Accident Investigation Board Norway

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REPORT ON INVESTIGATION OF MARINE ACCIDENT STAR ISMENE - LANT5, NANTONG CHINA 16 DECEMBER 2008

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Photo of ferry on the Norwegian west coast: Bente Amandussen

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NOTIFICATION OF THE ACCIDENT

The accident on board the *Star Ismene* occurred on 16 December 2008 at 13.30[1], while the ship lay at anchor in Nantong 'Inner Anchorage' (Yellow River), in China. During sounding of the tanks, two crew members lost consciousness. Both were admitted to hospital. The ship notified the Norwegian Maritime Directorate about the incident on 18 December. The Norwegian Maritime Directorate then notified the Accident Investigation Board Norway (AIBN) by email on the same day.

The AIBN contacted the shipping company on 19 December 2008 in order to obtain more information. At the same time, the AIBN contacted the Norwegian Centre for Maritime Medicine (NCMM) requesting a medical opinion on the degree of severity of the accident in relation to the term 'risk of significant personal injury'. On the basis of the NCMM's response, the AIBN informed the shipping company on 20 December 2008 and the Norwegian Maritime Directorate on 22 December 2008 that the AIBN would initiate an investigation pursuant to the provisions of the Norwegian Act of 24 June 1994 relating to shipping (the Maritime Code).

After unloading in Nantong, the *Star Ismene* sailed to Incheon, Korea, to pick up a new cargo. Two AIBN accident investigators travelled to Incheon and boarded the ship on 28 December 2008 and disembarked the following day. The investigators carried out technical investigations and interviewed the personnel involved.

Figure 1: The accident occurred while *the Star Ismene lay at anchor in Nantong.*

[1] All times referred to in this report are local times (UTC + 6 hours).

SUMMARY

The *Star Ismene* was in Nantong to offload copper concentrate. Before the unloading operation could commence, two cargo inspectors boarded the ship on 16 December 2009 in order to determine the volume of cargo. One cargo inspector accompanied the chief mate to read the foot marks, and the other accompanied the deck repairman and a shipping agent to sound the bunker and ballast tanks.

The sounding pipes are located in the enclosed spaces between the coamings of the large hatch covers, and these rooms are accessed from the passageway on the starboard side, via a landing in the shaft leading down to the cargo hold and, from there, up into the rooms between the hatch coamings. In order to gain access to the sounding pipes between holds 6 and 7, the deck repairman opened the hatch for accessing cargo hold 7, which held copper concentrate, and climbed down together with the shipping agent. Down on the landing, the deck repairman lost consciousness. The agent, however, managed to get out and ran to alert of the incident. Before a rescue operation was organised, the second mate went down to the area to help the deck repairman and was joined a short time later by the deck hand on watch. The second mate came back up, but the deck hand lost consciousness and fell across the deck repairman. Following the accident, readings were taken that showed an oxygen content of 5.9% on the landing where the accident occurred.

A short time later, the two crew members lying unconscious on the landing were rescued and brought to hospital for treatment. It is estimated that it took approximately 10 minutes from the time the deck repairman entered the shaft for accessing the cargo hold to the time both persons were brought back up. The deck hand who had spent the least time in the cargo hold, was discharged and returned to work the day after the incident. The deck repairman spent a longer time in hospital, but recovered and was declared 100% fit for work on 31 January 2009.

In accordance with its terms of reference, the AIBN has conducted a safety investigation to seek to determine the course of events and identify the underlying causes of the accident with a view to proposing safety recommendations to prevent the future recurrence of similar accidents.

Focusing on these matters, the AIBN has identified safety problems relating to the fact that the sounding pipes were accessed via the shaft leading down to the cargo hold combined with a lack of understanding on the part of the crew of the chemical properties of the cargo that resulted in a shortage of oxygen in the hold. The shipper had not issued any clear warning on this point.

Like some of the shipping company’s other ships, the *Star Ismene* is designed with a system for ventilation and dehumidification of the cargo holds, in which passageways and other rooms used by the crew also serve as ventilation ducts for the cargo holds. The crew regularly carry out sounding and other necessary operations in these rooms, both in connection with normal operations and in emergency situations. The complexity of this special design makes it very difficult to determine which spaces should be regarded as enclosed spaces at any given time. This has reduced the safety of the crew. In the Accident Investigation Board’s opinion, it would have been expedient if these risks of personal injury had been identified already in the design phase.

The operational challenges posed by the design were unsatisfactorily dealt with in the shipping company’s safety management system. In the AIBN's view, this contributed to the ship’s crew establishing a practice that was regarded as safe, but without clearly understanding which parts of the ship were to be regarded as enclosed spaces at any time.

The problem of the shipping company and the ship's safety management system not being sufficiently ship-specific was not identified in the supervisory authority's audits of the system.

The Accident Investigation Board proposes four safety recommendations in this report. These are addressed to the shipping company in relation to considering changes to the ship's design and in relation to establishing operational procedures for, among other things, operation of the ventilation system and entering enclosed spaces; to the authorities, represented by the Norwegian Maritime Directorate, in relation to considering the introduction of a requirement for risk analyses relating to the safety of the crew to be carried out already in the design phase; and to Det Norske Veritas in relation to identifying and implementing measures in connection with regulatory audits, that are more suited to the goal of ensuring that safety management systems are specifically adapted to the individual shipping companies and ships.

1. FACTUAL INFORMATION

1.1 Details of the ship and the accident

Ship's details

Name of ship	:	Star Ismene
Call sign	:	LANT5
IMO number	:	9182966
Owner / shipping company	:	Grieg International II AS, P.O. Box 513 Skøyen, NO-0214 Oslo
Responsible for ISM	:	Grieg Shipping Group AS, Org. No. 932350467, P.O. Box 781 Sentrum, NO-5807 Bergen
Type of ship	:	Open hatch bulk carrier
Year / place of build	:	2000 / Tamano, Japan
Country of registration / register	:	Norway / NIS
Classification society	:	DNV
Inspection authority for periodic inspection, incl. of ISM system	:	DNV
Home port	:	Bergen
Hull material	:	Steel
Length overall	:	198.00 metres
Breadth	:	31.00 metres
Gross tonnage	:	32,628
Engine power	:	10,525 KW / 14,300 BHP

Figure 2: Star Ismene. Photo: Knut Helge Schistad shipspotting.

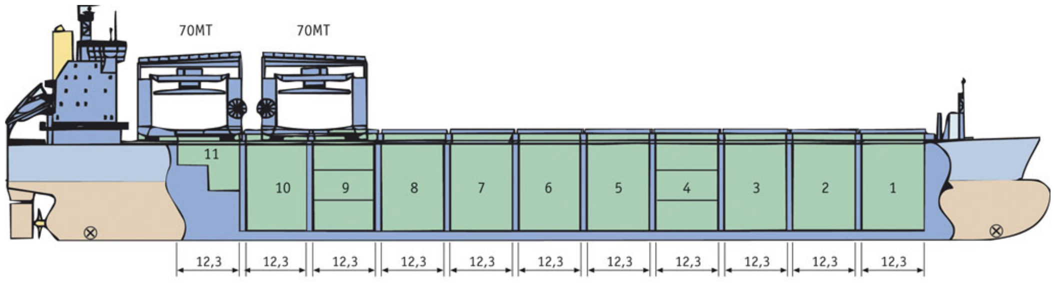

Figure 3: Illustration of Star Ismene in profile. Source: Grieg Shipping AS.

Details of the accident

Date and time	:	13.30 local time, 16 December 2008
Accident site	:	Nantong Inner Anchorage (Yellow River), China
Persons on board	:	21 crew members and 2 others[2]
Personal injuries/deaths	:	2 crew members injured
Damage to the ship	:	None

1.2 Course of events

The *Star Ismene* took on board timber products and copper concentrate in various ports in the area around Vancouver, Canada. In addition to timber, the ship carried a total of 23,641 tonnes of copper concentrate in bulk. Of the total copper concentrate cargo, 12,538 tonnes was stowed in cargo holds 3 and 7, and was to be unloaded in Nantong. The remaining 11,103 tonnes, which was stowed in holds 2 and 8, was to be unloaded in Qingdao. The copper concentrate in holds 3 and 7 had been taken on board on 7 to 9 November, while the concentrate in cargo holds 2 and 8 had been taken on board on 19 to 21 November. In connection with the loading of the copper concentrate, the crew received a material safety data sheet (MSDS) for the cargo and reviewed it in order to determine what risks the cargo could entail.

During the loading of wood pulp in Squamish, Canada on 17 November 2008, the local longshoremen could smell a strange odour emanating from the cargo of copper concentrate in holds 3 and 7. This resulted in them refusing to work on securing the wood pulp cargo in the adjacent cargo hold. In response to this, the chief mate, who was on board at the time, decided that the holds containing copper concentrate should be closed off. Cargo holds 3 and 7 were closed and secured with cable ties and labelled "DANGER OXYGEN DEPLETION NO ENTRY ' (see figure 5). Cargo holds 2 and 8 were closed and secured in the same manner when they were subsequently loaded with copper concentrate. Securing and labelling was carried out by the deck repairman, who, at the time of the accident, was the first person to reach the landing in the shaft leading down to cargo hold 7 and lose consciousness.

On 21 November 2008, the *Star Ismene* set sail from Vancouver across the Pacific for unloading in Korea and China.

Having unloaded timber products in Busan and Inchon, the *Star Ismene* arrived at Qingdao Berth at 16.12 local time on 13 December. The requisite port clearance was obtained, foot marks readings were taken and the bunker and ballast tanks were sounded

[2] Two cargo inspectors.

before commencing to unload the copper concentrate from cargo holds 2 and 8 at 18.50. The unloading was completed at 18.15 the following day. New readings of foot marks and sounding of tanks were carried out and the ship left the quay at 21.24 and set course for Nantong.

Following a brief stopover in Shanghai ‘Outer anchorage’ on the evening of 15 December, the *Star Ismene* arrived at Nantong ‘Inner anchorage’ at 10.06 on 16 December. The plan was to anchor up and transfer the copper concentrate from cargo holds 3 and 7 to some barges. Local authorities and agents arrived at 10.40 and the requisite port clearance was obtained.

At 13.00, two cargo inspectors, representing the recipient of the cargo, arrived to determine the cargo volumes so that the unloading operation could begin. This is done by calculating the ship’s displacement (total weight including cargo, bunkers, ballast water etc.) based on foot-mark readings, and then subtracting the ship’s light weight, plus the weight of bunkers, ballast water etc. The weight of the bunker fuel and ballast is determined by sounding the tanks in question. The cargo inspectors joined two separate teams. One cargo inspector accompanied the chief mate to read the foot marks, and the other accompanied the deck repairman to sound the bunker and ballast tanks. The team consisting of the deck repairman and one of the cargo inspectors was accompanied by an agent from Sinotrans's Jiangsu Nantong Branch, whose job it was to assist the cargo inspector, including communicating with the ship’s crew.

Shortly after 13.00 the work of sounding the ballast tanks started. The deck repairman and the Chinese cargo inspector started by sounding ballast tanks 6, entering from the starboard passageway below deck between cargo holds 9 and 10, and went on to sound tanks 5, between cargo holds 9 and 8. Cargo holds 2, 6, 8 and 9 had previously been fully unloaded and aired; see figure 4. The agent also took part in this work.

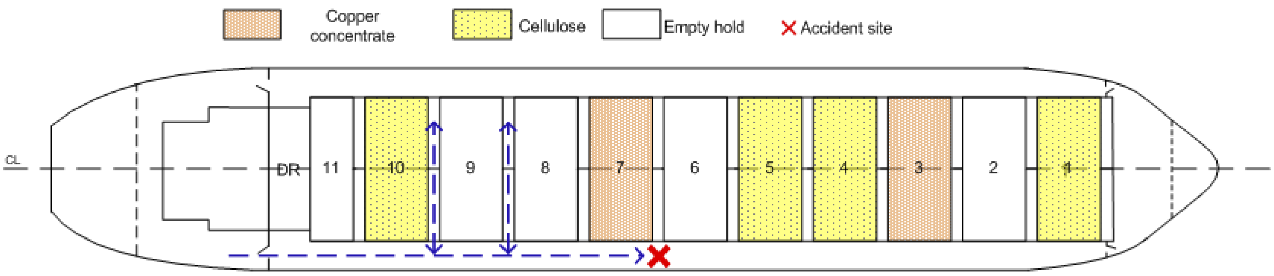

Figure 4: Cross-section of the deck with the passageways, seen from above. The sketch shows the distribution of cargo at the time of the accident. The route taken to sound the tanks on the day of the accident is marked in blue. Cargo holds 3 and 7 had been closed for 29 days.

When the deck repairman and the shipping agent[3] arrived in the area between cargo holds 6 and 7, the hatch providing access to the cargo hold was closed, and the cover was secured with cable ties and marked with 'DANGER OXYGEN DEPLETION NO ENTRY ', see figure 5.

[3] At this point, the cargo inspector had gone to the ballast control room to start calculating the amount of ballast.

