original terminal strip but the connection was correct.

However, the communication did not function well because the wire terminals in the terminal strip had become oxidized. It cannot be ascertained whether the wire terminals were oxidized and had any influence on the communication between the diver and the diving supervisor.

The diving company has stated:

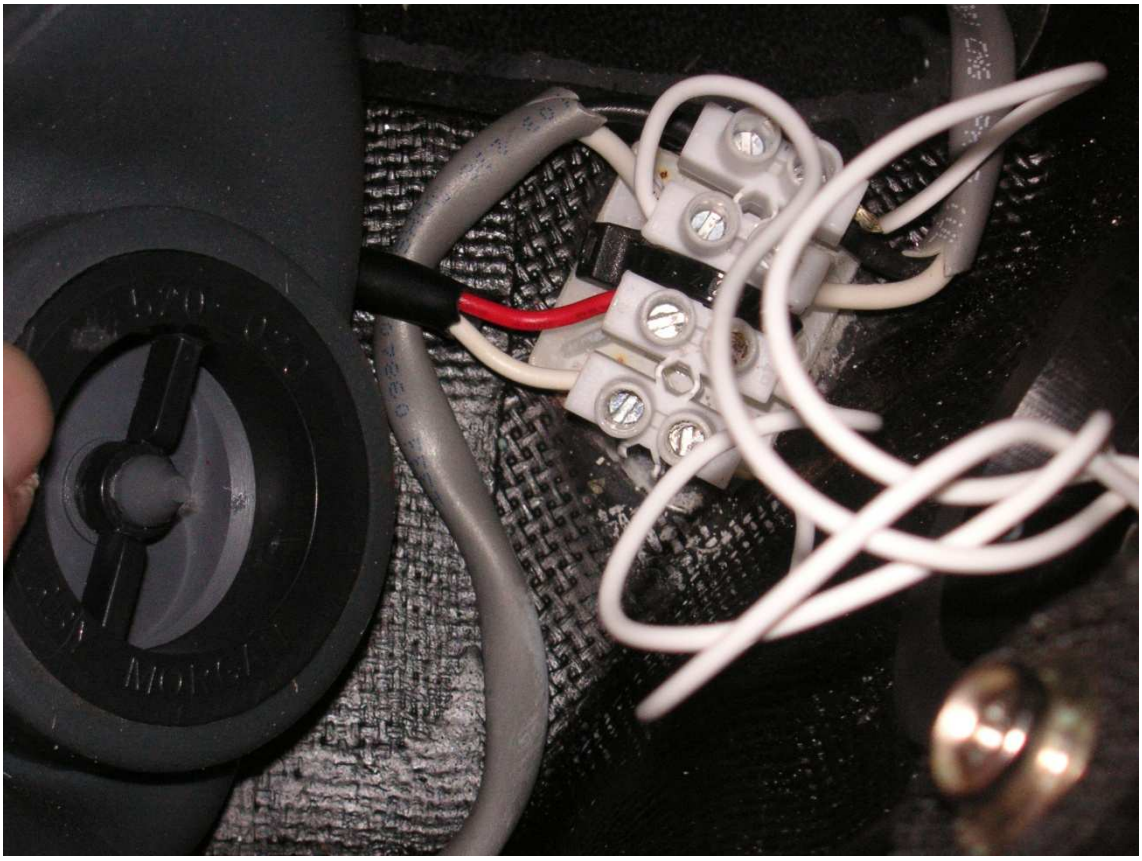
> *This is a brief explanation of why the communication between the divers and the supervisor did not work satisfactorily on the occasion of the fatal accident.*
>
> ***1.*** *The Containerised Diving system which was used when the fatal accident occurred was thoroughly tested during a period of days in June 2010. Thereafter the Diving system was left without further actions. The Diving system then left NDE's premises at Rindö, Stockholm, on the 14th of July 2010 heading for Emden, Germany.*
>
> *The function tests included communication and video tests by direct communicates through the helmets and the diver phone inside the dive control room, and by recording the communication and video onto DVD hard disc recorders. A tap-test was done directly on the dive helmets' microphones to be sure the system was correctly connected. By doing the tap-test we could be sure the communication system was correctly connected.*
>
> *If the communication system, which is a 4-wire system, is not correctly connected the tapping-test will immediately reveal this by the difference of the sounds the tapping-test makes.*
>
> ***2.*** *On the 17th of July the dive system was mobilized onboard the Vessel, Maersk Tender. Between the 17th and the 24th of July there was maintenance done on the diving helmets, for instance microphones and earphones with changes in one or two helmets. No records were made and the personnel on the site had different opinions of what was done.*
>
> ***3.*** *On the 25th of July the divers' communication systems were tested by the NDE Operations Manager. The tap-test showed that the communication was wrongly connected in two of the helmets. One was Diver 1 helmet and the other was Diver 3 helmet. The only helmet that was correctly connected was the helmet which was the one the deceased diver had used during the accidental dive.*

4. *During the investigation and hearing of NDE personnel made by the NDE Operations Manager, it was revealed that before the fatal dive it had been decided to use Diver 2 helmet and umbilical as equipment for the diver instead of Diver 1 equipment due to the bad functioning communication at the previous dive.*

