DUTCH
SAFETY BOARD

Electrocution in tank

Atlantic Dawn, Red Sea, 17 October 2016

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The Hague, August 2017

The Dutch Safety Board

When accidents or disasters happen, the Dutch Safety Board investigates how it was possible for them to occur, with the aim of learning lessons for the future and, ultimately, improving safety in the Netherlands. The Safety Board is independent and is free to decide which incidents to investigate. In particular, it focuses on situations in which people's personal safety is dependent on third parties, such as the government or companies. In certain cases the Board is under an obligation to carry out an investigation. Its investigations do not address issues of blame or liability.

Dutch Safety Board

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This report is published in the Dutch and English languages. If there is a difference in interpretation between the Dutch and English versions, the Dutch text will prevail.

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INTRODUCTION

On Monday 17 October 2016, a crew member on board the Dutch heavy lifter Atlantic Dawn, lost his life. He was painting the inside of an unused waste water tank in the engine room while the vessel was anchored near the coast of Saudi Arabia.

This involved a very serious accident as specified in the Casualty Investigation Code of the International Maritime Organisation (IMO) and EU Directive 2009/18/EC. Pursuant to the above, as the flag state, the Netherlands has the duty to arrange a safety investigation. This duty to investigate is also laid down in the Besluit Onderzoeksraad voor Veiligheid ('Dutch Safety Board Decree').

The investigation was conducted to draw safety lessons from this accident and focused on the following questions:

1. How could the accident have happened?
2. How were the risks associated with painting in the waste water tank managed?

The timeline method and MAIIF/IMO analysis method were used to investigate this accident. Failure mechanisms and operational and organisational factors are thus identified in order to pinpoint any potential safety issues.

Technical investigation data collection
Data collection began two weeks after the accident occurred. Two investigators from the Dutch Safety Board began this task when the vessel moored in a Turkish port. This was the first opportunity to visit the vessel since a visa could not be obtained for Saudi Arabia. As a result the circumstances could not be reconstructed with as much certainty, partly because witness information was no longer fresh in the memory. It was not possible to establish the exact condition of the atmosphere in the waste water tank at the time of the accident either. No autopsy was performed on the victim's body. Despite indications that point to electrocution as the cause of death other causes of death cannot be ruled out completely. In a confined space diverse risks may be identified that could make another cause of death possible, such as asphyxiation and poisoning, but a natural death caused, for example, by heart failure cannot be ruled out completely either.

The Nederlands Forensisch Instituut (Netherlands Forensic Institute) was commissioned by the Dutch Safety Board to examine the cable, the fitting and the lamp. They were examined for any technical faults that may have led to people being exposed to electricity.

FACTS AND BACKGROUND INFORMATION

On Thursday 13 October 2016, the Dutch heavy lifter Atlantic Dawn was anchored in the anchorage area of Jizan (the Red Sea). The vessel was approximately six nautical miles (nmi) from the port of Jizan (Saudi Arabia) and approximately three nmi from the coast.