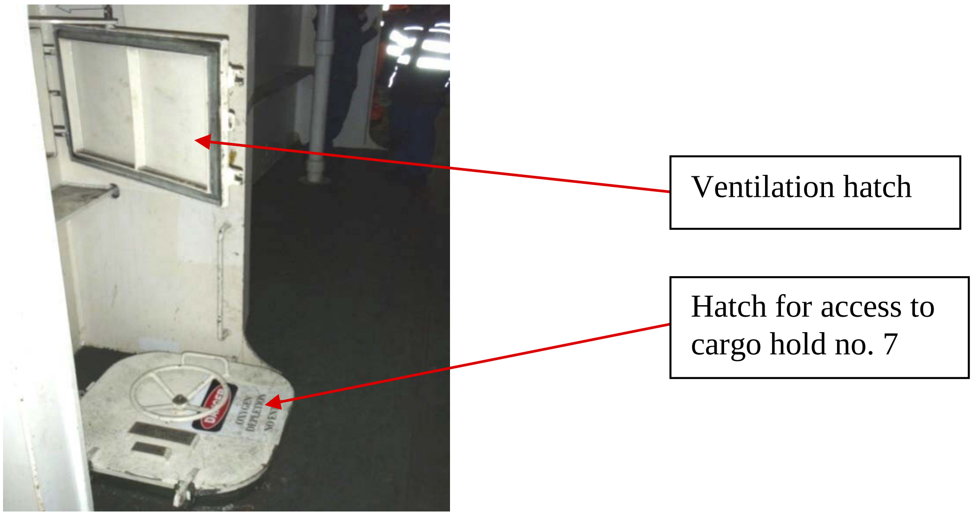

Figure 5: The hatch for access to cargo hold 7 and the ventilation hatch between holds 6 and 7.

The ventilation opening is often used to access the sounding pipes for the tanks, but because the deck repairman suffered from pain in his back and legs, he wanted to climb down through the hatch to the landing in the shaft used for accessing cargo hold 7, with the intention of climbing up into the room between the cargo hatches of holds 6 and 7, where the sounding pipes are located (figure 6). The ventilation opening has a smaller light opening than the hatch for accessing the cargo hold.

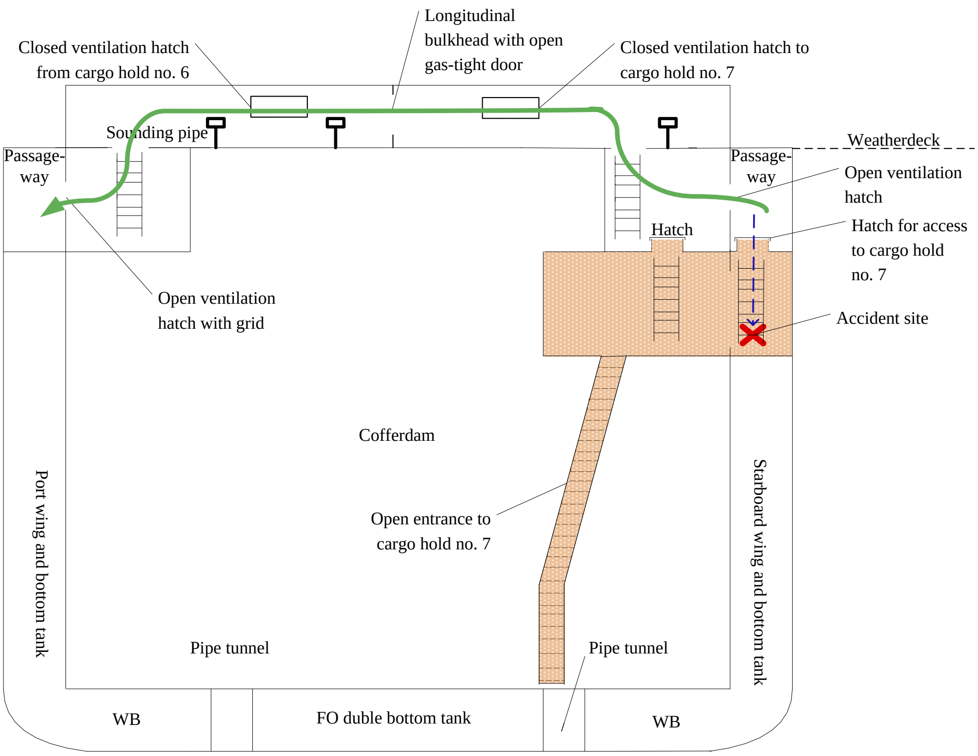

Figure 6: Sketch of cross-section of the ship between cargo hatches 6 and 7. The sketch shows which ventilation hatches, doors and access hatches are assumed to have been open and closed on the day of the accident. The area highlighted in brown shows that the atmosphere in the area where the accident occurred was the same as in cargo hold 7. Cargo hold 7 is closed off from the other spaces.

The deck repairman called the chief mate on the VHF radio. Due to problems with the radio connection, the chief mate was unable to hear what the deck repairman was enquiring about, but was under the impression that it had something to do with slings. While sounding was in progress, some of the other crew members were busy collecting slings that had previously been used in connection with the unloading of another cargo hold. The chief mate assumed that the enquiry related to this work and responded by saying that the deck repairman should not involve himself in the work with the slings, but should continue with the sounding.

The deck repairman opened the hatch for accessing the cargo hold and climbed down the ladder, followed by the Chinese agent. The agent noticed that there was something strange with the air and held his breath, but, nonetheless, he followed the deck repairman down to the landing in the shaft. After a short time, the deck repairman also noticed that something was wrong and started to climb back up towards the open hatch. The agent followed suit. The deck repairman lost consciousness just as he was about to get out of the shaft and fell back down onto the landing, three metres below. The agent managed to get out and made his way to the passageway guard and informed him of what had happened. In response, the passageway guard informed the chief mate that the deck repairman required assistance. The chief mate, as well as others who overheard the radio communication, understood this to mean that the deck repairman required routine assistance and not that the situation was critical.

Over the VHF radio, the chief mate instructed the deck hand on watch to assist the deck repairman. The deck hand, who was on the bridge at the time, headed for the starboard passageway in order to assist the deck repairman. The boatswain, who was below the poop deck at the time, overheard the conversation on the VHF frequency and, he too, proceeded to the starboard passageway with the intention of providing assistance to the deck repairman. The ship’s second mate, who was in the deck office with the chief mate at the time, also headed for the starboard passageway in order to provide assistance to the deck repairman, if required.

As the boatswain passed the access hatch to cargo hold number 7, he observed that the deck repairman was lying unconscious on the landing below. The agent and the ship's second mate arrived just after this. The second mate climbed down straight away to check the condition of the deck repairman, but found it difficult to stay on his feet and quickly reached the conclusion that there was something wrong down there. He became dizzy, but managed to climb up through the opening and made his way aft to get help. On his way aft along the passageway, he met the deck hand on watch, who was on his way forward. He intended to inform the deck hand that something was wrong, but believes that he failed to communicate this message because he was dizzy and felt unwell.

The deck hand arrived at the accident site and was instructed by the boatswain to climb down to the landing to attach a strap to the deck repairman. The boatswain had just witnessed the second mate climb down and come back up, and did not, therefore, suspect that there might be risks involved in climbing down. The deck hand climbed down to examine the deck repairman and to attach a lifting strap. He felt that there was something wrong and tried to climb back up again, but passed out, fell and ended up lying halfway across the deck repairman (see photo, figure 7). The boatswain now realised the danger of climbing down onto the landing and notified of the situation over the VHF radio.

Figure 7: Photo taken from the passageway on the starboard side looking down onto the landing through the access hatch for the cargo hold. Reconstruction of how the deck hand was found lying unconscious partially on top of the unconscious deck repairman.

The chief mate, who had overheard the boatswain notify of a critical situation over the VHF radio, arrived at the accident site carrying a smoke-diving apparatus, and accompanied by the junior third mate. The chief mate donned the smoke-diving apparatus and entered the room, but did not manage to bring the two unconscious men back up. A short time later, the second mate returned with another smoke-diving apparatus, donned it and climbed down onto the landing. By then more personnel had arrived and assisted the boatswain by pulling the two injured men out of the hold and laying them on the deck in the passageway. The deck hand was the first to be brought up, followed by the deck repairman. Both were breathing by themselves when they were brought up and were given oxygen from portable cylinders. They were carried aft towards the gangway and to the sick bay, where they received more treatment with oxygen. They were then transferred to the barge that was moored alongside and brought ashore to hospital in Nantong, all the while receiving oxygen treatment.

Based on a reconstruction of the chain of events, the AIBN estimates that approximately 10 minutes passed from the time when the deck repairman, who went first, climbed down to the landing in the shaft for accessing the cargo hold and until both persons were brought back up again.

The access hatch to hold number 7 was closed as soon as the two injured persons had been brought up into the passageway. The access hatch and the cargo hatch to hold number 7 remained closed for the rest of the day. About one hour after the accident occurred, the ship's crew gauged the atmosphere on the landing in the shaft for accessing cargo hold 7, where the accident occurred, using a multi-gas meter. The meter did not register hydrogen sulphide (H_2S), hydrocarbons (HC) or carbon monoxide (CO). The meter did however register an oxygen content of only 5.9%.

1.3 Extent of injuries

The deck hand who had spent the least time on the landing in the shaft for accessing cargo hold 7 was discharged from hospital and returned to work the day after the incident. The deck repairman was admitted to hospital for a longer period. He was declared to be well and reckoned to be 100% fit for work with no permanent impairment as from 31 January 2009.

1.4 Physiological effects of reduced oxygen levels in the atmosphere

In a normal ambient atmosphere the expected O_2 level would be around 20.9%, by volume. In general, O_2 deficiency leads to a loss of mental alertness and a distortion of judgment and performance. This happens within a relatively short period of time, without the person's knowledge and without prior warning.

Table 1 indicates the effect of O_2 deficient atmospheres on humans[4]. These values are approximate and can vary. Note that exposure to an atmosphere containing less than 18% of O_2 by volume poses a significant risk, and that O_2 concentrations of less than 11% pose a risk of death.

Table 1: Asphyxia – effect of O_2 concentration

O_2 (volume %)	**Effects and symptoms**
18 - 21	No discernible symptoms can be detected by the individual.
11 - 18	Reduction of physical and intellectual performance without the sufferer being aware.
8 - 11	Possibility of fainting within a very few minutes without prior warning. **Risk of death below 11 vol.%**.
6 - 8	Fainting occurs after short time. Resuscitation possible if carried out immediately.
0 - 6	Fainting almost immediate. Brain damage may occur, even if rescued.

1.5 Shipping company and fleet

The *Star Ismene* is owned by Grieg International II AS. Grieg International II AS is part of the Grieg Shipping Group with offices in Bergen and Oslo and branch offices in the USA, China and the Philippines. As of August 2010, the company operates a fleet of 26 'open hatch'[5] bulk carriers. Fourteen of these ships (classes H, I, J and K) have a design whereby the areas between the hatch coamings are enclosed. The company's ships were built between the mid-1980s and 2010. All of the company's ships are manned by Philippine crews. The company is certified under the International Safety Management (ISM) Code and had a valid Document of Compliance (DOC) at the time of the accident.

The shipping company has been forthcoming and has helped to facilitate the AIBN's safety investigation following the accident on board.

1.6 The ship

The *Star Ismene* was built by Mitsui Engineering & Shipbuilding, Tamano Works in Japan in 2000 and is 198.00 metres long overall. The ship has 11 cargo holds with a total storage space of 55,285 m^3, and a deadweight tonnage[6] of 46,428 tonnes. Between each

[4] Source: University of Oxford http://www.admin.ox.ac.uk/safety/s403.shtml. Norwegian translation performed by the AIBN.
[5] Open hatch bulk carrier Ships with rectangular cargo holds where the hatchways are the same size as the cargo holds.
[6] Describes the ship's cargo capacity.

cargo hold are cofferdams of 1.20 metres in length. Above the cofferdams, between the hatch coamings, are enclosed spaces (rooms) that can be opened towards both the cargo holds and the passageways. These rooms also make up part of the ship's mechanical system for dehumidification and ventilation of the cargo holds.

The *Star Ismene* mainly carries forestry products from North America and Canada to the East, and various types of general cargo on the return voyage. The ship also carries various cargoes in bulk.

All the ship's certificates as required by the authorities, as well as its class certificate, were valid at the time of the accident. Among other certificates, the ship had a valid Certificate of Compliance for the carriage of dangerous goods, issued by the classification society DNV. The ship also had a valid "Statement of Compliance for the carriage of Solid Bulk Cargoes of Group A[7] and B[8]".

1.7 Alongship passageways

The ship is designed with enclosed passageways on the starboard and port sides below the weather deck. The passageways run from the forecastle to the accommodation area aft. There are watertight doors in both the forward and aft ends of the passageways. The doors are marked 'DANGER CONFINED SPACE, HAZARDOUS ATMOSPHERE', cf. figure 8.

Figure 8: Photo of the door at the aft end of the passageway on the starboard side.

In the deck inside the passageways, there are openings with hatch covers for accessing the cargo holds. There are also openings with hatch covers in the bulkhead, for ventilation/dehumidification of the cargo. Signs posted on or next to the hatch covers show the type of hatch, i.e. what the hatch provides access to. There are no permanent warning signs. Temporary signs with the text 'DANGER, OXYGEN DEPLETION, NO ENTRY' are attached to the hatch covers for accessing the cargo holds when this is required.

[7] Cargoes that may liquefy when the moisture content exceeds the transportable moisture limit.
[8] Cargoes that do not liquefy (group A) and cargoes that are not hazardous (group B).

The AIBN has been informed that the starboard passageway is often used by the crew when the ship is at sea and in port.

Figure 9: Enclosed passageway on the starboard side looking forward from the aft end. An access hatch for one of the cargo holds can be seen at the bottom left of the photo.

1.8 Arrangement for ventilation and dehumidification of the cargo holds

The passageways on both sides form part of the ship's arrangement for ventilation and dehumidification of the cargo holds. In front of the superstructure, fans have been installed to dehumidify the cargo. Dry air from this dehumidifier room is fed into the aft end of the passageway on the starboard side, see figure 10.