5. *The common way when testing communication is to talk directly into the diver helmets. The same way works for testing the earphones either by putting your head inside the helmet or just putting your ear to the opening of the helmet. This way of testing gives a clear communication check both if the communication system is a "common" 2-wire system or a 4-wire system.*

6. *With a wrongly connected 4-wire system (where the microphone is connected to the earphone wires and the earphones are connected to the microphone wires), the problem starts when the diver has put his hat liner on and then puts on the helmet. When he is still on the surface the communication can be perceived as a bit unclear but still ok for both the diver when spoken to by the dive control (supervisor) and vice versa.*

When the diver then goes below the surface, the problem occurs to its full magnitude. The diver must try to hear what is communicated to him through the microphone (which is placed in the nasal mask) and the supervisor must try to hear what the diver says through the earphones which are covered by the hat liner.



Wiring of the ear and head phones in the dive helmet. *Photo: The Investigation Division*

5.18 The umbilical

The umbilical was of the make and certification of Cortland Fibron BX. It was pressure and electrical tested on 24 February 2009 and 2 March 2009, respectively.

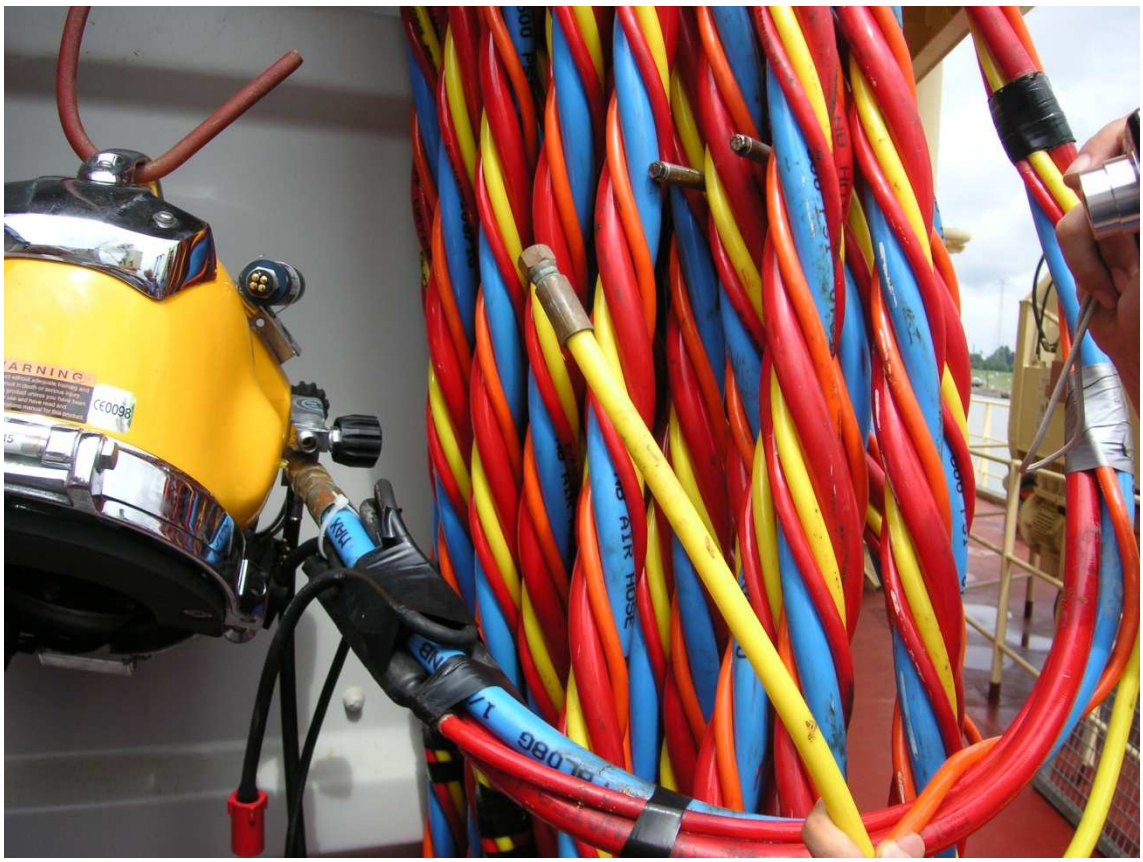
The umbilical was 152 metres long consisting of five parts:

- blue hose for air supply (½ inch bore)
- red hose for warm water (½ inch bore)
- yellow hose for depth gauge, the pneumofathomer or “pneumo”, ($^1/_4$ inch bore)
- orange cable for helmet camera and communication
- red cable for helmet lamp

During the diving operation in question, the hose for warm water was not used. This gave the umbilical buoyancy, making it easier to handle. However, the buoyancy also caused the umbilical to more easily get entangled in gear not lying on the seabed.

Because the ship was on DP (dynamical positioning) mode, the diver’s umbilical was shackled to the diving basket’s hoisting wire every 10-15 metres to prevent the umbilical from being caught in the ship’s propellers.

At the request of the German Water Police, a sample piece of 3 metres in length of the diver’s umbilical was subject to an examination by the Bundeswehr Technical Centre for Ships and Naval Weapons, Germany, to find out whether the air supply could be cut off by pinching the umbilical. It was found that the air supply could be totally cut off if the umbilical was bent by a great force and the air hose was at the inner position.