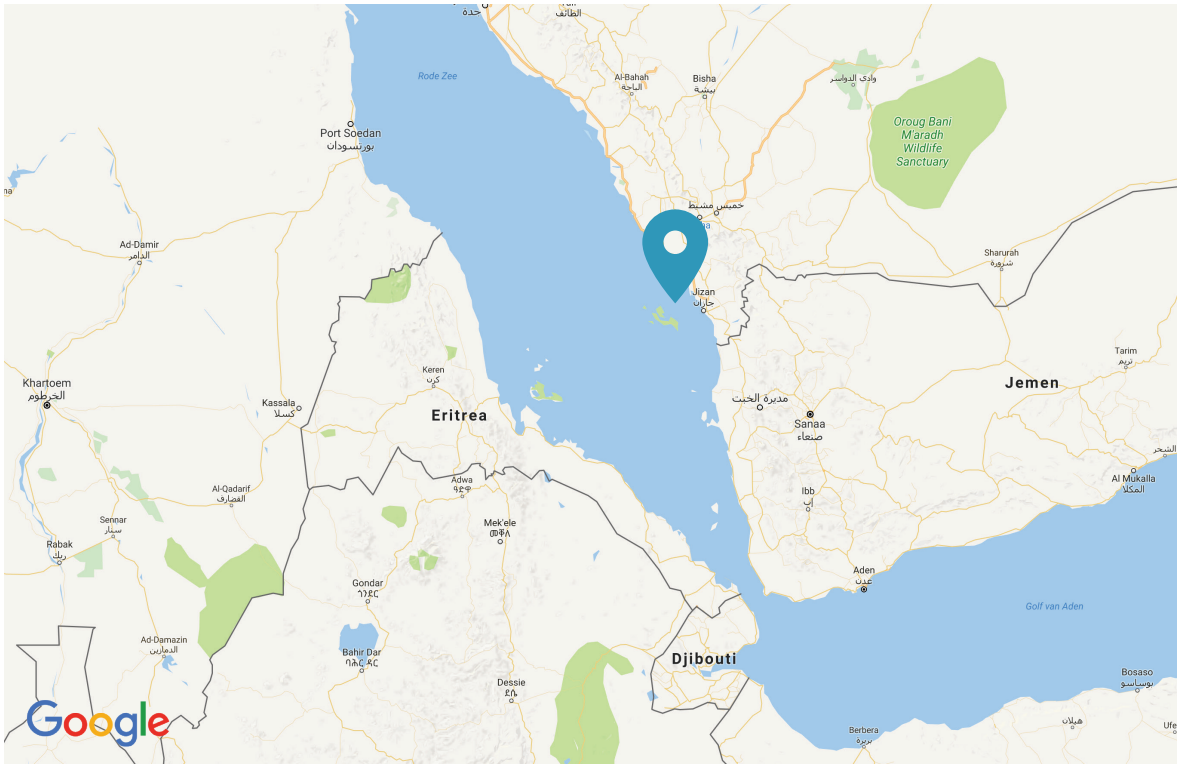

Figure 1: Location of the vessel at the time the accident occurred (Source: Google Maps)

Ship and crew

The Atlantic Dawn was built in 2012 by Shipkits B.V. in Groningen. The ship is under the management of Hartman Shipping. The shipping company also manages a second sister ship, the Pacific Dawn. The ship is suitable for sailing worldwide and was also used to do so. See Appendix A for further ships' data.

The crew of the Atlantic Dawn consisted of ten people. Nine Philippine nationals and one Lithuanian; the working language on board was English. All crew members had the correct certificates of competency. The bosun involved in the accident was a Philippine national and had been on board five months at the time the accident occurred. He had over five years' experience at sea.

Accident

The crew were using the period during which the ship was anchored to carry out maintenance work on the vessel. One of the jobs was to paint the unused waste water

tank (bilge water tank) in the engine room. On Friday 14 October, the crew opened the tank for the purpose of ventilating it.

On Saturday 15 October, the bosun, assisted by an apprentice, began painting the waste water tank. On Sunday 16 October, the crew did not work in the tank.

On Monday 17 October, the bosun and the apprentice continued the job. The bosun first completed a navigational watch from 04:00 – 08:00[1], after which he went to the engine room with the apprentice. The waste water tank had been open all this time and ventilated naturally; a mobile ventilation system was used while the work was being carried out.

The first mate granted permission for entering the tank and the painting job in accordance with the procedure. At 08:30 on Monday morning he tested the air in the waste water tank for oxygen and completed the job's work permit, along with the bosun. The work permit displays the following measured values: oxygen 20.9% vol, hydrocarbon 0% LFL and toxic gases 0 ppm[2].

At 08:35 the bosun and the apprentice began painting. The bosun worked in the tank and the apprentice assisted in the engine room (on the roof above the tank) by mixing paint and passing down material. The bosun wore an overall with a safety harness, as well as a dust cover for the mouth and nose and safety goggles. The bosun used torches and rechargeable lamps to provide light in the tank. They ventilated the tank using a mobile ventilator.