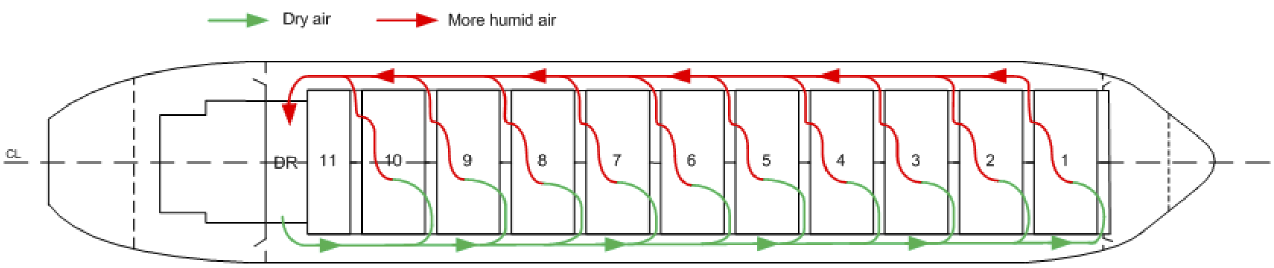

Figure 10: Plan showing the schematic arrangement for dehumidifying the cargo. Cross-section of the deck with passageways, seen from above. DR: dehumidification room/fan room.

The air is pushed through the ventilation hatches in the passageway bulkhead and into the rooms on the inside of the passageway, from where it moves up into the spaces above the deck between the coamings of the large cargo hatches. From there, the dry air is pushed down to the bottom at the forward end of the cargo hold aft of each space. The humid air is pushed back up at the aft end of the cargo hold, and moves up into the port side of the space between the hatch coamings. From there, the air moves back down below deck and out into the passageway on the port side. Figures 11 and 12 show a simplified and schematic presentation of how the arrangement for the dehumidification of the cargo holds works.

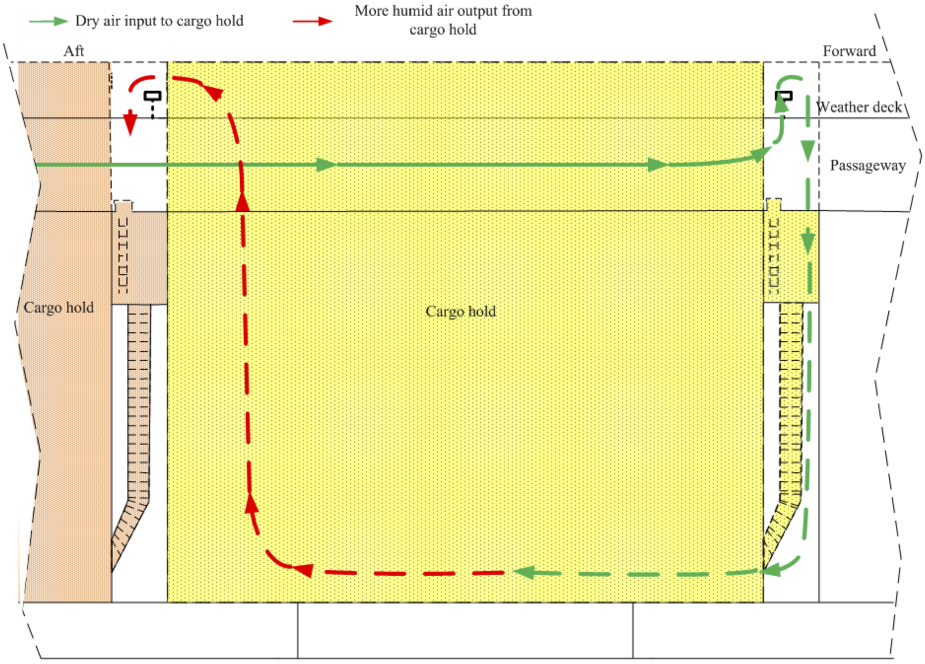

Figure 11: Profile drawing showing the schematic arrangement for dehumidifying the cargo. Seen from the starboard side. Dry air is fed into the starboard passageway (green, solid line) and then into the rooms between the hatch coamings.

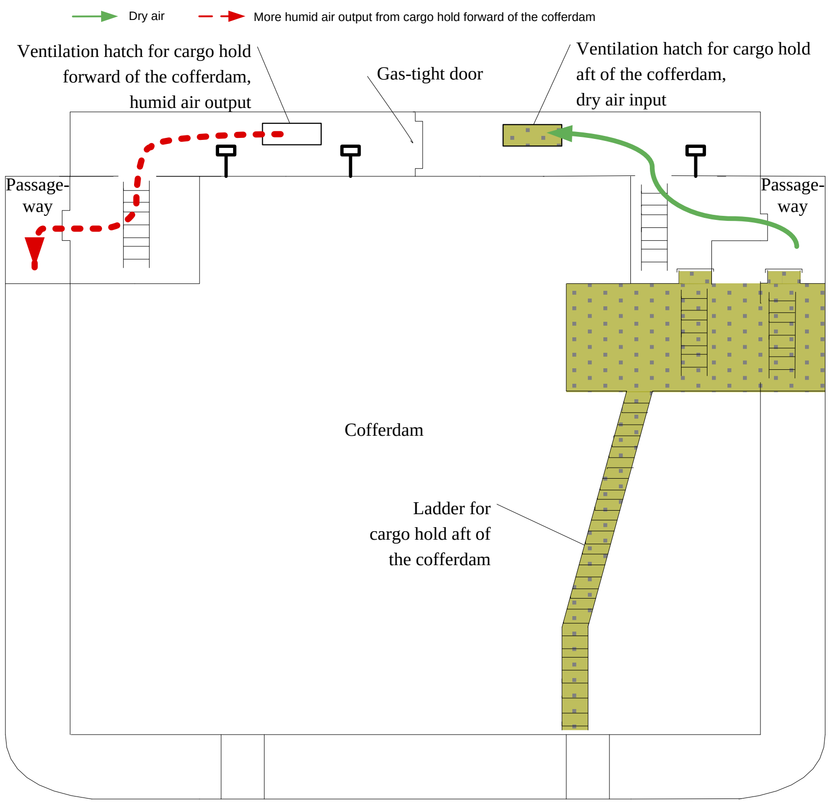

Figure 12: Simplified and schematic cross-section between two cargo holds showing the arrangement for dehumidifying the cargo hold. The dry air is pushed down from the space at the forward end of the cargo hold. The humid air moves back up at the aft end of the cargo hold.

When the ship has a cargo of dangerous goods, it is required to seal the cargo hold; this is done by closing the access hatches from the passageway and the ventilation hatch on the air inlet to the cargo hold. The ventilation hatch for the air outlet at the aft end of the cargo hold must also be closed.

The system was installed when the ship was new. The shipping company has carried out risk assessments of the system to ascertain the risk of damage to the cargo, but not the risk of harmful effects relating to health, safety and the environment. The system has been approved by DNV without the imposition of any special conditions/requirements for the operation of the system.

After the accident, the AIBN has attempted to establish whether the ventilation and dehumidification system was in operation before and when the accident occurred on 16 December 2008. According to the information received by the AIBN from the shipping company, this information is not logged on board, despite the requirements in the safety management system's procedures to do so. However, the AIBN has been informed that the dehumidification machinery was probably in operation, but that the circulation fans were probably not.

1.9 Arrangement for manual sounding of tanks

In addition to the *Star Ismene*'s automatic tank sounding system, the ship has sounding pipes for manual sounding of all bottom tanks. These sounding pipes are located in the spaces between the coamings of the large cargo hatches. Figure 13 shows the sounding pipe for water ballast tank 4 on the starboard side.

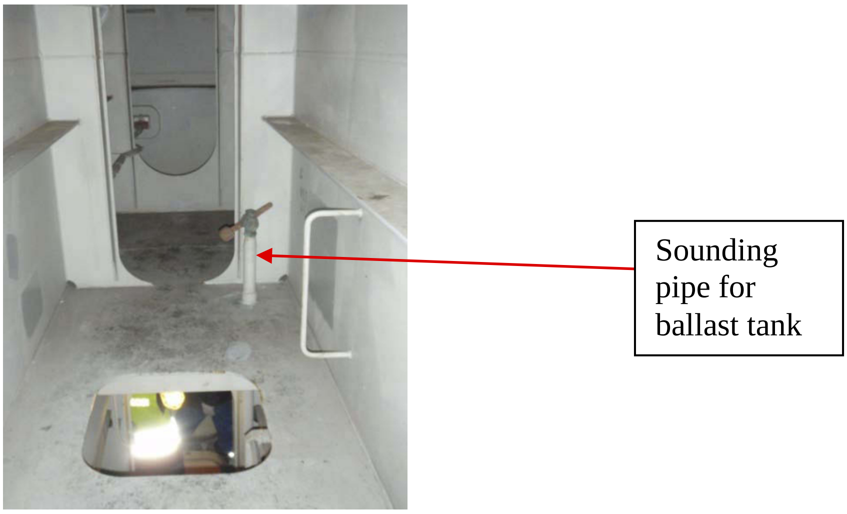

Figure 13: Space between the hatch coamings for cargo holds 6 and 7.

The only possible access to the spaces between the hatches is via the passageway below the main deck on the starboard side. Hatches in the deck inside the passageway (see figure 5) lead down to a landing in each of the shafts for accessing the cargo holds.

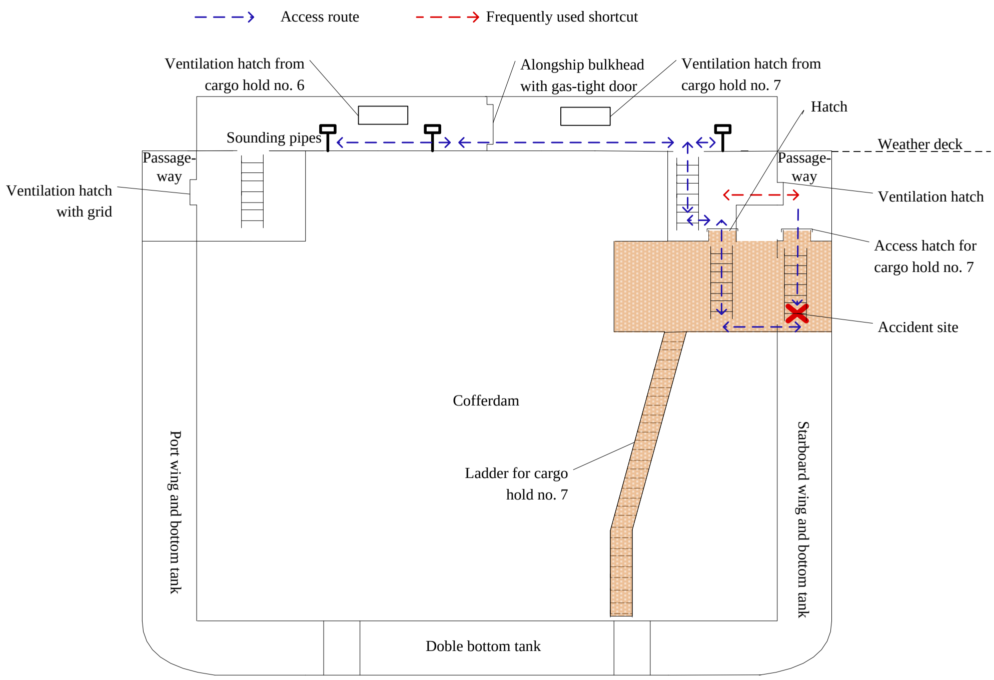

Figure 14: Cross section of the rooms between the cargo holds showing how the sounding pipes and ventilation hatches could be accessed.

A ladder near the ship's centreline leads back up to the room on the inside of and on the same level as the passageway. From here, a second ladder leads up to the space between the cargo holds, where the sounding pipes are located; see figure 14. The two crew members who lost consciousness were found on the floor in the room below the passageway on the starboard side, marked with a red X.

It is also possible to access the room on the inside of the passageway through the ventilation hatches in the passageway bulkhead. Since neither the outside nor the inside of the bulkhead have any step arrangement, the hatches are not easily accessible for passing through. The ventilation hatches are also relatively small, measuring only 616 x 418 mm. This is less than the standard for access hatches. Nevertheless, as far as the AIBN has been able to ascertain, the ventilation hatches are often used to access the spaces between the cargo hatches.

1.10 The shipping company's safety management system

The shipping company has established a safety management system [9] in accordance with IMO`s ISM Code[10] and the Safety Management Regulations[11]. The safety system is generic, and the procedures apply to all the shipping company's ships. A three-level system has been established:

Level 1 consists of overall objectives and strategies, and descriptions of the organisation and its activities.

Level 2 consists of overall procedures for the company's activities.

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[9] Safety, Security and Quality Management System (SSQM System).
[10] International Safety Management Code, IMO Res. A 741 (18).
[11] Regulations No 306 of 14 March 2008 relating to safety management systems on Norwegian ships and mobile facilities.

Among other things, level 3 consists of vessel-specific operating manuals, instructions, (including job instructions for the shipboard crew), HSE documentation, training and drill manuals and various checklists.

The shipping company and ship's master are responsible for continually improving the safety management system, among other things by conducting internal safety audits to verify that activities relating to safety and the prevention of pollution are in accordance with the safety management system. Reports (SAFIR)[12] about accidents, near-accidents, non-conformities and hazardous situations are important elements in the shipping company's efforts to improve matters relating to health, safety and the environment. Such reports are sent from the ships to the shipping company's offices for further analysis. The shipping company assesses the need to take action and whether information about the incident should be disseminated to the shipping company's other ships.

The shipping company conducts regular reviews of the safety management system (management reviews). The ship's master is responsible for reviewing the safety system on board, and for reporting any deficiencies to the onshore management (master's review). One of the main objectives of this latter review is to ensure that rules and procedures and the manner in which the work is actually carried out on board are in compliance with each other.