Umbilical of the same type as the one used by the diver, the yellow hose is the pneumo

Photo: The Investigation Division

5.19 The diving station air distribution panel

It has been stated that noise from reduction valves and other valves and narrow pipes and/or something wrongly connected in the air distribution panel disturbed the communication between the divers and the diving supervisor and that, for that reason, he used to throttle the air flow to the diver.

It has also been stated that something was wrong with the air distribution panel so that it was necessary to constantly regulate the pressure manually on the controller; otherwise the pressure went down to below 10 bar. However, it has been stated that this should be no problem during the distressed diver's dive because according to the gauge, he had more air than needed until his umbilical got stuck.

The Investigation Division has not identified any technical failure of the air distribution panel during the accident investigation on board.

The diver who in vain attempted to locate the dredger pipe barely two hours before the fatal dive has stated that he had problems with air supply. The regulator could not quite provide the helmet with air.

The diving company has provided drawing of the dive system and information about certain valves in the system to the Investigation Division, but no such information of which the cause of communication problems caused by the panel has been identified.

5.20 Other communication errors

The diving control panel caused a certain annoying noise while operating. Thus, the diving supervisor used to adjust the regulator to adjust this vibration noise. The diving supervisor had reported that to the diving company management. The management would consult the manufacturer about the issue.

5.21 Diving company procedures

The diving operations were, to a certain degree, carried out in accordance with the IMCA guidelines.

This was the first time the diving company conducted diving from a ship in the DP mode.

Information about the exact depth to the seabed is not available. 39 to 41 metres and also 43 metres have been mentioned.

No check list for the diving project in question has been produced to the Investigation Division.

There was no so-called bridging document to map out the mutual work procedures between the parties involved in the project.

Prior to the diving, drills were conducted in accordance with the NDE's management system. Test dives were made at 0 to 10 metres' depth on 22 July 2010.

Video and audio recordings were made by a separate recorder for each diver's helmet camera.

Video and audio recordings were made for all divers on a common DVR recorder (the black box).

No risk assessment for the rescue of a distressed diver had been made in writing. It was solely up to the diving supervisor's judgement to act expediently.

The diving company requested the Auto Dynamic Positioning Services Ltd (ADPS), Plymouth, UK, to examine and assess the crew of MAERSK TENDER in preparation for utilizing the ship for DP diving operations. A representative of the ADPS was undertaking this task, while the ship was alongside in Emden on 20 July 2010.

There was no system in the diving company which ensured that the diving equipment was surveyed by the Danish Maritime Authority prior to the diving operations.

There was no system in the diving company which ensured that the diving operations were carried out in accordance with Danish diving legislation.

A work permit, valid from 22 July until 5 August 2010 was issued on 21 July 2010 from the BARD Engineering GmbH on the basis of a toolbox meeting held on 20 July 2010. Documentation of this toolbox meeting has not been presented to the Investigation Division.

According to BARD the mentioned toolbox meeting was carried out in a form of a HIRA/HAZID/HAZOP meeting were the procedure was presented and all risks were discussed. Since no additional items were raised during the meeting, BARD was convinced that the procedure covered the scope of work and the permit was released with no extra mitigations or actions which would have been addressed in the permit.

5.22 Ship procedures

The dives were carried out from the ship in the dynamically positioned mode (DP) on demand from the operator (BARD 1).

The ship's check list for DP2 operations had been followed and all DP2 conditions for diving were in order and recorded. The so-called "traffic light" showed a green light indicating that the DP conditions were OK for diving operations.

The ship's position at the time of the accident was alongside the transformer platform BARD 1, approximately 15 metres from the east side of the platform, heading 180. The dredging pipe was hanging in the ship's starboard crane.

The chief officer and the 2nd officer were on duty on the bridge. During diving operations, their task was solely to keep the ship in position. They had nothing to do with the dives.

When the ship was in the DP mode, the officers on duty carried out their tasks in turns.

There was no system in the shipping company ensuring that the diving equipment was surveyed by the Danish Maritime Authority prior to the diving operations.

5.23 Toolbox meeting

Before the diving operations took place on 24 July 2010, a toolbox meeting was held with the participation of six persons from the diving crew and only one crew member from the ship.

The crew member acting as a crane driver during the accident did not participate in the toolbox meeting because he went on duty at 16:00 relieving another crew member who had participated in the toolbox meeting.

At the toolbox meeting, the following was dealt with: the task, safety checks, tools, material and equipment required, potential hazards and actions taken to eliminate hazards and other special precautions.

The possible need to rescue a distressed diver and how to perform a rescue operation was not dealt with at the toolbox meeting, nor was any other written procedure for a rescue operation drawn up.

5.24 Risk assessment

According to Danish legislation, which applied to these diving operations, a risk assessment must be prepared for the individual tasks. For particularly risky tasks, the assessment must be prepared in writing.

A general risk assessment had been made in writing, but no one for this individual task. The present risk assessment is a standard version from the diving company's management system.

According to the diving company the general risk assessment was made with the conclusion that the dredging operation should be done by using ROV. Since the job execution deviated from the method statement another risk assessment should have been made out.