At approximately 10:00 the bosun and the apprentice went for a coffee in the accommodation area and returned to the tank to carry on working at approximately 10:35. The first mate was also present at that time. At that moment the bosun had a cable with him, which had a lamp fixed to one end and a plug on the other. Tape was wrapped around both the lamp's fitting and the plug to attach them to the cable. The bosun inserted the plug in a wall socket near the tank and took the lamp with him into the tank.

At approximately 11:45 the bosun asked the apprentice for a bottle of water and when he received it, asked him to mix a new supply of paint. At that moment the lamp the bosun had fetched with him, was lit. A few minutes later, as soon as the apprentice wanted to hand the bosun the mixed paint, the latter did not reply. When the apprentice looked into the tank, illuminating it with a torch, he saw the bosun was lying unconscious at the bottom of the tank.

The apprentice then alerted the rest of the crew. They removed the bosun from the tank, with the help of breathing apparatus[3], and began resuscitation. The captain alerted the authorities via the shipping company and the shipping agent. The Saudi Arabian

1 All times mentioned in this report are given in local time.
2 Vol: volume percentage, LFL: Lower Flamable Limit, ppm: parts per million.
3 According to the 'enclosed spaces recovery' procedure.

coastguard arrived in a vessel alongside approximately two hours later. The crew lifted the bosun on board the vessel after which he was transported to the coast and brought to the hospital by a waiting ambulance. The crew had continued resuscitation until the bosun was transferred to the ambulance. To do so two crew members accompanied the victim on board the coastguard's vessel. At the hospital the doctor on duty pronounced the bosun dead. No section was performed on the body.

The vessel's electrical installation

Electrical equipment on board must be safe to use. Therefore, all electrical equipment and cables on board must be certified and inspected at least on an annual basis.

Electricity on board the Atlantic Dawn is supplied by a network consisting of three phases and a neutral. The power source is not earthed[4], but the neutral is earthed by a switch disconnector in the mainpanel, users (electrical devices) are earthed individually or in groups. In the event of an isolation fault in a device the leakage current is discharged via this earth to prevent anyone coming into contact with the current.

In the case of an excessive load the slow fuse ensures that the power circuit is interrupted. This fuse is a security feature intended to protect equipment, not people, and operates at a current intensity as of 16A. This means that if contact occurs an electrical power supply can continue to flow without the fuse being triggered. This is why effective isolation of the system as a whole is essential for personal safety. In the case of faulty equipment or unearthed cables the power supply could pass uninterrupted through someone.

Home-made cable with lamp fitting

The construction the victim was using consisted of:

- Wire/cable 9.3 m in length
- Plug
- Fitting
- Lamp attached to the fitting

Two wires of the cable connected the pins in the plug to the cable. The plug's protective earth was interrupted and was protruding. The cable's outer casing was partially missing and wrapped in green insulation tape (see figure below).