Matters relating to health, safety and the environment on board are attended to through the elected safety representatives. There are monthly meetings of the so-called Protection and Environment Committee[13] in which the ship's management and safety representatives come together to discuss and follow up accidents and near-accidents, including incidents from the shipping company's other ships, reports of which have been received via the onshore organisation. Monthly crew meeting are held at which safety issues can be raised by everybody on board. The ship's officers also hold weekly meetings, among other things to follow up matters relating to health, safety and the environment. The ship reports annually on the Protection and Environment Committee's work. The work and experience of the PEC meetings are also important aids in connection with the master's review of the safety management system.

1.10.1 Procedures for sounding tanks

Pursuant to the procedure 'Sounding of Tanks, Bilges and Void Spaces/Stripping of Hold Bilges'[14] the tanks are to be sounded daily and the data logged in a 'Sounding Book'. The purpose of this is to monitor any changes that may occur, for example as a result of leakages. The chief mate is responsible for ensuring that this is done. Pursuant to his job description, the deck repairman shall assist the chief mate in this work[15]. The safety management system does not contain any detailed procedures for how the tanks should be sounded.

However, alarms have been installed in the bilges on the *Star Ismene*, and according to the above-mentioned procedure, the instructions on daily manual sounding are therefore not applicable. On ships with alarm systems, the alarm panels, which are localised in the ballast control room, are checked on a daily basis and the results are entered in the deck

[12] Safety Improvement Report.
[13] PEC meetings.
[14] Level 3: Manuals/04 – Shipboard Work Instructions Manual/10 – Deck Operations.
[15] Level 3: Manuals/03 – Job Description Manual/02 – Vessel Organisation.

log. Readings from remote sounding of the ballast tanks can also be taken in the ballast control room.

1.10.2 Procedures for entering enclosed spaces

The procedure 'Health, Safety and Environmental Precautions'[16] states that all enclosed spaces that are not regularly ventilated, such as cargo holds, ballast tanks and cofferdams, can contain toxic or combustible gases or insufficient oxygen to be occupied by people. There is no specific mention of the arrangement for ventilation and dehumidification of the cargo holds or of the passageways on either side.

It is also evident that a shortage of oxygen may occur in holds where oxygen is absorbed or consumed by the cargo. In that connection, appropriate precautions are prescribed. Among other things, the procedure includes requirements for good ventilation and measurement of the oxygen content prior to any person entering such spaces. Separate checklists have also been prepared for use when entering such enclosed spaces[17].

1.10.3 Procedures for shipping bulk cargoes

General instructions for taking on board/carriage of bulk cargo are included in 'Instruction when loading Bulk Cargo'[18]. The instructions refer to the provisions of IMO's BC Code[19]. Among other things, the procedure stresses the importance of the ship's crew being in no doubt about the physical and chemical properties of the cargo.

The management system also includes a checklist 'Deck Checklist prior to loading Bulk Cargo'[20], for shipping bulk cargoes. Among other things, the checklist requests confirmation that the Material Safety Data Sheets (MSDSs) have been received from the shipper, and that the precautions prescribed in the MSDS for the bulk cargo in question have been understood and are complied with.

1.10.4 Procedures for dehumidification of the cargo holds

In the ship's Cargo Handling Manual, the need for ventilation and dehumidification, as well as the use of the ventilation and dehumidifier system, are described in general terms. Among other things, the system is required to be shut down when the cargo hatches are open, and it must be ensured that the ventilation hatches are not blocked by cargo. For further details, the Cargo Handling Manual refers to the instructions of the system supplier. The latter provide a technical description of the structure of the system and how it works.

With respect to the dehumidifier system, neither the shipping company's safety management system nor the supplier's user manual provides any detailed instructions concerning, for example, when the ventilation hatches and doors should be opened and closed and the impact that this has on safety.

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[16] Level 3: Manuals/04 – Shipboard Work Instructions Manual/14 – Health – Safety and Environmental Protection.
[17] Level 3: Manuals/04 – Shipboard Work Instructions Manual/17 – Checklists/Logs/Work Permits/Records.
[18] Level 3: Manuals/04 – Shipboard Work Instructions Manual/12 – Deck Operations.
[19] Code of Safe Practice for Solid Bulk Cargoes.
[20] Level 3: Manuals/04 – Shipboard Work Instructions Manual/17 – Checklists/Logs/Work Permits/Records.

It is evident from the chief mate's job instructions[21] that the chief mate is responsible for ventilation and dehumidification of the cargo holds and for log-keeping in that connection.

1.10.5 Procedures relating to training and practice/drills

Pursuant to the management system[22] new recruits shall complete a familiarisation programme in order to get to know the ship and its equipment. In that connection, all officers are given an introduction to the dehumidifier system on board, and all deck crew are given an introduction to the arrangement for sounding the bottom tanks. Other training on board is mainly in the form of practical on-the-job training whereby inexperienced crew learn from the more experienced crew.

In addition to the familiarisation programme and the practical on-the-job training, there are regular drills on board. These drills cover all shipboard emergency procedures, including firefighting and rescue operations, and training in the use of shipboard equipment. The training programmes include rescue of personnel from enclosed spaces.

1.11 The crew

The *Star Ismene* has a crew of 21 seafarers from the Philippines. The deck crew consists of the master, four deck officers and seven deck hands, including one cadet. The engine department consists of the chief engineer, three engine officers, one electrician and two engine crew. In addition to the above, there is a catering department consisting of two persons. Work in the deck department is generally based on a three-watch system when the ship is at sea, in which the crew work 4-hour watches followed by 8-hour free periods twice every 24 hours. Each watch is manned by one officer of the watch (navigator) and one deck hand. Other deck crew work as daymen. In port, the sea watches are discontinued and replaced by a system of 6-hour watches followed by 6-hour free periods. Each watch is manned by one deck officer and two deck hands. The remaining deck crew work as daymen and assist during loading and unloading operations as required. The ship is classified to operate with an unmanned engine room (E0), which means that the engine crew working as daymen are organised in E0 watches when the engine room is unmanned.

The shipping company has a low crew turnover rate and many crew members have sailed for the shipping company for a long time, and the general level of experience is therefore high.

As far as the two injured crew members are concerned, both the deck repairman and the deck hand have been with Grieg Shipping for many years and know the shipping company well. This means that they also have extensive experience of this type of ship.

1.12 Physical and chemical properties of the cargo, classification and shipper's responsibility

The cargo had been taken on board in various ports in the area around Vancouver in Canada and consisted of timber products and copper concentrate. The cargo was to be unloaded in China and Korea.

[21] Level 3: Manuals/03 – Job Description Manual/02 – Vessel Organisation.
[22] Level 3: Manuals/04 – Shipboard Work Instructions Manual/12 – Deck Operations.

The copper concentrate in holds 3 and 7 and holds 2 and 8 was of the same type. Both lots were taken on board in Vancouver Washington Berth No 7, but they were sent by different shippers.

1.12.1 Physical properties of copper concentrate

Pursuant to the IMSBC Code[23], copper concentrate, which is one of a group of mineral concentrates, liquefies when the moisture content of the concentrate exceeds a certain limit. Mineral concentrates are not flammable or involve little fire risk. It is also clear from the Code that mineral concentrates can cause the bilge filters to disintegrate, and that continous carriage of this type of cargo may have detrimental structural effects over a long period of time.

1.12.2 Chemical properties of copper concentrate

The IMSBC Code does not contain any information about any special chemical properties of copper concentrate. However, following the accident, the AIBN ordered an analysis of the copper concentrate in question from an independent laboratory[24]. The following conclusion was drawn in the laboratory's report following the analysis:

> *No sulphur-bearing gas species was detected being emitted from the sample. The only gas species detected originating from the powderised copper ore concentrate was CO_2. This gas is released from the sample when dry, when subjected to neutral water, basic water, and in particular high gas contents, i.e. 10% CO_2, was released when exposed to acids. The known accessory presence of the carbonates Calcite and Ankerite are not likely the source of the emitted CO_2, particularly not at neutral or basic conditions. Hence the release of CO_2 at all measured lab conditions is indicative of presence of a foreign reactive substance high in Ca, Mg, K and Na with poor crystallinity since almost all XRD peaks could be attributed to phases known to occur in the concentrate. Chips of paint and metal turnings found in the concentrate are not the source for the released alkalies[25]. The insignificant change in theoretical versus measured density points towards that only minor quantity of foreign matter may have been added at some point, unless the additive had similar (heavy) density as the concentrate, which is doubtful.*

Carbon dioxide (CO_2) is an invisible and odourless gas. It is heavier than air and is not in itself toxic.

1.12.3 Classification and shipper's responsibility for providing information about any hazards associated with the carriage of the cargo

Pursuant to the IMSBC Code, the shipper shall provide the ship with relevant information about the cargo before the cargo is taken on board, so that necessary precautions can be taken to ensure safe carriage. In that connection, a local firm[26] issued certificates on behalf of the shipper which show the permitted moisture limit for the carriage of copper concentrate, and certificates that show the actual moisture content of the copper concentrate that was to be taken on board the *Star Ismene.* According to these certificates,

[23] International Maritime Solid Bulk Cargoes Code.
[24] Institute for Energy Technology, Kjeller.
[25] Alkalies are basic hydroxides which are soluble in water and neutralise acids by forming salts.
[26] Seaport Marine Surveys, INC., Vancouver.

the permitted moisture limit for carriage was 11.38%, while the average measured moisture content was 6.48%.

The IMSBC Code also requires that any dangerous goods to be shipped in bulk shall have been classified, and that, if applicable, the information supplied by the shipper shall include the UN number contained in the IMDG Code[27].

In this case, the ship had been provided with the same Material Safety Data Sheet (MSDS) for the two shipments of copper concentrate. The transport information contained in the MSDS shows that the shipper had classified the copper concentrate as an 'Environmentally Hazardous Substance' with UN number 3077 with danger class 9. An 'Environmentally Hazardous Substance' is a substance hazardous to the aquatic environment and marine life forms.

Substances with UN number 3077 are a miscellaneous class of substances not covered by the definitions related to the other classes. Since this class can include many different substances, the IMDG Code can obviously not define necessary precautions to take in connection with the carriage. Hence the code[28] requires that each individual substance with UN number 3077 be examined in order to determine any hazards associated with its carriage. Such examinations shall be carried out by the shipper or by the relevant competent authority where this is specified in the code.

The transport information in the MSDS issued by the shipper in the present case did not make it clear that the copper concentrate consumes oxygen and emits CO_2. The chapter on (chemical) stability and reactivity states that the copper concentrate is non-corrosive under normal conditions, but that oxidation may occur at high temperatures and under other special conditions.

1.13 Previous accidents and incidents

According to the shipping company, one serious incident has previously been registered relating to the atmosphere in the cargo holds on board one of its other ships[29]. The incident occurred on 29 March 2005 and involved three crew members who were present in cargo hold 6. They experienced sudden breathing problems and had to evacuate the hold. Two of the crew members recovered after half an hour. The third crew member suffered more serious problems, including that his body temperature rose to 42 degrees Celsius, and it took almost three hours before he felt restituted.

According to the shipping company's investigation of the incident, it was caused by the presence of toxic gas in cargo hold 9. The lights in cargo hold 9 had not been switched off, and hence they ignited the bulk cargo, which consisted of wood pellets. The smouldering fire which developed in cargo hold 9 emitted toxic gases which spread to other cargo holds.

Further investigations by the shipping company showed that the cargo holds were not gas-tight on any of its ships and that gas could be transported from one cargo hold to another, particularly when the dehumidifier was in operation. Fixed procedures were

[27] International Maritime Dangerous Goods Code.
[28] IMDG Code Chapter 3.1 No 3.1.1.2.
[29] The *Star Herdla* – LAVD4.

therefore introduced for conducting air quality inspections in the cargo holds throughout the voyage on the shipping company's ships when carrying this kind of cargo.

1.14 Current rules and regulations

1.14.1 Overriding requirements for the design, construction and fitting out of ships

Pursuant to the Ship Safety and Security Act section 9[30], ships shall be designed, built and fitted out so as to adequately safeguard human life and health, the environment and material assets, having regard to the ship's intended use and trade area. The Ministry issues regulations relating to how ships should be designed, built and fitted out in order to meet the above requirements.

Section 6 of the Act states that the shipping company has an overall duty to ensure that the ship is built and operated in accordance with the rules issued pursuant to the Act, including observance of rules and regulations by the ship's master and others who work on board.

1.14.2 Requirements for sounding pipes

Pursuant to Shipbuilding Regulations section 10[31], the dimensioning and design of the hull, watertight bulkheads with closing devices for bulkhead openings, superstructures, deck houses, rudders, mooring equipment etc. in classified ships shall meet the requirements of the classification society relating to building materials, size, type and area of application.

Pursuant to Det Norske Veritas' rules for the classification of steel ships Part 4, Chapter 1, Section 4, K500, all tanks, cofferdams and pipe tunnels shall be equipped with sounding pipes or other approved means of checking liquid levels. Spaces that are not always accessible shall be equipped with sounding pipes. The sounding pipes shall be easy to access at all times and shall be labelled. The sounding pipes shall normally extend as far as to the bulkhead deck. Sounding pipes for fuel oil tanks, lube oil tanks and other tanks containing combustible liquids, and that could be exposed to pressure increases, shall, in principle, extend to the free atmosphere above. However, there are some exceptions to this rule.

An arrangement for remote sounding can replace manual sounding pipes provided that the system is of an approved type. Two independent signal lines shall be established for tanks that are not accessible at all times. It must be possible to connect both lines to the remote sounding panel. A single signal line can be accepted for tanks equipped with alternative sounding arrangements (emergency sounding of tanks). When the alternative sounding arrangement is a sounding pipe, Det Norske Veritas does not make easy accessibility a requirement. In other words, access to such sounding pipes through, for example, an access through a manhole secured by closely spaced bolts which have to be removed, is acceptable.

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[30] Act No 9 of 16 February 2007 relating to ship safety .
[31] Regulations No 695 of 15 September 1992 concerning the building of passenger ships, cargo ships and barges.