The possible need to rescue a distressed diver and how to perform a rescue was not dealt with in the general risk assessment.

5.25 External factors

At between 0 and 12 metres' depth, the standby diver observed a current of 3-4 knots and at the seabed there was a varying current of 0-2 knots. The strong current made it hard for a diver to swim and to handle the umbilical.

At every 10-15 metres, the diving tenders on deck had to secure the umbilical to the basket's hoisting wire by shackles to prevent the umbilical from getting entangled with the ship's thrusters.

The dredger pipe had been furnished in the lower end with two heavy H-girders making a gap between the dredger pipe and the H-girders. However, nobody had imagined that this construction implied any risk for the diver. Nevertheless, this was the situation as the diver's umbilical got trapped in this gap twice creating a loop.

At the seabed, there was a lot of wire debris making it difficult for divers to operate safely. The diving company has stated that they had not been informed about the presence of a lot of wire debris by BARD prior to the diving operations. However, in the scope of work of the order confirmation from the diving company "cutting and collection of wire debris with divers" is included.

BARD has stated that since they (BARD) knew about the slipped wires from the platform, NDE was first requested to first survey the area around the platform to develop a strategy of recovery.

5.26 Normal/correct procedure

According to the diving company, it is common practice to have a diver in action and a standby diver on the ship's deck. However, this practice does not taken into account that the ship is in the DP mode.
The diving procedure was predetermined by the diving company and could not be altered by the diving supervisor.

According to Danish regulations, diving on atmospheric air is permitted only at a maximum depth of 50 metres. A recognized good practice is to use mixed gas at depths above 30 metres.

According to Danish regulations, there must be a spare diver and a spare diving assistant ready for immediate rescue, or appropriate similar safety measures, approved by the diver, when diving under particularly harsh or risky conditions.

5.27 Maintenance system

The diving company had a PMS, a planned maintenance system. However, the diving supervisor was not aware of that system, and the diving company declared to the Investigation Division that the system was not complete.

5.28 Testing of diving equipment

The diving equipment had not been surveyed and certified by the Danish Maritime Authority or by any other authority as prescribed for diving operations from a Danish ship.

The communication between the standby diver and the diving supervisor was hampered by a wrong connection in the wiring of the communication system inside the standby diver's helmet.

According to the diving company, the containerised diving system was thoroughly tested during a period in June 2010. Thereafter, the diving system was left without further action.

The diving system was then shipped from the company's premises in Sweden on 14 July 2010 for Emden, Germany. The function tests included communication and video tests by direct communication through the helmets and the diver phone inside the diving control station and by recording the communication and video onto DVD hard disc recorders.

A tap-test was made directly on the dive helmets' microphones to be sure that the system was correctly connected. By doing the tap-test, the users thought they could be sure that the communication system was correctly connected.

If the communication system, which is a 4-wire system, was not correctly connected, it was believed that the tap-test would immediately reveal this by the difference of the sounds from the tap-test. However, the wrong connection was not revealed by the tap-test.

On 17 July 2010, the diving system was mobilized on board the ship MAERSK TENDER. Between 17 and 24 July 2010, maintenance was carried out on the diving helmet, e.g. microphones and earphones were changed in one or two helmets. No records were made, and the personnel on site have different opinions of what was done.

On 25 July 2010, the divers' communication systems were tested by the diving company's operational manager. The tap-test showed that the wiring had been wrongly connected in two of the helmets. One of these was the Diver 1 helmet and the other was the Diver 3 helmet. The only helmet that was correctly connected was the Diver 2 helmet which was the one used during the accidental dive.

During the operational manager's hearing of the company's personnel, it was revealed that prior to the fatal dive it was decided to use the Diver 2 helmet and umbilical as equipment for the diver instead of the Diver 1 equipment due to the poorly functioning communication during the previous dive.

The common way of testing communication is to talk directly into the helmets. The same goes for testing the earphones, either by putting your head inside the helmet or just putting your ear to the opening of the helmet. This way of testing should provide a clear communication check of whether the communication system is a "common" 2-wire system or a 4-wire system as well.

With a wrongly connected 4-wire system (microphone connected to the earphones' wires, and the earphones connected to the microphone wires), the problem starts when the diver has put his hat liner on and then puts on the helmet. When still at the surface, the communication may be slightly unclear, but still satisfactory for the diver when spoken to by the diving supervisor and vice versa. When diving, the problem occurs in its full magnitude. The diver must try to hear what is communicated to him through the microphone, placed in the nasal mask, and the supervisor must try to hear what the diver is saying through the earphones which are covered by the hat liner.

5.29 Diving team

The diving team on board MAERSK TENDER consisted of seven persons: One diving supervisor and four divers, one technician and one air-lift operator, six of whom were Swedish citizens and one British.

The diving team had been composed for the determined diving method and procedure.

5.30 Diving company organization

The diving company had not been well informed about the diving project, and the company did not know about the large number of old wire debris on the seabed, etc.

A thorough risk assessment had not been made by the diving company in preparation for carrying out the job with one diver on the seabed and one standby diver on the ship's deck. It was the opinion of the diving company that the diver's safety had been considered, having three alternative spare air supplies. According to the diving company BARD had stated that a pre-investigation of the circumstances was not necessary.