4 As a result, an earth leakage breaker is of no use.

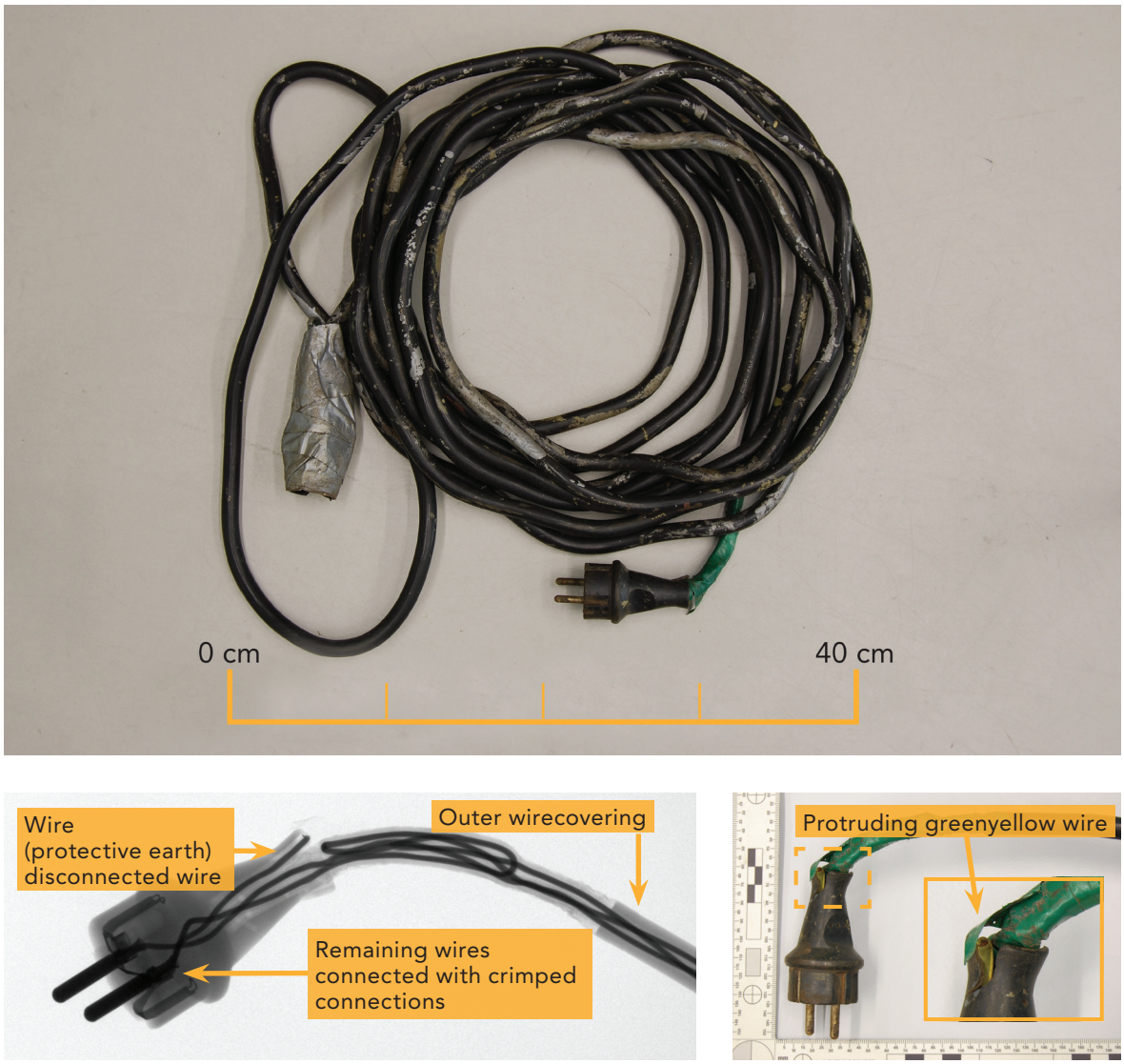

Figure 2: Cable used in tank (Source: NFI)

At the other end of the cable a fitting extension with a double socket had been attached as a lamp fitting. The lamp fitting and the connection to the cable were completely wrapped in silver-grey tape. Part of the blue wire protruded just outside the tape in a loop. Red insulation tape was also visible underneath the silver-grey tape at the other end where the cable was attached to the lamp fitting. One of the cable's wires was connected to the bottom central connector and the other wire was wrapped around the bottom screw fitting. A third wire was ragged and ended at an angle; it was not connected. A piece of plastic was missing from the front end of the lamp fitting and the adhesive side of the tape was visible (see figure below).