1.14.3 Requirements for cargo hold ventilation

Both the Building Regulations and the Safety Regulations[32] include provisions relating to the ventilation of cargo holds. However, the provisions of the Safety Regulations only apply to cargo holds in which machinery is used that is operated by combustion engines (motor vehicles etc.). The Building Regulations have more general application and refer to ILO Convention number 152[33], but the provisions of the ILO Convention have the same limitations as those of the Safety Regulations.

The Regulations relating to the carriage of dangerous goods also contain provisions on ventilation of cargo holds. Pursuant to section 6, ships built after 1 July 2002 shall comply with the provisions of Rule II-2/19 in SOLAS 2004. Correspondingly, ships built after 1 September 1984, but before 1 July 2002, shall comply with the provisions of Rule II-2/54 in SOLAS 2001. Since, the *Star Ismene* was built in 2000 and approved for carrying dangerous goods, the latter provisions are applicable. However, as far as ventilation is concerned, the requirements are identical in these two editions of SOLAS:

- Adequate mechanical ventilation shall be provided in enclosed cargo spaces. The arrangement shall be such as to provide for at least six air changes per hour in the cargo space, based on an empty cargo space, and for removal of vapours from the upper and the lower parts of the cargo space, as appropriate.

- The fans shall be such as to avoid the possibility of ignition of flammable gas/air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

- Natural ventilation shall be provided in enclosed cargo spaces intended for the carriage of solid dangerous goods in bulk, where there is no provision for mechanical ventilation.

The above requirement for mechanical ventilation is applicable according to the type of goods carried. The requirement is not applicable in the case of dangerous goods in class 9.

1.14.4 Requirements relating to control of gas hazards etc.

Requirements for control of gas hazards etc. are provided for in the Safety Regulations. Before persons without approved breathing equipment enter tanks, confined, enclosed spaces, tunnels or similar where gas may be present or where there may be a shortage of oxygen, the Regulations require that measurements of the air inside such spaces is carried out as necessary to ensure that entry is not hazardous. Measurements shall be taken at various levels and repeatedly if required.

The Regulations also require the presence on board of at least one instrument for measuring hydrocarbons and at least one instrument for measuring the oxygen content of the air or to determine whether the air in the enclosed space contains toxic or hazardous gases. If any cargo is carried that requires the use of special measuring equipment to measure toxic, hazardous or explosive gas concentrations, such equipment shall be kept on board. The Regulations also require that those who carry out the measurements receive necessary training in the use of the equipment. Furthermore, the Regulations

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[32] Regulations No 507 of 15 June 87 concerning safety measures etc. on board passenger ships, cargo ships and barges.
[33] C 152 Occupational Safety and Health (Dock Work) Convention, 1979.

require that all doors, hatches, hatch covers etc. leading to spaces with a gas hazard or in which there may be a shortage of oxygen, shall be clearly marked with a sign or adhesive plate that warns of the danger of poisoning and/or oxygen deficiency that a person may suffer on entering the space.

On 27 November 1997, after many accidents in connection with entering enclosed spaces, IMO adopted resolution ResA.864(20) Recommendations for entering enclosed spaces aboard ships. Pursuant to that resolution, which is enclosed as Annex 3, the carriage of various types of goods in bulk can lead to a shortage of oxygen in cargo holds. However, copper concentrate is not mentioned among the examples of such goods.

The AIBN knows that international initiatives are being taken under the auspices of both MAIIF and IMO to reduce the number of accidents in connection with entering enclosed spaces.

1.14.5 Requirements for safety management

Requirements for safety management systems are regulated by the Safety Management Regulations[34]. Among other vessels, the Regulations apply to Norwegian cargo ships with a gross tonnage of 500 or more. Pursuant to section 2 of the Regulations, all shipping companies shall have a safety management system in place at all times that covers both the onshore organisation and each individual ship in accordance with the ISM Code.

1.14.6 Requirements for risk analyses

Matters relating to personal safety are regulated by the Working Environment Regulations[35]. For ships required to have safety management systems, the shipping company shall ensure that the requirements that follow from the Working Environment Regulations are complied with through the safety management system. The Regulations include the requirement that hazards on board be identified. When a hazard has been identified, the risk that it poses shall be assessed. Such risk assessments shall be carried out on a regular basis. The results of the risk assessments shall be documented in writing. If risks relating to the safety and health of employees are identified, necessary measures shall be implemented to remove or reduce such risks. The Working Environment Regulations apply to everybody working on board a Norwegian ship unless he or she only works on board while the ship is in port or only carries out inspections on board. The Regulations are designed to ensure that work and free periods on board are arranged and organised with due attention to the safety and physical and mental health of the employees.

1.14.7 Requirements relating to the carriage of goods in bulk

At the time of the accident, Norwegian provisions relating to the carriage of cargo included the Cargo Carriage Regulations[36] and the Dangerous Cargo Regulations [37]. The latter has since been replaced by a set of Regulations relating to the transport of

[34] Regulations No 306 of 14 March 2008 concerning safety management systems on board Norwegian ships and offshore mobile units.
[35] Regulations No 8 of 1 January 2005 concerning the working environment, health and safety of workers on board ships.
[36] Regulations No 785 of 29 June 2006 concerning the carriage of cargoes on cargo ships and barges.
[37] Regulations No 786 of 29 June 2006 concerning the carriage of dangerous cargoes on cargo ships and barges.

dangerous goods[38]. The former is a general set of Regulations concerning the carriage of cargoes that may require special precautions because they represent a particular danger to the ship or the people on board. The latter set of Regulations concern the carriage of dangerous cargoes in the form of packaged goods or solid bulk, the carriage of liquid chemicals or gases in bulk, and the carriage of irradiated nuclear fuel, plutonium and high-level radioactive waste. Since the copper concentrate carried by the *Star Ismene* was classified by the shipper as dangerous goods under the IMDG Code, both sets of Regulations are applicable in the present case.

Pursuant to section 5 in the first set of regulations, the carriage of goods in bulk is subject to the provisions in SOLAS[39] Chapter VI, among others. SOLAS Chapter VI Part A contains general provisions and, among other things, requires the shipper to provide the ship with appropriate information to enable the master to take necessary precautions for proper stowage and safe carriage. For more details on the type of information referred to, the Convention refers to MSC/Circ.663, 'Form for cargo information'. Part B contains specific provisions relating to bulk cargoes that may liquefy when the humidity exceeds a certain limit, and to bulk cargoes that pose a risk because of their particular chemical properties. With respect to the former type of bulk cargoes, the Convention refers to the provisions of the IMSBC Code, and with respect to the latter type of cargoes, the Convention refers to the IMDG Code.

The Dangerous Cargo Regulations section 7 requires that all ships carrying dangerous goods shall keep a special list, consignment note or detailed stowage plan that informs about the dangerous goods carried and where such goods is located on board. In addition to the above, the Regulations require compliance with the provisions of SOLAS Chapter VII and the IMDG Code.

1.15 Approval and supervision/inspection by the authorities and the classification society

The shipping company chose to have the ship built with Det Norske Veritas class, which means that the ship had to be built in accordance with the applicable class rules at the time.

The *Star Ismene* is registered in the Norwegian International Ship Register (NIS). In the case of ships registered in NIS, the Norwegian authorities have delegated supervisory responsibilities to five recognised classification societies[40]. In order to ensure that this arrangement works as intended, the Norwegian Maritime Directorate carries out audits of the classification societies. Details surrounding the arrangement are described in agreements between the Norwegian Ministry of Trade and Industry and the respective classification societies.

In the case of the *Star Ismene* and the shipping company Grieg International II AS, the NIS Agreement means that DNV has approved the construction drawings and carried out initial inspection as well as all subsequent periodic inspections of the ship and shipboard equipment. On that basis, DNV has issued the relevant certificates relating to the ship and shipboard equipment. All the ship's certificates were issued in 2004 and 2005, and were

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[38] Regulations of No 1481 of 8 December 2009 nr. relating to the transport of dangerous goods on board Norwegian ships.

[39] International Convention for the Safety of Life at Sea, 1974, including the 1988 Protocol.

[40] Det Norske Veritas (DNV), American Bureau of Shipping (ABS), Lloyds, Germanischer Lloyd (GL) and Bureau Veritas (BV).

valid at the time of the accident. For example, the Cargo Ship Safety Construction Certificate (CCC) was issued on 7 October 2005, while the Cargo Ship Safety Equipment Certificate (CEC) was issued on 3 March 2005, and both were valid until 31 January 2010.

The *Star Ismene* has been issued with a ‘Statement of compliance for the carriage of Solid Bulk Cargoes of Group A and C’. DNV has also issued a ‘Certificate of Compliance for the Carriage of Dangerous Goods’, which is a confirmation that the ship meets the requirements of SOLAS 1974 (2001 edition) Chapter II Regulation 54. The certificate covers the carriage of both dangerous packaged goods and dangerous goods in bulk. It shows that the *Star Ismene* is not certified for the carriage of dangerous goods requiring mechanical ventilation.

On behalf of the Maritime Directorate, DNV is also the supervisory authority in relation to the shipping company and ship's safety management systems. This supervisory role means that DNV is responsible for verification and approval of the shipping company's safety management systems, both in the onshore organisation and on board the ships. The system-oriented supervisory activities are intended to ascertain whether instructions and work procedures have been drawn up in the requisite areas. The classification society shall check that the company and shipboard management operate in accordance with the approved safety management system. On this basis, DNV issued the ship with a Safety Management Certificate (SMC) on 3 January 2007, and a Document of Compliance (DOC) was issued to Grieg Shipping Group AS on 10 June 2007.

With respect to the carriage of bulk cargoes, both national and international systems have been established for unnotified inspections on board ships, and both the flag state and the port state have the authority to check that the shipper has provided information in the form of MSDSs in connection with unnotified inspections of ships carrying cargoes of this type. However, the authorities have limited possibility of checking whether the information provided by the shipper is correct.

2. ANALYSIS

2.1 Introduction

The accident occurred on the landing in the shaft for accessing hold 7 when a local shipping agent and one crew member were on their way up to the sounding pipes which are located in the space between the hatches for cargo holds 6 and 7 in order to sound the bottom tanks. Access to the sounding pipes is through the starboard passageway via the landing in the shaft for accessing hold 7 and back up to the space between the hatches.

The analysis discusses how much the crew knew about the atmosphere in the shaft where the accident occurred. The discussion is based on the chemical properties of the cargo in cargo hold 7. This is discussed in the light of the information provided by the shipper concerning the properties of the cargo and the conditions for safe transport.

Both the passageways and the spaces between the cargo hatches are part of the ventilation and dehumidification system for the cargo holds. Based on the above, the analysis considers the relevant design features relating to the accessibility of sounding pipes, ventilation hatches and other installations in the spaces between the cargo hatches.

The analysis goes on to consider what precautions the crew takes when entering the passageways and the spaces between the cargo hatches and how the associated risks are controlled in the ship's and the shipping company's safety management systems. The analysis endeavours to understand why the shaft in which the accident occurred was entered in non-compliance with the procedure for entering enclosed spaces.

Based on the fact that neither through the shipping company's design process when the ships of this design were designed and built, nor through the shipping company's safety management system or through the authorities or the classification society's supervisory activities and inspections were the risks involved in operating in the passageways and in the spaces between the cargo hatches identified, the AIBN finds it necessary to consider the rules and regulations relating to ship design as well as the supervisory authority's conduction of audits concerning the shipping company's safety management system.

Through its investigation of this accident, the AIBN has not found any need for a thorough analysis of the rules and regulations relating to the carriage of bulk cargoes, the location of sounding pipes, ventilation of cargo holds, entry into enclosed spaces and the authorities' supervisory activities in relation to the shipper in the light of this accident.

2.2 The atmosphere in the shaft where the accident occurred

When the accident occurred, cargo hold 7 held copper concentrate. The cargo hold had been closed for 29 days at the time of the accident. The accident occurred on the landing in the shaft for accessing this cargo hold.

The analysis of the cargo, which was ordered by the AIBN after the accident, concluded that the only gas type found to stem from the copper ore concentrate was CO_2. Based on the analysis of the concentrate, the AIBN consider it highly unlikely that there were any toxic gases in the cargo hold or on the landing for accessing the cargo hold at the time of the accident. However, it has been substantiated that the copper concentrate released CO_2. The AIBN assumes that the copper concentrate consumed oxygen in this process, thereby reducing the oxygen level in the hold. Since CO_2 is heavier than air, the CO_2 gas will also have displaced oxygen at the lower levels inside the hold. This is also in accordance with the measurements carried out by the ship's crew with the aid of a multi-gas meter approximately one hour after the accident. The meter did not register hydrogen sulphide (H_2S), hydrocarbons (HC) or carbon monoxide (CO), but showed an oxygen content of only 5.9%.

According to table 1, which shows the effects of various O_2 concentrations and related symptoms, there is a high risk of asphyxiation at O_2 concentrations below 6%. A person entering a space with such a low O_2 concentration will lose consciousness almost immediately, and brain damage can occur even if the person is rescued.

On this basis, the AIBN deems it probable that there was a shortage of oxygen at the time of the accident and that climbing down into the shaft for accessing cargo hold 7 was a very dangerous operation.

2.3 Information from the shipper concerning the physical properties of the copper concentrate

According to the information obtained from MSDS, the shipper had classified the copper concentrate as an Environmentally Hazardous Substance, with UN number 3077 in the

IMDG Code's Dangerous Goods List. This is a class of miscellaneous substances that are not covered by the definitions related to the other classes in the Code.

The shipping company's safety management system requires the ship's crew to familiarise themselves with the information contained in the MSDS provided by the shipper. The management system includes a checklist to be used in connection with the carriage of bulk cargoes. However, the shipper had not issued any clear warning that the copper concentrate could consume oxygen. Hence, the ship's crew were not aware of this property in the cargo or of the life-threatening danger of entering the cargo hold. The crew did therefore not take any special precautions when the copper concentrate was taken on board or in connection with its carriage.