According to BARD they have requested and received a risk assessment. Regarding the details of the operation it was stated, that this is covered under the IMCA certification umbrella. This was sufficient for BARD.

5.31 Video records of the diver's problems and standby diver's rescue attempt

At the diving control station on the ship's deck, video recordings were made of both dives. The video recordings were pictured by the divers' helmet cameras and stored on separate video recorders and on a prescribed common DVR recorder, colloquially known as the "black box".

Copies of the recordings stored on separate video recorders were immediately handed over by the diving supervisor to the Investigation Division during the investigation on board the ship.

For some reason not clarified the video recording of the distressed diver's dive and accident stored on the separate recorder was without audio recording.

The DVR recorder was taken into custody by the German water police immediately upon the ship's arrival at the port of Emden. It turned out that also the video recording stored on the distressed diver's channel on the DVR recorder was without any audio recording.

However, the video recording stored on the standby diver's channel on the DVR recorder contained audio recordings for both divers.

The DVR recorder displays time of day/month/year – hour: minute: second UTC, i.e. the ship's time minus 1 hour. In this report, the times are indicated as the ship's time.

5.32 External investigations

Police and public prosecutor's investigations

The accident was investigated by the German Water Police, Emden, Germany, and by the public prosecutor in Aurich, Germany, with reference to possible legal actions.

Coroner's inquest

On 25 July 2010, the body of the deceased diver was subject to a coroner's inquest. The coroner' inquest concluded:

> *"The inspection of the body has shown absolutely no signs of trauma to the body of the deceased during his lifetime by third parties".*

The coroner's inquest gives no information about the cause of death.

No autopsy of the deceased diver was carried out. Thus, the exact cause of the diver's death has not been established.

Records from the diving operations

The VDR recorder recorded on two channels:

- Channel 2: the diver's fatal dive.
- Channel 1: the standby diver's dive and rescue attempt.

The recording on channel 2 was without any audio track.

However, the missing audio track from the recording of the fatal dive had been recorded on channel 1 on the standby diver's recording.

At the request of the Investigation Division, the National High Tech Crime Centre (NITEC) of the Danish National Police has made it possible for the Investigation Division to watch a synchronized playback of the recordings of video and audio tracks from channel 1 and channel 2 simultaneously from 24 July 2010 for the time span 1445 hours to 1546 hours (UTC), i.e. 1545 hours to 1646 hours ship's time.

5.33 Legislation

The Danish Maritime Authority's Consolidated Act on Diving Operations and Diving Equipment etc. applies to all diving operations from Danish vessels, no matter where.

Prior to the diving operations on the BARD project, the diving company had asked BARD 1 about the legislation to be followed. The diving company received no answer before the diving operations commenced.

The diving company did not consider offshore regulations of relevance because this was no hydrocarbon project. But the company did not ask, and thus the company was not aware that offshore regulations actually applied to this project.

BARD required an IMCA certified diving company even the BSH Standard is referring to the German BGV C23 rules, which was in BARD's opinion not adequate for diving at 40 m water depth.

5.34 Survey

According to Danish legislation, diving equipment, including auxiliary equipment, used for diving operations or for hiring out must be surveyed by the Danish Maritime Authority.

The diving equipment had not been surveyed by the Danish Maritime Authority.

6 Analyses

This accident is composed of many elements: First and foremost, the accident itself and then the attempt to rescue the distressed diver. Within each main element there are immediate causes and contributing causes.

Therefore, the analysis is sectioned as follows:

- **Immediate causes of the accident (6.1)**
    - Unsafe actions
    - Unsafe environments/conditions

- **Contributory causes of the accident (6.2)**
    - Unsafe actions
    - Unsafe environments/conditions

- **Immediate causes of the result of the accident (6.3)**
    - Unsafe actions
    - Unsafe environments/conditions

- **Contributory causes of the result of the accident (6.4)**
    - Unsafe actions
    - Unsafe environments/conditions

- **Safety system (6.5)**

In this section, the facts are written in normal font and the Investigation Division's conclusions are in italics.

6.1 Immediate causes of the accident

Unsafe actions

The fatal accident basically consisted of the entanglement and squeezing of the diver's umbilical, which the diver did not manage to get loose.

The diver's umbilical got entangled because the circumstances made it possible. It had not been prevented.
The diver did not manage to loosen the umbilical by himself for many reasons.

According to Danish diving legislation, a risk assessment of each individual task must be prepared. For particularly risky tasks, it must be prepared in writing.

The Investigation Division finds that this diving task should have been considered particularly risky because:

- the diving supervisor did not consider the diver an experienced diver,

- the diving task took place at approximately 41 metres' depth,

- this was the diver's first dive for two months; his latest dive prior to this fatal dive was at a depth of 13.5 metres in Balha, Yemen,

- this was the diver's first dive for over a year at more than 30 metres' depth,

- this was the diver's first dive from a ship in the dynamically positioned mode,

- this was the diver's first dive with this diving team,

- this was the diver's first dive from this ship,

- the diver was under the influence of nitrogen narcosis,

- the diving operation was carried out by one diver only, he was his own tender at the seabed, and he had to handle his umbilical by himself,

- a lot of wire debris was lying on the seabed and

- strong currents could be expected.