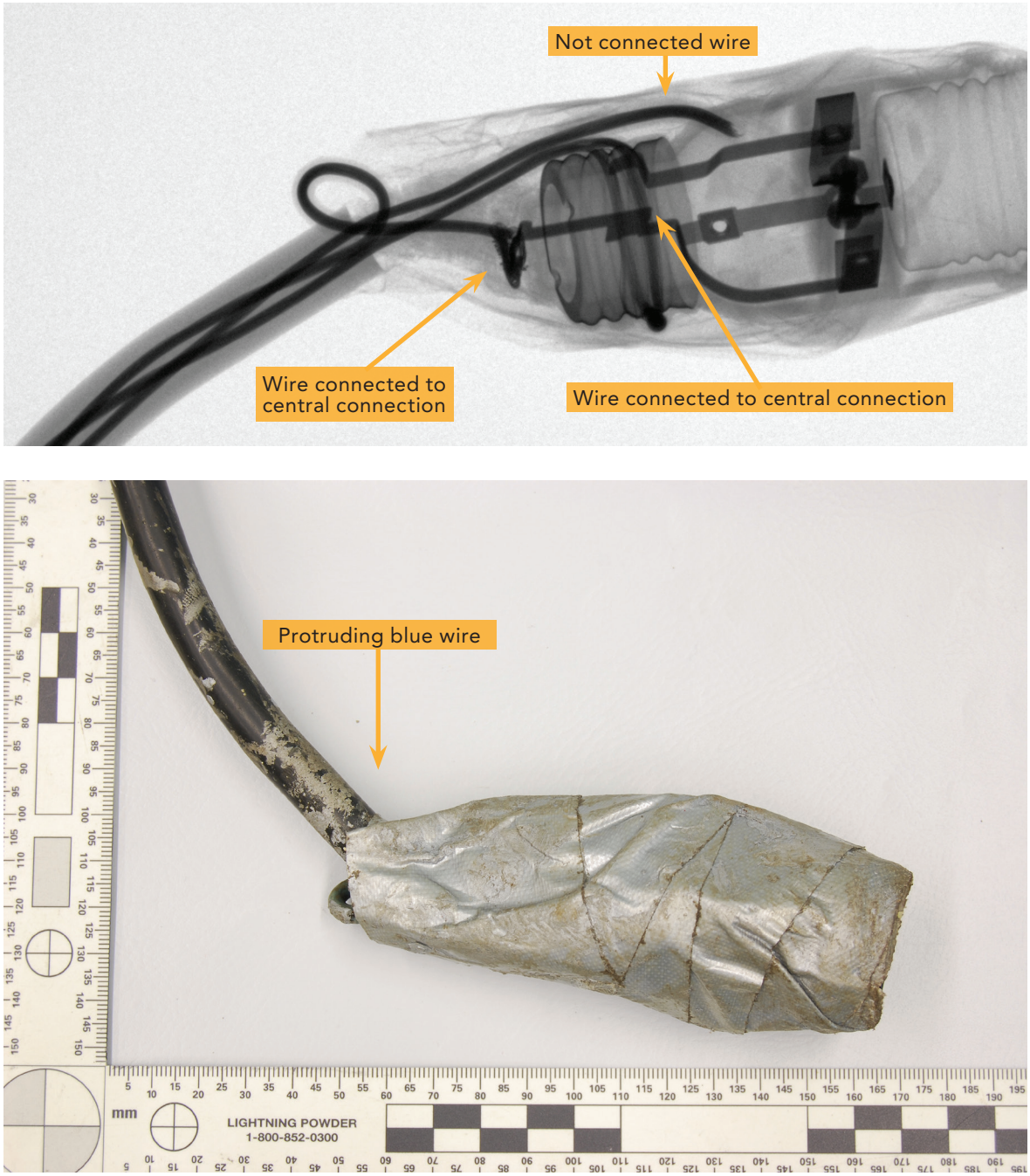

Figure 3: Fitting as connected to cable (Source: NFI)

The lamp could only be screwed into the fitting in one way and was therefore always fixed in the same position in the fitting.

At the transition from the lamp fitting to the lamp the construction of the power cable and the lamp had an opening that was large enough to provide contact between the conductive parts and the bare hands. Therefore this construction was also faulty and unsafe for use.