During the loading of cellulose in Squamish, Canada on 17 November 2008, the local longshoremen experienced a strange odour from the cargo of copper concentrate in holds 3 and 7. This resulted in them refusing to work on securing the wood pulp cargo in the adjacent cargo hold.

The AIBN understands that the closing and securing of the hatches for descending into cargo holds 3 and 7 was probably done to satisfy the longshoremen rather than to prevent the crew from entering these holds at a later point in time.

The AIBN believes that it is very important in terms of safety that the crew be provided with reliable information about the cargo under carriage and its properties, so that relevant and necessary measures can be implemented to protect the crew and ensure the ship's safety. In the opinion of the AIBN, it is the shipper who must procure and communicate this information.

2.4 Design features relating to accessibility and occupation of passageways and spaces between the hatches that also serve as ventilation ducts

On the *Star Ismene* the sounding pipes for the bottom tanks are located in the spaces between the cargo hatches. The crew have to enter these spaces for several reasons. In addition to the manual sounding of the ballast and fuel tanks and bilge wells, the ventilation hatches are operated from there. These spaces also contain electrical installations in need of regular inspection. In an emergency situation, for example in connection with the ingress of water or the outbreak of a fire, it may be desirable to sound the tanks manually and close the ventilation hatches.

The *Star Ismene* is fitted out with an automatic tank sounding system, so that the contents of the tanks can be monitored from the ballast control room, but the AIBN knows that many cargo shippers and recipients refuse to accept remote sounding and demand manual sounding of the tanks in connection with loading and unloading. In that connection, standards and procedures have been drawn up under UN auspices for sounding tanks and reading draughts on ships that carry coal[41].

In the opinion of the AIBN, where there is a need for manual sounding of tanks or other manual work operations, for example the opening or closing of ventilation hatches, it must be possible to carry out such operations in a safe manner. Among other things, this means that the crew and others must be able to enter and occupy the spaces between the

[41] ECE/ENERGY/19 Code of Uniform Standard and Procedures for the Performance of draft surveys of Coal Cargoes.

cargo hatches without any risk of personal injury. Rapid access to these spaces may also be required in an emergency situation.

In order for the ventilation and dehumidification system to be effective in relation to the cargo holds, the spaces between the hatches are divided at the centreline by an alongship bulkhead with gas-tight doors. On the starboard side, gas tight hatch covers separate the spaces between the cargo hatches from the starboard passageway and the shafts for accessing the cargo holds. On the port side, gas-tight hatch covers separate these spaces from the port passageway, but the crew says that the hatches towards the port passageway are always left open.

In order to evaluate the ship's design in relation to the operations that have to be carried out in these spaces between the cargo hatches, it is expedient to analyse this by addressing two issues. The first issue concerns the fact that access to these spaces is via the cargo holds. The second issue is that the passageways and spaces between the cargo hatches are a part of the ventilation and dehumidification system for the cargo holds.

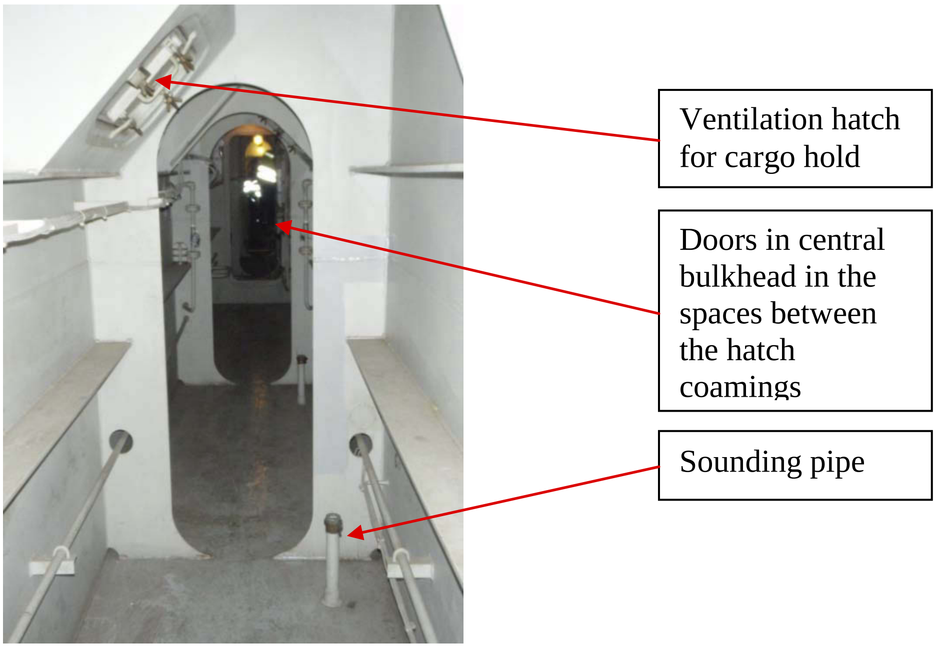

Figure 15: The photo shows the space between the hatch coamings for cargo holds 6 and 7, where the sounding pipes are located. The photo is taken from the port side looking towards starboard.

2.4.1 <u>Access via cargo hold</u>

Access to the spaces between the cargo hatches is through the passageway on the starboard side, via a landing in the shaft for accessing the cargo holds, up into a room on the inside of the passageway and up into the space between the hatches. It is also possible to proceed directly from the passageway to the room on the inside of it by climbing through a ventilation hatch in the bulkhead. However, the ventilation hatches are small and they are located at some height above the deck without there being any steps or ladders in place. According to the crew, this alternative is often used for accessing the spaces between the hatches.

Since the atmosphere in the cargo holds, and hence also in the shafts for accessing the cargo holds, could constitute a health hazard, the AIBN considers that a design of this type, whereby the crew must enter the shaft for accessing the cargo hold to gain access to the spaces between the hatches, is very unfortunate. In the AIBN's opinion, changes to the design should therefore be considered to remove the need to climb down onto the landing for accessing the cargo holds in order to gain access to the sounding pipes and other installations in the same spaces.

2.4.2 The passageway and the spaces between the cargo hatches as a part of the ventilation and dehumidification system for the cargo holds

As far as the remaining spaces providing access to, among other things, the sounding pipes are concerned, i.e. the starboard passageway, the rooms on the inside of it and the spaces between the hatch coamings, the air quality depends on several factors and, in the AIBN's opinion, it is in no way obvious when it is safe to enter these parts of the ship.

If the hatches for accessing the shafts leading down to the cargo holds are not closed, polluted air or air that is low in oxygen could spread from the cargo holds and, given insufficient air circulation, the atmosphere in these spaces could constitute a health hazard. In the AIBN's opinion, it is necessary to have clear procedures for ventilation of these spaces. The passageways on both sides, the rooms on the inside of the passageways and the spaces between the hatch covers are not arranged with natural ventilation. In the AIBN's opinion, a basic condition for regarding the above rooms as anything other than enclosed spaces must therefore be that the ventilation system is in operation.

Whether the rooms on the inside of the starboard passageway and the starboard and port-side spaces between the cargo hatches should be regarded as enclosed or open spaces will depend on a number of factors, including whether hatches and doors are open or closed, whether the ventilation system is in operation, whether or not the spaces have been ventilated for a sufficiently long time and the properties of the cargo. Different combinations of open and closed hatches could change the status of these rooms from open to enclosed spaces. The fact that one and the same space can be regarded as enclosed or open, demands considerable understanding on the part of the personnel who are to enter these spaces.

As a consequence of the complexity relating to the operation of the ventilation system and opening/closing of hatches and doors, the AIBN believes that there is a need for clear and explicit procedures and other measures to ensure that entry into these spaces takes place in a safe manner.

2.5 The crew's lack of awareness of the danger of entering the passageways and the spaces between the cargo hatches, and the shipping company's safety management system

The deck repairman, cargo inspector and shipping agent had entered the passageway on the starboard side and the shaft leading down to cargo holds 10 and 9 without experiencing any problems as a result. However, when the deck repairman and the shipping agent were to open the hatch for the access shaft to cargo hold 7 in order to gain access to the sounding pipes between cargo holds 6 and 7, they halted and contacted the chief mate. This was because the hatch was closed and secured with cable ties. They contacted the chief mate and probably understood that he gave clearance for the removal of the securing ties and opening the hatch. On this basis, they climbed down onto the landing without using the checklist for entering enclosed spaces.

The AIBN has observed that the crew often enter the passageway without using the safety checklist for entering enclosed spaces. This is despite the fact that the fore and aft entrances to the passageways are marked with a warning sign to show that these are enclosed spaces in which the atmosphere constitutes a health hazard.

The AIBN's interviews of the crew showed that there was uncertainty among the crew relating to which rooms/spaces on board the ship were to be regarded and treated as enclosed spaces. As far as the AIBN has been able to ascertain, the crew operate inside the rooms between the cargo hatches and in the passageways without considering which hatches and doors are open or whether the ventilation system is in operation or not and, hence, whether these passageways and spaces are to be regarded as enclosed or not.

The AIBN believes that the ship's crew did not understand which parts of the ship were to be regarded as enclosed spaces at any time; rather, based on the experience that rooms marked with danger signs could be safely entered, it had become normal practice among the crew to ignore danger signs on hatches and doors. This practice probably developed over a long period of time, so that it was not linked to any particular composition of crew. Apparently, this practice did not involve any problems until the present accident occurred. This can partially explain why the crew entered the shaft leading down to the cargo hold even though the hatch was marked with a danger sign and secured with cable ties. The further analysis seeks to understand this problem complex.

The shipping company has established procedures and checklists for entering enclosed spaces by means of its safety management system. The procedure 'Health, Safety and Environmental Precautions'[42] states that all enclosed spaces that are not regularly ventilated can contain toxic or combustible gases or too little oxygen to be occupied by people. Cargo holds, ballast tanks and cofferdams are mentioned as specific examples of enclosed spaces, while the passageways on both sides and the spaces between the hatches are not mentioned explicitly or defined as enclosed spaces. Nevertheless, the fore and aft entrances to the passageways are marked with 'DANGER CONFINED SPACE, HAZARDOUS ATMOSPHERE'.

In the AIBN's opinion, with respect to the procedure and checklist for entering enclosed spaces, the safety management system is characterised by the use of standard wording taken from recognised templates for such procedures and checklists. The special challenges on board the *Star Ismene* relating to the design and operation of the system for ventilation and dehumidification of the cargo holds are not mentioned at all. Nor is there any specific description of the challenges involved in deciding whether the passageways on both sides, the rooms on the inside of the passageways and the spaces between the hatches are to be regarded as open or enclosed spaces depending on which hatches are open and closed. This has contributed to the crew establishing a practice that has been regarded as safe, although there was a lack of understanding as to which parts of the ship were to be regarded as enclosed spaces at any time.

The AIBN believes that the above issues are a result of choices that were made when the ship was designed. Those choices appear to be based on the need to find practical and technical solutions to the need for ventilation and dehumidification of cargo. Little attention was paid to ensuring that the system could be physically operated in a manner that would ensure the safety of the crew.

[42] Level 3: Manuals/04 – Shipboard Work Instructions Manual/14 – Health – Safety and Environmental Protection.

Based on the above, the AIBN is of the opinion that risk analyses should be carried out of the operation of the ventilation and dehumidification system and operations involving entry into passageways and spaces. Based on the risk analyses, it should be considered whether the design needs to be changed or whether operative procedures and other measures can be established to ensure the safety of the crew.

Given that shipping companies and ships vary, and that the conditions therefore also vary, the ISM Code is based on general principles, functional requirements and objectives. Since the ISM Code was drawn up in this form, management systems are required to be specifically adapted to each individual shipping company, the ships being operated and the conditions for safe operation.

The special design of the *Star Ismene* and many of the other ships being operated by the company requires the implementation of special measures to limit hazards to the crew. The AIBN is therefore of the opinion that the shipping company's safety management systems was not sufficiently adapted to the ships in that safe practice and a safe working environment was not ensured in the operation of the ships.

Based on the fact that the hazards associated with entering enclosed spaces are well-known in shipping, the AIBN believes that, through its safety management system, the shipping company had several opportunities to discover that the special design constituted a hazard to the crew and required additional measures to those that had already been established.

- Firstly, the Working Environment Regulations require risk analyses to be carried out regularly. The Working Environment Regulations are designed to ensure that work and leisure activities on board are adapted and organised so that the physical and mental wellbeing of employees is ensured. Through such risk analyses, it would have been possible to identify the hazards involved in entering the passageways and spaces beyond.

- Pursuant to the Safety Management Regulations, one of the shipping company's safety management objectives shall be to provide protection against all identified risks. In the effort to provide protection against the hazards involved in entering enclosed spaces, it would have been possible to discover that further measures were needed on account of the design and the special ventilation and dehumidification system.

- The problem could also have been identified in connection with the drawing up of plans for loading and offloading. The Safety Management Regulations require that plans shall be prepared for important shipboard operations that relate to safety and pollution prevention. The shipping company has carried out a risk assessment of the ventilation and dehumidification system, but it was limited in that it only assessed the risk of damage to the cargo. In that connection, the assessment should also have included any risks to the crew that the system might pose.

- The Safety Management Regulations require the company to introduce procedures whereby potential emergency situations on board can be identified, described and responded to. This includes the establishment of programmes for training and exercises/drills to prepare for action in an emergency situation. In this connection, risks to the crew associated with, for example, manual sounding of bottom tanks in the event that the ship had sustained any structural damage or in connection with measures to contain a fire in one of the cargo holds (closing the ventilation hatches), could have been identified.