A risk assessment had been made in writing, but not for this individual task. The present risk assessment is a standard version from the diving company's management system, not directly addressing anything about the divers' safety or anything about a possible rescue effort.

The Investigation Division assesses that because a risk assessment had not been properly made for this particular task carried out by diver, it was not realized that the diving operation might have been performed more safely, e.g. by more than one diver at the seabed or as a wet bell diving.

Two H-girders were attached to the lower end of the dredger pipe in a way that could lead to trapping of an umbilical. This was obviously not considered a potential risk to safe diving.

The diver's umbilical got trapped and entangled, creating a loop between the dredger pipe and two attached H-girders. The loop on the umbilical caused a squeezing of the umbilical whereby the air flow was cut off.

The risk assessment dealt only with the possible risks of the umbilical getting in touch with the ship's propellers/thrusters. The risk assessment did not directly address anything about the divers' safety.

It is the Investigation Division's assessment that because a risk assessment of this particular task had not been properly made, it was not realized that the diver's umbilical could be trapped between the H-girders and the dredger pipe. Thus, no initiatives were taken to avoid that.

After having positioned the dredger pipe, the diver followed his umbilical back towards his basket. He approached the dredger pipe and passed above it. When he was at the opposite side of the dredger pipe, his umbilical was leading below it just at the upper end of the H-girders. In agreement with the diving supervisor, he passed under the dredger pipe and continued following his umbilical.

The Investigation Division assesses that the diver's umbilical came near the gap between the dredger pipe and the H-girders when the diver passed under the dredger pipe. It is a general rule not to stand or pass under a suspended load. Therefore this should have been avoided by directing the diver to pass the dredger pipe at a greater distance rather than passing under it and by having a second diver at hand to tend the umbilical.

At a time after 16:00, when the crane operator had taken over the duty from his colleague, he was ordered to lower the dredger pipe a little, which he did. Then he was ordered to heave it up which he did. The crane operator demanded to receive orders from only one particular person in order not to create dangerous situations. He was ordered to lower the dredger pipe down completely, and further down, but he could not lower it further down.

The Investigation Division assesses that the umbilical was trapped and created a loop when the dredger pipe was lowered after the diver had passed under it on his way back to the diving basket. The umbilical's buoyancy may have been a contributing factor.

Not knowing that the umbilical had been trapped and entangled, the diver attempted in vain to haul back the entangled umbilical after he had returned to his diving basket.

The umbilical loop had become so very tight and locked between the dredger pipe and the H-girders that it was impossible for the diver to loosen it.

The Investigation Division assesses that the umbilical loop became so very tight and locked between the dredger pipe and the H-girders not only because of the diver's own force in his attempt to haul it back, but also because of movements/lowering of the dredger pipe and because even relatively minor movements between the ship and the dredger pipe would have a significant impact on the tension of the umbilical that was already tightened up by the diver and kept tight by the crew on deck.

At 16:12, when the diver reached the dredger pipe, passed over it and then under it and then began dragging himself rather fast along the umbilical, his breaths increased from 10 to18 per minute.

The diver came in a sudden emergency because his main air supply became shut by the squeezed umbilical. Then, he had only the air that was left at a certain pressure in the umbilical between him and the dredger pipe, i.e. 10-12 metres which would suffice only for a very short time.

The Investigation Division assesses that the diver's increase of breaths after having passed the dredger pipe on his way back to the diving basket was caused by an emerging shortage of air supply which in turn was caused by the squeezed umbilical.

Unsafe environments/conditions
The diving operations took place at a depth of approximately 41 metres.

Nitrogen narcosis occurs while diving at depths of 25-30 metres or more.

The effect of nitrogen narcosis is similar to that of being under the influence of alcohol (lost ability to make decisions, loss of focus, impaired judgment, multi-tasking and co-ordination). The diver may feel invulnerable and disregard normal safe diving practices.

The diver kept the locking pin in his hand for no purpose from when he took it out of the umbilical in the basket and all the time while he was in serious distress even though the diving supervisor urged him to throw it away.

The diver passed under the dredger pipe on his way back to the diving basket, in agreement with the diving supervisor, even though it is a general rule not to stand or pass under a suspended load.

After having been in serious trouble caused by the entangled umbilical and lack of main air supply for several minutes, the diver said at 16:16: *"Thanks – no bailout".* He did not manage to use his pneumo or to follow any of the diving supervisor's instructions.

The diver had no more air available in his bailout bottle when he came into trouble with his umbilical because he had used it deliberately or because he inadvertently and under the influence of nitrogen narcosis had opened one of the valves on the helmet's side block.

The Investigation Division assesses that the diver was under the influence of nitrogen narcosis while at the seabed and thus his reactions could not be expected to be rational.

The diving operations were carried out while the ship was in the dynamical position.

There was a lot of wire debris at the seabed.

The diving company had not been well-informed about the diving project, and the company did not know about the large number of wire debris on the seabed, etc.

A pre-investigation of the circumstances was not carried out.

The Investigation Division assesses that the divers' safety was not addressed well by the planning of the diving operation and by the diving method used.

The warm water hose in the umbilical was not in use. Thereby, the umbilical was easier to handle in some respects because it had buoyancy. On the other hand, it also implied a certain risk because it could be moved by the current.