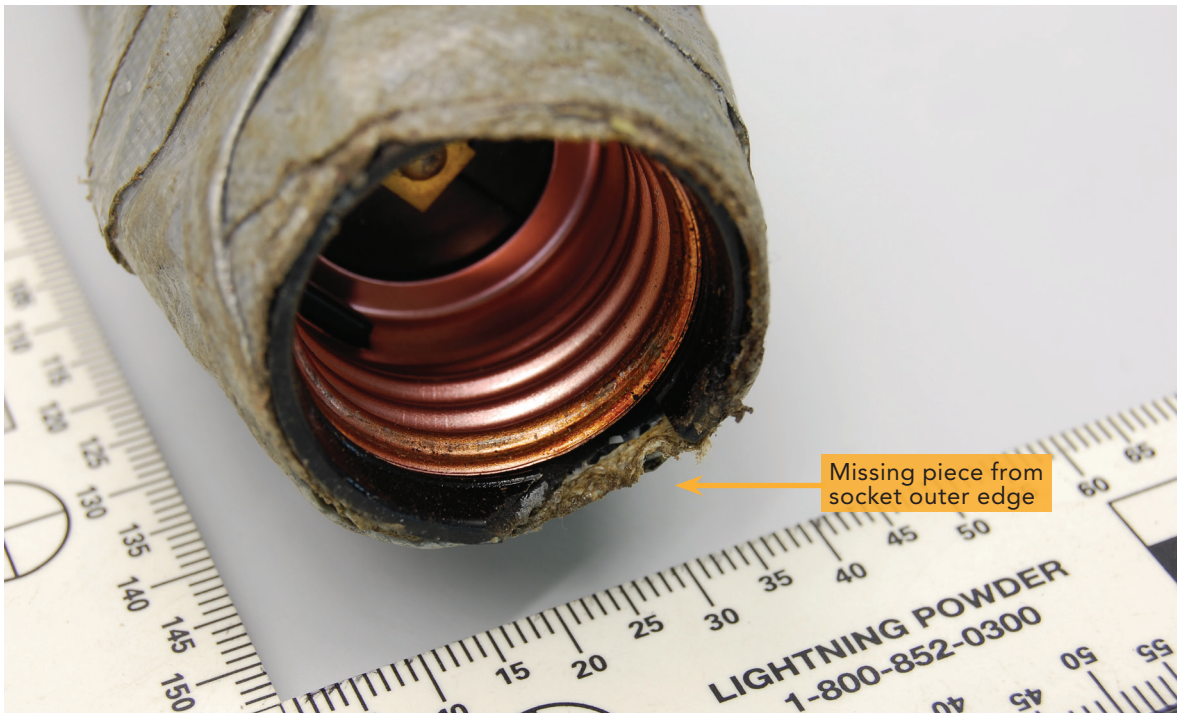

Figure 4: Lamp socket (Source: NFI)

Working in confined spaces

The waste water tank is a confined space, which means a space with restricted openings for accessing or exiting the space, insufficient ventilation and one that is not designed to be worked in continuously. These spaces include cargo holds, double bottoms, fuel tanks, etc. and adjacent connected spaces[5].

Besides an increased risk of a contaminated atmosphere (due to working with paint and solvents in a confined space) working in the waste water tank involved risks related to the use of electrical equipment. There was a risk of fire and / or explosion due to the use of (faulty) electrical equipment. There was a fire hazard arising from the presence of a combustible substance combined with the presence of oxygen and an ignition source. A certain mixing ratio of a gas or vapour with oxygen also creates a risk of explosion. This risk was caused by the evaporation of a solvent in the paint combined with the faulty cable as a potential ignition source.

Moreover there was a risk of electrocution in the waste water tank from the use of faulty electrical equipment. The restricted dimensions of the tank (it was impossible to work standing up) in which the victim was working, meant he worked virtually constantly in contact with metal or other conductive components. Furthermore it was difficult for him to escape this danger. There is also a good chance that a person will perspire when working in a small space (this is also the case when the ambient temperature increases). Damp skin reduces a person's resistance, which facilitates electrical conduction.