- The safety management system shall include reports and analyses in connection with non-conformities, accidents and hazardous incidents. Procedures shall also be introduced for taking corrective action. In connection with this work, it would have been possible to discover that the procedure and other measures established for entering enclosed spaces were inadequate in relation to the risks to which the crew were exposed. The problem could also have been identified if non-conformities with procedures and experience of hazards that the crew became aware of, for example in connection with the sounding of the tanks, had been reported and analysed.

- According to the shipping company’s safety management system, the ship’s master shall regularly review the management system on board and report any deficiencies to the onshore management. In connection with such reviews, it could have been possible to discover the fact that plans for important operations and procedures for handling emergency situations lacked the required degree of measures to reduce the hazards to the crew in connection with entering the passageways and the spaces beyond.

- According to the shipping company’s safety management system, internal audits of the shipboard management system shall be conducted, among other things for the purpose of comparing practice on board with the standards of the organisation. In connection with such audits, it would have been possible to discover the fact that plans for important operations and procedures for handling emergency situations failed to adequately describe measures to reduce the hazards to the crew in connection with entry into the passageways and spaces beyond. Furthermore, such an internal audit would have been able to identify the delimitations made in connection with the risk analysis of the ventilation and dehumidification system and risk analyses pursuant to the Working Environment Regulations.

- Correspondingly, the problems could have been identified on one of the other ships of similar design that the shipping company operates. Through the shipping company’s review of the effectiveness of the safety management system, it would have been possible to determine that the problems also concerned other ships with a similar design.

Based on the above, the AIBN is of the opinion that, within the framework of the safety management system, there were a number of opportunities to establish that the special design constituted a risk to the crew and that this required additional measures.

On the other hand, the safety management system had been certified by the supervisory authority in accordance with the requirements of the ISM Code. The AIBN does not exclude the possibility that this may have contributed to increasing the shipping company's faith in the management system meeting the expected quality requirements, and may therefore have increased the threshold for considering the need for making changes to the safety management system.

2.6 Rules and regulations relating to shipbuilding

The design solution relating to access to the spaces between the hatch coamings and the operation of the ventilation system on board the *Star Ismene* were of decisive importance in connection with the accident on 16 December 2008. In that context, it is first and foremost the access arrangement via the landings leading down to the cargo holds that constitutes a safety problem.

In accordance with the Ship Safety and Security Act, ships shall be designed, built and fitted out so as to adequately safeguard human life and health, and the shipping company is responsible for ensuring that this is done. Neither the Shipbuilding Regulations nor any other regulations pursuant to the Act require the shipping company to carry out any overall assessment of the design in the design phase with a view to ensuring the safety of personnel. The Shipbuilding Regulations contain detailed requirements relating to building-technical features, but do not require any assessments in the form of risk analyses relating to ship design. The Working Environment Regulations requires risk analyses to be carried out, but the Regulations apply to those who work on board only, i.e. the crew, and Regulations are designed to ensure that work and free periods on board are arranged and organised with due attention to the safety and physical and mental health of the employees. Hence, the Working Environment Regulations regulate operational matters and do not concern the design or construction phase. In this case, safety problems have been found to exist relating to the fact that the passageways and other spaces used by the crew also serve as air ducts for the ship's ventilation and dehumidification of the cargo holds. In the opinion of the AIBN, this type of safety problem could and should have been identified already in the design phase.

As long as the regulations do not require risk analyses to be carried out in the design phase, effective safety barriers may not be incorporated and, hence, personal safety may become too dependent on organisational matters relating to the operation of the ship.

2.7 The authorities’ supervisory activities and the classification society's inspections

The ship’s design and the resulting complexity relating to what should be regarded as enclosed spaces, combined with inadequate adaptation of the shipping company’s safety management system to the specific ship, contributed to the ship's crew establishing a practice that was regarded as safe, without actually understanding which parts of the ship were to be regarded as enclosed spaces at any time.

Since the *Star Ismene* is registered in NIS and supervisory activities on board ships registered in NIS are delegated to five recognised classification societies, DNV carried out an initial inspection followed by subsequent periodic inspections of the ship and the ship's equipment in accordance with both regulatory and class requirements. DNV has also conducted ISM audits of the shipping company and ship's safety management systems on behalf of the Norwegian authorities. Accordingly, the *Star Ismene* was in possession of valid regulatory and class certificates at the time of the accident.

The design solution based on passageways and other spaces doubling as ventilation ducts is special for cargo ships, but has been used for several of the shipping company's ships. The AIBN is not aware that DNV, in its audits of the shipping company and the 14 ships of this design, has pointed out that the safety management system was not sufficiently adapted to the ships. Just as the shipping company could have established this on several occasions, the AIBN believes that the supervisory authority had several opportunities to discover that the safety management system was not sufficiently adapted to the ship design.

One example of how the supervisory authority's audits of the ship's management system (third-party audit of the ship's SMC) could have discovered such a deficiency is during its review of the risk analyses that were carried out. Since risk analyses carried out in accordance with the Working Environment Regulations are required to be documented in writing, the results of the work should be readily available in connection with audits. In a review of the governing documents, it would have been possible to determine whether the management system was sufficiently ship-specific. For example, in a review of protection against the hazards involved in entering enclosed spaces, it would have been possible to determine that the established procedures were based on standard wording only and did not deal with the specific ship design. The same applies to any review of important operations such as the operation of the ventilation and dehumidification system, operations in connection with loading and offloading, and emergency situations.

In addition to a review of the ship's governing documents and other documents, audits also include interviews with the ship's crew. During such interviews, it would have been possible to discover something about the master and crew's understanding of risk, uncertainty and experience in connection with entry into enclosed spaces, the arrangement for ventilation and dehumidification, loading and offloading operations, and associated measures. Any need for further training of the crew over and above the established programme could also have been discovered. Furthermore, an audit can reveal how these matters have been dealt with in the ship's improvement system and in relation to the onshore organisation.

An inspection of the relevant area on board could have revealed the crew's work procedures in connection with entry into enclosed spaces and the crew's understanding of which spaces this applied to. These factors could also have been discovered through observations of drills to deal with emergency situations such as grounding, a fire in one of the cargo holds or rescue of a person. In the view of the AIBN, an inspection of the relevant area on board would have provided a better understanding of the complexity of the system and hence aroused some interest in what had been done to ensure the safety of operations in this area.

That the system was not sufficiently adapted to the ships and how experience and observations, if any, from the ships had been analysed and what measures this had given rise to could also have been discovered in connection with audits of the safety system by the onshore organisation (third-party audits of the shipping company's DOC).

Since DNV was also responsible for supervisory activities on behalf of the authorities and class inspections in connection with the design and construction of the *Star Ismene* (and other ships belonging to the shipping company), the AIBN takes the view that it would have been possible to observe these problems at an early stage.

2.8 Implemented measures

At the time of the accident on board the *Star Ismene*, the shipping company had already started work to modify ships with similar design solutions for ventilation and dehumidification of the cargo holds. The modification in question involved the installation of a gas-tight door in the shaft for accessing the cargo holds, between the landing and the ladder leading down into the cargo holds. This modification had not been made on the *Star Ismene* at the time of the accident, but has been effected since then.

3. CONCLUSION

The Accident Investigation Board Norway's investigation of the accident on board the *Star Ismene* on 16 December 2008 can be summed up as follows:

3.1 The atmosphere in the shaft where the accident occurred

The accident occurred on the landing in the shaft for accessing cargo hold 7, when a shipping agent and one crew member were on their way to sound the tanks. In all probability, the copper concentrate in cargo hold 7 did not generate any toxic gases, but consumed oxygen. This meant that the oxygen level in the cargo hold and the shaft for accessing the cargo hold, which at the time of the accident had been closed for 29 days, was very low, whereby entry to the shaft and hold constituted a threat to human life. The oxygen content of the shaft one hour after the accident was measured to be 5.9%.

3.2 Information from the shipper concerning hazards associated with the carriage of the cargo

It was not evident from the transport information issued by the shipper in the MSDS in the present case that the copper concentrate consumes oxygen and emits CO_2. In the chapter on (chemical) stability and reactivity, it is stated that the copper concentrate is non-corrosive under normal conditions, but that oxidisation can occur at high temperatures or under other special conditions.

The ship's crew were not aware that the copper concentrate could consume oxygen or of the possibly life-threatening danger of entering the cargo hold. Hence, they did not take any special precautions when taking on board the copper concentrate or in connection with its carriage.

The AIBN believes that it is important in terms of safety that the crew is provided with reliable information about the cargo and its properties, so that relevant and necessary action can be taken to protect the crew and the ship's safety. It is the shipper who must procure and communicate this information. The AIBN is of the opinion that, in the present case, the shipper’s transport information could have included a clearer warning that the copper concentrate could consume oxygen.

3.3 The design whereby the spaces between the hatches are accessed via the cargo holds

The sounding pipes for the bottom tanks are located in the spaces between the cargo hatches, and the *Star Ismene* is designed so that the sounding pipes are accessed via the landing in the shaft for entering the adjacent hold. The crew have to enter the spaces between the hatches, both in connection with the performance of their regular tasks and in connection with emergency situations. In addition to the manual sounding of the ballast and fuel tanks and bilge wells, the ventilation hatches are operated from there. These spaces also contain electrical installations in need of regular inspection. In general, cargo holds are deemed to be enclosed spaces that are dangerous to enter. In practice, this means that access to the spaces between the hatches is limited, both in emergency situations and in connection with regular tasks. A change of design should therefore be considered, so that it is no longer necessary to access the spaces between the hatches via the shafts for entering the cargo holds. A safety recommendation is submitted to the shipping company in this connection.

3.4 The design whereby spaces which are occupied by people double as ventilation ducts and the understanding of the term 'enclosed space'

Like other ships owned by the same shipping company, the *Star Ismene* is fitted out with a system for ventilation and dehumidification of the cargo holds, whereby passageways and other spaces providing access for carrying out routine operations and maintenance double as ventilation ducts. The complexity of this special design means that it is very difficult to assess which rooms are to be regarded as enclosed spaces at any time.

This complexity is not reflected in the ship's safety management system. Among other things, it is evident that, in the safety management system, hazards in connection with the entry into enclosed spaces are only dealt with in accordance with standardised norms and not according to the specific ship. Among other things, the system has no procedures relating to when the ventilation system must be in operation or informative guidelines relating to how the operation of the ventilation and dehumidification system affects the level of danger in the passageways and other spaces that double as ventilation ducts. Hence, the safety management system does not facilitate any safe adaptation by the ship's crew to the special design solution. In the opinion of the AIBN, there were a number of possibilities within the framework of the safety management system for the shipping company to identify the special design as constituting a particular hazard for the crew and something that required further measures.

The ship’s design and ensuing complexity relating to what must be regarded as enclosed spaces, together with the shortcomings of the shipping company’s safety management system, have contributed to the ship’s crew establishing a practice that was regarded as safe, although there was a lack of understanding as to which parts of the ship were to be regarded as enclosed spaces at any time.

Based on the above, the AIBN is of the opinion that risk analyses should be carried out of the operation of the ventilation and dehumidification system. Based on the risk analyses, it should be considered whether the design needs to be changed or whether operative procedures and other measures can be established to ensure the safety of the crew in connection with the performance of routine tasks as well as in an emergency situation. Such operational measures must be reflected in the safety management system. A safety recommendation is submitted in this connection.

3.5 Requirement for risk analyses in the design phase

In this case, safety problems have been found to exist relating to the fact that the passageways and other spaces used by the crew also serve as air ducts for the ship's ventilation and dehumidification of the cargo holds. In the AIBN's opinion this type of safety problem could and should be identified already in the design phase.

Pursuant to the Ship Safety and Security Act, ships shall be designed, built and fitted out so as to adequately safeguard human life and health, but neither the Shipbuilding Regulations nor any other regulations pursuant to the Act require the shipping company to undertake any overall assessments of the design during the design phase. As long as the regulations do not require risk analyses to be carried out in the design phase, effective safety barriers may not be incorporated and, hence, personal safety may become too dependent on organisational matters relating to the operation of the ship.

A safety recommendation is submitted to the authorities on introducing a requirement for risk analyses to be conducted in the design phase.

3.6 The authorities' audits of the safety management system

The shipping company and ship's safety management system was not sufficiently ship-specific. When auditing the system on behalf of the Norwegian authorities, DNV did not discover this. A safety recommendation is submitted to the supervisory authority in this connection.

4. SAFETY RECOMMENDATIONS

The investigation of this marine accident has identified four areas in which the Accident Investigation Board Norway deems it necessary to propose safety recommendations for the purpose of improving safety at sea[43].

Safety recommendation MAR No 2010/28T

The *Star Ismene* is designed so that access to the spaces between the cargo hatches is gained via the landing in the shafts for accessing the cargo holds. In general, cargo holds are to be regarded as enclosed spaces which are dangerous to enter, and, in practice, this reduces the accessibility of the spaces between the hatches in emergency situations and in connection with routine tasks.

The AIBN recommends that the shipping company change the design to remove the need to enter the landings in the shafts for accessing the cargo holds in order to gain access to the spaces between the hatch coamings on the *Star Ismene* and any other ships having the same design that are owned by the shipping company.

Safety recommendation MAR No 2010/29T

Like other ships owned by the same shipping company, the *Star Ismene* is designed with a system for ventilation and dehumidification of the cargo holds, whereby passageways and other spaces used by the crew double as ventilation ducts for the cargo holds. The air quality in these spaces will vary from satisfactory to potentially hazardous to health, depending on whether hatches and doors are open or closed, on whether the ventilation system is in operation or not and on the properties of the cargo. Since the complexity of the design is not addressed in the safety management system, the ship's crew have not understood which parts of the ship are to be regarded as enclosed spaces at any time.