There was a strong current in the area during the diving operations. This meant that the umbilical was even harder to handle – especially for one diver only. The diver had to go to his diving basket and leave his slack umbilical behind him before he could take it home by hauling it from the basket. Thereby he was not able to control the umbilical and because of its buoyancy, and probably also due to the current, the umbilical could get trapped between the dredger pipe and the H-girders.

The Investigation Division assesses that there was a need for another diver at the seabed to tend the umbilical for the diver in action. Because the diver was not able to tend his own umbilical, he could not prevent it from being trapped and entangled by the dredger pipe and the H-girders.

6.2 Contributory causes of the accident

Unsafe actions

The diving operations were carried out as surface supplied air dives.

However, the use of nitrox as a respiratory medium would not have prevented the divers from becoming influenced by nitrogen narcosis.

According to Danish regulations, diving on atmospheric air is permitted only at a maximum depth of 50 metres. A recognized good practice is to use mixed gas at depths above 30 metres.

The Investigation Division assesses that the use of atmospheric air as a respiratory medium was a contributory cause for the diver not being able to act rationally when in distress and thus a contributory cause that he e.g. passed under the dredger pipe.

6.3 Immediate causes of the result of the accident

Unsafe actions

The breathing air was supplied at a pressure of 12-14 bar at the outlet from the diving control station panel.

The diver who in vain attempted to locate the dredger pipe barely two hours before the fatal dive had problems with air supply.

It has been stated that something was wrong with the air supply from the diving control station.

The Investigation Division assesses that the air pressure at the outlet from the diving control station panel was at the minimum needed for safe diving under the given circumstances.

The diver had at his disposal three alternative possibilities of emergency air supplies:

- One 10-litre bailout bottle at 260 bar.
- The pneumo which the diver had to put into his helmet via the neck dam.
- One 50- litre air bottle of 200 bar in the diving basket to be used in the same way as the pneumo.

The diver was not saved by any of his emergency air supplies.

The bailout bottle valve was open as usual during the dive.

To use the bailout the diver had to open a valve on the right side of the helmet, very close to the valve for free float.

At 16:15:46, air bubbles and the sound of air like free flow came from the distressed diver's helmet for a very short while.

The diver was under the influence of nitrogen narcosis and thus his reactions could not be expected to be rational.

After having been in serious trouble caused by the entangled umbilical and lack of main air supply for several minutes, the diver said at 16:16: *"Thanks – no bailout".* He did not manage to use his pneumo as an emergency air supply or to follow any of the diving supervisor's instructions.

The Investigation Division assesses that the diver had no more air available in his bailout bottle when he came into trouble with his umbilical despite it is not seen on the DVR-record that he opened the bailout. The brief air flow from his helmet at 16:15:46 may have been free flow with the very last air in his bailout bottle.

The Investigation Division assesses that the relatively low air pressure at the outlet from the diving control station panel may have caused or contributed to the diver using air from his bailout, which meant that he had no more bailout air available when needed for his rescue.

At 16:07:51 and at 16:08:06, before the diver came into trouble with the entangled umbilical, he asked for more air.

The diving supervisor agreed and gave him more air.

During his attempt to rescuing the distressed diver, the standby diver said several times that he needed more air.

The diving supervisor repeatedly answered that the standby diver had plenty of air.

The standby diver used air from his bailout several times during his rescue attempt.

It has been stated that noise from reduction valves and other valves and narrow pipes and/or something wrongly connected in the air distribution panel disturbed the communication between the divers and the diving supervisor and that for that reason he used to throttle the air flow to the diver.

It has also been stated that something was wrong with the air distribution panel so that it was necessary to constantly regulate the pressure manually on the controller; otherwise the pressure went down to below 10 bar.

The Investigation Division assesses that a technical malfunction at the diving control station air distribution panel not identified by the Investigation Division caused a periodically inadequate air supply for the divers.

The Investigation Division assesses that inadequate air supply may have caused or contributed to the diver using his bailout to supplement his air supply, as did the standby diver for the same reason during his rescue attempt, or the diver may have opened his bailout instead of free flow as a mistake because he was under the influence of nitrogen narcosis.
In this connection, it should be remembered that the knob for opening the bailout and the knob for opening for free flow are situated very close to each other on the so-called side block on the right side of the helmet.

The Investigation Division assesses that the diver had no more air available in his bailout because he had used it while he had trouble with his umbilical or because he inadvertently and under the influence of nitrogen narcosis had opened one of the valves on the helmet's side block. Thus he was unable to use his bailout when needed.

The Investigation Division assesses that the relatively low air pressure at the outlet from the diving control station panel caused serious troubles, even risk of life, to the standby diver during his attempt to rescue his distressed colleague.

The Investigation Division assesses that it cannot be determined whether the inadequate air supply for the standby diver had any delaying and/or decisive effect on his attempt to rescue the distressed diver.

The communication between the standby diver and the diving supervisor proved to be problematic because the communication line had been connected incorrectly in the standby diver's helmet.

The malfunctioning communication system caused severe misunderstandings between the standby diver and the diving supervisor and delay in loosening the umbilical.