Managing the risks of working in a confined space

The crew members involved took measures to manage the risks related to entering a confined space before they started painting. They performed the tasks specified on the 'entering a confined space' checklist. Among other things, they arranged continuous ventilation and measured the atmosphere and when work began, first used torches, head torches and battery-powered lighting to illuminate the space.

The working method that applied on board the Atlantic Dawn complied with the guidelines of the International Maritime Organization (IMO). The 'entering a confined space' procedure must be followed to manage the risks outlined above. In addition to a risk assessment, ventilation and measuring the atmosphere for oxygen and hazardous substances, the crew must also inspect the tools used and ensure adequate lighting. Adequate lighting for this type of work was available on board, as were spare batteries. All the precautions and measures to be taken are specified on a checklist that is part of

5 Definition according to the applicable procedure for entering a confined space on board. This definition complies with the international definition by the IMO

the work permit, which must be issued on behalf of the captain before anyone enters a confined space on board.

Moreover, to prevent the risk of electrocution, all electrical equipment must be assembled and used in such a way that they do not cause injury when handled as intended or upon contact[6]. The Working Conditions Act states that the safety aspects of all work equipment in the workplace must be evaluated at least once a year by a safety expert. Ships sometimes have household electrical goods on board too, the crew's private property. These must also be properly assembled.

Furthermore the use of safe voltage is recommended in a confined space to prevent a fault resulting in electrocution. This means:

1. In principle movable electrical equipment has an integrated power source.
2. If an integrated power source is not possible, the movable equipment must be fitted with extra low voltage, namely:
   a. alternating current maximum 50 Volts, provided the circuit is separated from the main circuit by an isolation transformer or
   b. DC voltage maximum 120 Volts provided the DC circuit is separated from the main circuit by an isolation transformer.

Cause of the fatal accident

Although other causes cannot be ruled out entirely, based on the following findings the Board deems that the victim probably died as a result of electrocution from direct contact with the phase of the electricity network (from the opening in the wire):

- The victim's body displayed wounds to the left hand. The doctor on duty described them as deep burns on a surface measuring approximately 2x1 cm, most likely electrical burns. No section was performed on the body to establish the exact cause of death.
- The victim was using a home-made cable with a lamp to provide light when painting in the tank. The cable consisted of an electric wire, to which a plug had been affixed at one end and a fitting at the other.
- Technical examination of this home-made construction[7] revealed that there was an opening at the transition from the lamp fitting to the lamp, large enough for bare hands to make contact with the conductive parts.
- Skin tissue was found on the lamp at the opening near the lamp fitting.
- There was no short circuit, because the 16A fuse was not triggered.
- If a person comes into direct contact with the phase, the current could pass through that person. Any moisture on the skin increases the effectiveness of the conductivity.

6 International Convention for the Safety of Life at Sea, 1974 (SOLAS), Chapter II-1, Section, Rule 45.
7 Conducted by the Netherlands Forensic Institute (NFI) on behalf of the Dutch Safety Board.

Risk of electrocution:
The current the victim was using could be fatal. The connection used to connect the electrical wire to the lamp was a 230V, 16A and 50Hz wall socket. Technical examination of the lamp revealed that the current intensity through the lamp was 215mA.

Whether or not electricity is fatal depends on a number of factors:

- Voltage
- Current intensity
- AC or DC current type (also frequency with regard to AC)
- Period of time the current passes through the human body.
- The route the current passes through the body
- The resistance (to electrical charge (R)) and condition of the victim
- The size of the contact surface and degree of contact made.
- The material of the clothing worn by the victim
- The floor on which the work is being carried out
- The operation of security features.

The International Electrotechnical Commission (IEC) studied and published the effects of current flow.[8] Generally for 50Hz alternating current the release value, or the value at which muscle cramping occurs, is 10mA for a current flow of 2 sec. With a far greater current intensity and if it runs through the region of the heart (such as with a current that flows from the left hand to the feet), there is a risk of ventricular fibrillation. This means that the heart's normal rhythm is disrupted and the heart displays random muscle contractions. This may halt blood circulation and result in the victim's death. This is a complex process in which many factors and mechanisms play a role. It is also not possible to specify a single value of current intensity that causes ventricular fibrillation. This varies from 500 mA for a fraction of a second, 50 mA for one second to 40 mA for a current duration of three seconds or longer. As of these values the risk of ventricular fibrillation occurring increases.