The Investigation Division assesses that the malfunctioning communication system caused by wrongly connected microphone/earphones was not identified and rectified because of an inadequate test procedure.

The Investigation Division assesses that the malfunctioning communication system caused delay in the standby diver's efforts to rescue his distressed colleague.

The Investigation Division assesses that it cannot be determined what impact the delay caused by the malfunctioning communication system had on the distressed diver's possibility of survival.

The standby diver was on board the ship until an emergency occurred.

At 16:14:40, the diver's umbilical began tightening up and he pulled hard.

At 16:15:00, the diver expressed being annoyed by his umbilical.

At 16:16:07, somebody on the ship's deck expressed: *"He gets no air!"*

At 16:17:00, the standby diver's helmet began moving, indicating the standby prepared for diving.

At 16:20:50, the standby diver's basket was being deployed.

At 16.25:26, the standby diver left his basket at the seabed.

The Investigation Division assesses that the time spent getting the standby diver available for assistance at the seabed was far beyond the time needed to be of any efficient life saving assistance to the distressed diver.

The Investigation Division assesses that the diving method with one diver in action at the seabed and one standby diver on the ship's deck was a causal factor that the distressed diver got no efficient assistance in due time when needed.

At 16:25:45, the standby diver approached the dredger pipe and the distressed diver who lay lifeless on the seabed became visible. The diving supervisor instructed the standby diver to get the distressed diver's umbilical loose.

The standby diver worked very hard and intensively for approx. 10 minutes to loosen the umbilical in order to re-establish the air supply to the distressed diver.

At 16:35:50, the standby diver arrived at the distressed diver and opened his free flow, while the diving supervisor instructed him to do so. However, the distressed diver's free flow was already open and the air supply through the umbilical was re-established, but the distressed diver remained lifeless.

The Investigation Division assesses that the distressed diver may have opened the valve for free flow as a mistake while opening the valve for emergency air supply from his bailout, because he was under the influence of nitrogen narcosis and/or otherwise not acting rationally because of his emergency situation.

The Investigation Division assesses that the standby diver ought to have been directed straight to the distressed diver when he arrived at the sea bed in order to possibly re-establish an emergency air supply by the use of the distressed diver's own bailout or his pneumo, though it later was revealed that the distressed diver had no more air available in his bailout.

However, the Investigation Division assesses that it cannot be determined whether the rescue attempt would have led to a positive outcome if the standby diver had been directed straight to the distressed diver instead of working with re-establishing the air supply by loosening the umbilical.

At 16:40:00, the standby diver had managed to move the distressed diver into his basket, and the basket was being hoisted up.

The distressed diver showed no signs of life.

Because of the weight of the diving helmet and because of his lifeless condition, the distressed diver was not able to keep his head upright.

The standby diver was not able to assist the distressed and lifeless diver on the way up because his own umbilical was lead through his own diving basket and because he had to make decompression stops.

When back on the ship's deck, the diver was not breathing or moving. He had white/pink foam and blood flowing from his mouth and nose and was immediately taken from his basket, divested of his diving suit and taken into the diving company's decompression chamber on board the ship and rendered first aid/cardiac massage.

The Investigation Division assesses that because the diver was lifeless and thus not able to keep his head upright and his respiratory tract free, the differential pressure in his lungs could not be equalized during his way upwards to the surface and therefore he sustained lung overexpansion injuries.

The Investigation Division assesses that the diving method used implied that the standby diver was not able to render maximum assistance and support to the distressed diver.

6.4 Contributory causes of the result of the accident

Unsafe environments/conditions

Carbon dioxide poisoning leads to, among other things, confusion or inability to think. In extreme cases, it may cause convulsions and panic attacks as well as hyperventilation.

The diver's breaths increased remarkably at 16:12 when his umbilical became stuck and squeezed.

The diver's breath gave no indication that he was under the influence of carbon dioxide poisoning before his umbilical got squeezed.

The Investigation Division assesses that the diver may have become under the influence of carbon dioxide poisoning when the umbilical became squeezed because of a lack of air. This may have contributed to him not managing to act rationally or follow the diving supervisor's instructions.

6.5 The safety system

No formal approval of the diving equipment had been conducted.

A common toolbox meeting was held. However, the crane operator on duty at the time of the accident had not participated.

Nobody had observed or recognized the risk of the umbilical being trapped by the dredger pipe and the H-girders.

No risk assessment for the particular diving task had been made.

The method and procedure for repairing and checking the communication system on diving site in the diver's helmets proved inadequate.

No check list for the diving project in question has been produced to the Investigation Division.

No specific legislation was followed in relation to the diving operations. The diving operations were to a certain degree carried out in accordance with the IMCA guidelines.

This was the first time the diving company conducted diving from a ship in the DP mode.

There was no so-called bridging document to map out the mutual work procedures between the parties involved in the project.

There was no system in the diving company ensuring that the diving equipment was surveyed by the Danish Maritime authority prior to the diving operations.

There was no system in the diving company ensuring that the diving operations were carried out in accordance with Danish diving legislation or adequate procedures.

The Investigation Division assesses that lack of proper checklists, lack of proper planning, lack of knowledge of relevant legislation, inadequate procedures on the diving site were contributory factors that led to the operation being performed by means of a non-secure method which led to the fatal accident.