Safety awareness
The victim may have underestimated the danger of working with electricity on board. After the coffee break, the bosun took the home-made cable with the lamp to provide light while painting.

Moreover this risk had also been pointed out to him twice before. A representative from the shipping company had already told the victim to no longer use a home-made telephone charger on board. The captain had already seen the home-made cable with the lamp fitting before and indicated at the time that it was not to be used any longer. Furthermore adequate battery-powered lighting was available on board the ship.

8 NPR-IEC/TS 60479-1:2005/A1:2016. Effects of current on humans and livestock - Part 1: General aspects. NPR-IEC/TS-2007/2 Effects of current on humans and livestock - Part 2: Special aspects. NPR-IEC/TR-5:2007/C1:2013. Effects of current on humans and livestock - Part 5: Touch voltage threshold values for physiological effects.

It is no longer possible to ascertain why the victim still used the home-made cable with the lamp fitting. Use of this home-made cable and the telephone charger indicate that he did so more often. It is possible that since the use of these materials had never caused any issues before, this led to him underestimating the danger involved with these kinds of constructions.

In addition the risks of electricity increase when working in a confined space. The crew were not used to working solely with safe voltage in this situation. This was also not specified in working methods or procedures.

Risk assessment: maintenance in the tank
Bearing in mind all the risks involved in painting in a confined space, it is doubtful whether this work should have been carried out. The Board is of the opinion that a shipping company should establish in advance which work in a confined space is absolutely necessary and the captain should assess whether it can be carried out safely at that time. Here one should bear in mind that entering a confined space in itself involves all kinds of risks and painting in a tank increases these risks.

The shipping company believed that maintenance to the ship was important and therefore wanted minimal rust on the ship. The captain had the complete inside of the tank painted after the crew discovered rust there during an inspection. Painting the complete inside of a tank is not normally carried out by the ship's crew, but by specialist personnel when the vessel is in the dockyard, under controlled conditions. However, this case concerns an unused tank that had not been treated since the ship was delivered by the shipyard in December 2013.

Moreover the work was carried out in difficult conditions, which increased the risk of working in a confined space. The work was carried out in hot conditions, anchored in front of the coast of Saudi Arabia. The temperature while work was carried out in the waste water tank in the engine room was not measured, but based on the seawater and external temperature in October (an average of 32°C and 34°C respectively) one can deduce that it must have been hot inside the tank.

CONCLUSIONS

The victim probably died as a result of electrocution. He had a home-made cable to which he had affixed a fitting and a plug; this construction had been assembled in an unsafe manner. The victim probably made contact with the phase through an opening on the fitting. Safe voltage was not used.

The victim may have underestimated the danger of working with electricity on board. The risks of electricity increase when working in a confined space. In addition to the perceived risk of electrocution this also involved a fire hazard and risk of explosion.

Bearing in mind all the risks involved in painting in a confined space, it is doubtful whether this work should have been carried out in the tank at that moment by the ship's crew.

APPENDIX

Ships' data	Atlantic Dawn
Photo:	
Call sign:	PCUS
IMO nummer:	9671450
Flag state:	The Netherlands
Home port:	Urk
Ship type:	4400 DWT Heavy Lifter
Classification society:	Bureau Veritas
Year of construction:	2012
Shipyard:	Shipkits
Length overall (LOA):	111.7 m.
Length between perpendiculars (Lpp):	102.0 m.
Beam:	16.8 m.
Actual draught:	5.94 m.
Gross Tonnage:	5,460
Engines:	MAK 8M32C
Propulsion:	1 thruster, 1 bow thruster
Maximum propulsive power:	4,000 kW
Maximum speed:	17.0 knots
Ship's certificates:	All valid

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