The AIBN recommends that the shipping company review its safety management system so that it can be adapted to each specific ship. This could include risk analyses on the basis of the design. Based on the risk analyses, it should be considered whether the design needs to be changed or whether operative procedures and other measures can be introduced to ensure the safety of the crew.

[43] The investigation report will be sent to the Norwegian Ministry of Trade and Industry, which will take necessary measures to ensure that due account is taken of the safety recommendations.

Safety recommendation MAR No 2010/30T

The choice of design reflects the need for ventilation and dehumidification of the cargo, but it has not been sufficiently emphasised that it must be possible to operate the system in a manner that ensures the safety of the crew. Pursuant to the Ship Safety Act, ships shall be designed, built and fitted out so as to adequately safeguard human life and health, but neither the Shipbuilding Regulations nor any other regulations pursuant to the Act require the shipping company to undertake any risk analyses in the design phase. As a consequence, effective safety barriers may not be incorporated and, hence, personal safety may become too dependent on organisational matters relating to the operation of the ship.

The AIBN recommends that the Maritime Directorate consider the introduction of a requirement for risk analyses to be carried out in the design phase so that solutions involving major operational challenges can be avoided.

Safety recommendation MAR No 2010/31T

The supervisory authority carried out audits of the shipping company and ship's safety management system without discovering that the management system did not address the operational challenges that follow from the special design of the ship's system for ventilation and dehumidification of the cargo holds. Based on these audits, the shipping company and ship were issued with certificates that verified that the safety management system had been found to be in accordance with the requirements of the ISM Code, even though the system was not sufficiently ship-specific.

The AIBN recommends that Det Norske Veritas consider the process whereby it issues and verifies ISM certificates with a view to identifying and implementing measures that will put DNV, as the supervisory authority, in a better position to identify non-conformities with the requirement that safety management systems shall be adapted to each individual shipping company and ship.

Accident Investigation Board Norway
Lillestrøm, 8 November 2010

APPENDICES

Appendix A: Relevant abbreviations

Appendix B: Report following analysis of copper concentrate

Appendix C: IMO Res. A864(20) Recommendations for entering enclosed spaces aboard ships

APPENDIX A: RELEVANT ABBREVIATIONS

DNV	:	Det Norske Veritas
DOC	:	Document of Compliance
ETA	:	Estimated time of arrival
HSE	:	Health, safety and the environment
IMDG	:	International Maritime Dangerous Goods
IMSBC	:	International Maritime Solid Bulk Cargoes Code
IMO	:	International Maritime Organisation
ISM	:	International Safety Management
NIS	:	Norwegian International Ship Register
MSC	:	Maritime Safety Committee
DSDS	:	Material Safety Data Sheet
PEC	:	Protection and Environment Committee
SAFIR	:	Safety Improvement Report
AIBN	:	Accident Investigation Board Norway
SMC	:	Safety Management Certificate
SMS	:	Safety Management System
SSQM System	:	Safety, Security and Quality Management System
VHF	:	Very High Frequency

IFE/KR/F – 2009/094

Generation of gas species from a copper ore concentrate

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Report number	Date
IFE/KR/F-2009/094	11-06-2009
Report title Generation of gas species from a copper ore concentrate	**Revision number**
Client FLO, Kjeller & Havarikommisjonen, Kjeller	**Number of pages** 7
Client reference Øyvind Frigaard, FLO & Kåre Halvorsen, Havarikommisjonen	**Number of issues** 4
Summary A powderized copper ore concentrate has been subjected to GC, XRD and Capillary Electrophoresis analysis to establish the amount(s) and type(s) of gas species that may be generated by exposure to air, water, weak and strong acids and bases.	**Distribution** FLO (Digital) Havarikom. (1) IFE (3)

Keywords: Copper ore, CO_2, Chalcopyrite, Pyrite

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IFE

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1 Introduction

IFE received a parcel with some 200 g sampled powderized copper concentrate originating from a mine in Nevada, which had been shipped bulk from Vancouver towards Korea by a Norwegian registered ship. Visually the sample consisted of a fine grinded greyish black powder with accessory chips of white paint and turnings. Two men had fainted while checking on the storage of this copper concentrate during the sailing of the ship. Knowing the sulphide contents in general of commercial copper ore potential harmful gas species to likely to have been released where though of as being H_2S or SO_2 prior to this study.

2 Analytical methods applied

Gas Chromatography (GC) was applied in detecting released gas species and gas concentration. Capillary Electrophoresis (CE) was used in quantifying dissolved cation species from water reacting with the concentrate. X-Ray Diffractometry (XRD) was used for identifying the main mineral species in the concentrate for comparing to the official mineral contents as supplied by Quadra Miner, owners of the Nevada quarry. pH measurements where done to access if the concentrate was water reactive or not. Specific density was measured for comparing with the official mineral data.

2.1 Gas Chromatography (GC)

Four doublets of 5g samples where added to 10 ml Vacuutainers™. Doublets #1 were sealed dry. Doublets #2 were added 1 ml distilled water. Doublets #3 were added 1 ml diluted hydrochloric acid HCl (pH 3). Doublets #4 were added 1 ml Sodium Hydroxide solution at pH 10. The samples were then subjected to a shaker at 50-55 deg C over 24 hours.

2.2 Capillary Electrophoresis (CE)

The technique of capillary electrophoresis (CE) is designed to separate cation species based on their size to charge ratio in the interior of a small capillary filled with an electrolyte.

2.3 X-Ray Diffractometry (XRD)

1g of the concentrate was added to the XRD sample holder and run from an angle of 2 to 70 deg 2Theta. No further sample preparation was done in view of the powderized appearance of this sample default to the XRD analytic method

2.4 pH

pH was measured using a calibrated digital Radiometer™ probe.

2.5 Specific Density

The specific density of the sample was measured by done by adding 20 ml of water to a calibrated volumetric cylinder and adding 5, 10, 15 and 20 g of the sample and measuring the corresponding volumetric.

2.6 Total Carbon and Sulphur Analyser

Three parallels of 1g sample were analysed on a LECO SC632 instrument. This method heats the sample up to 1400 deg C and gives total (organic + inorganic) Carbon and Sulphur contents.

3 Results

3.1 GC

Background lab CO2 levels were measured to 380-400 ppm (Agilent 7890 RGA).

Doublet #1	DRY:	1400 ppm CO2
Doublet #2	Start pH 6:	2000 ppm CO2
Doublet #3	Start pH 3:	2400 ppm CO2
Doublet #4	Start pH 10:	1700 ppm CO2

Additionally CO2 was measured in a very acidic fluid at start pH 1. Conditions were 1 g sample into 1ml 1N HCl @ 1 hour/20deg C, resulting in the generation of 100.000 ppm CO2 (10% CO2). No other foreign gas species such as H_2S or SO_2 were detected in any of the Vacuutainers™.

3.2 CE

1.3 g sample was added to 1 ml of ion-exchanged water for 24 hours. Cationic species detected by Capillary Electrophoresis were:

Ca	693 mg/l
K	47 mg/l
Na	30 mg/l
Mg	81 mg/l
Fe^{2+}	< 25 mg/l

Total cation concentration in reference to 1g sample/1 ml water: 654 ppm

Uncertainly is set at 5%. Note that the Cu^{2+}_{aq} species is not readily detectable by CE.

A larger quantity of 20 g carefully selected sample powder, visually omitting any (foreign) white pigment chips or metal turnings, was added to 20 ml water for 24 hours. Cationic species detected by Capillary Electrophoresis were:

Ca	459 mg/l
K	12 mg/l
Na	23 mg/l
Mg	34 mg/l
Fe^{2+}	< 25 mg/l

Total cation concentration in reference to 1g sample/1 ml water: 528 ppm

3.3 XRD

The following mineral phases were readily detected by XRD arranged by decreasing quantities:

Chalcopyrite	$CuFeS_2$	> 70%
Pyrite	FeS_2	> 5%
Quartz	SiO_2	< 5%

These three minerals account for 98% of the peaks in the XRD spectrum (Figure 1). There are two minor peaks, one at 45-48 2theta and one close to 65 2theta, that not are accounted for. No spectral fit was identified to any naturally occurring carbonates (e.g., Calcite and Ankerite) nor sulphates (e.g., Jarosite) as reported in Tab. 1 Hence these mineral species are suggested to occur in quantities below the detection limit for the XRD method.

The slight increase in background with increasing 2theta is due to the sample powder size distribution not optimized for the XRD analysis; a finer grinding of the sample powder would most likely increase the S/N ratio somewhat.

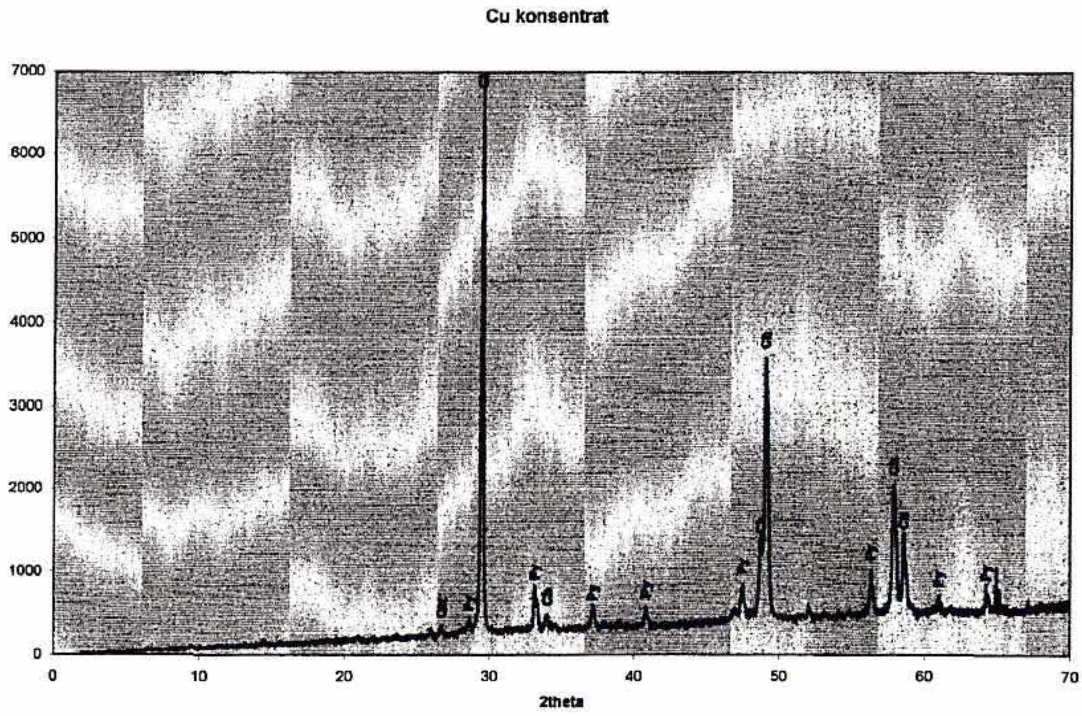

Figure 1 XRD spectrum of the powderized sample

3.4 pH

The reference ion-exchanged water was measured to pH 6.65. 1g of the sample powder was added to 10 ml of this water and left for 24 hours, after which pH was re-measured to 8.67.

3.5 Specific Density

According to the mineral contents of the copper concentrate powder as proved by the mine operator in Nevada (Tab. 1) the sample specific density would equal 4.08 g/cm^3. Measurements made here at IFE equal 3.91 ± 0.15 g/cm^3.

Mineral	Formula	Concentrate	Tails
Chalcopyrite	$CuFeS_2$	88,65	10,51
Pyrite	FeS_2	2,77	3,2
Jarosite	$KFe_3(SO_4)_2(OH)_6$	1,39	8,26
Quartz	SiO_2	1,17	13,06
Ankerite	$CaFe(CO_3)_2$	0,93	2,16
Bornite	Cu_5FeS_4	0,86	0,45
Augite	$(Ca,Mg,Fe)_2(Si,Al)_2O_6$	0,78	5,05
Calcite	$CaCO_3$	0,63	4,81
Chlorite	$(Fe,Mg,Al)_6Si_4O_{10}(OH)_8$	0,61	0,39
Pyroxene	$(Ca,Fe,Mg)_2Si_2O_6$	0,59	5,58
Olivine	$MgFeSiO_4$	0,4	3,31
Sphalerite	$(Fe,Zn)S$	0,39	0,09
Biotite	$K(Mg,Fe)_3(Si_3Al)O_{10}(OH)_2$	0,23	3,48
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	0,17	15,73
K-Feldspar	$KAlSi_3O_8$	0,12	12,55
Talc	$Mg_3Si_4O_{10}(OH)_2$	0,07	0,34
Andradite	$Ca_3Fe_2(SiO_4)_3$	0,06	6,06
Molybdenite	MoS_2	0,06	0,06
Diopside	$CaMgSi_2O_6$	0,03	1,07
Apatite	$Ca_5(PO_4)_3(OH)$	0,03	0,19
Garnet	$Fe_3Al_2(SiO_4)_3$	0,02	0,05
Gypsum	$CaSO_4*2H_2O$	0,02	0,15
Kyanite	Al_2OSiO_4	0,01	1,31
Rutile	TiO_2	0,01	0,08
Epidote	$Ca_2FeAl_2(Si_2O_7)(Si\ O_4)O(OH)$	0,01	1,61
Sphene	$CaSiTiO_5$		0,3
CuMnO	CuMnO		0,14

Table 1 Overall Mineralogy, wt%

3.6 Total Carbon and Sulphur measurements

Total Carbon contents were measured to 2.0 ± 0.15 wt%. Total Sulphur contents were measured to 23.9 ± 0.5 wt%.

4 Discussion

Mineral phases such as Pyrite and Sphalerite are known to readily react with acids forming H_2S at room temperature. In a longer time scale these sulphides react with moisture and oxygen to produce H_2SO_4 and sulphate minerals of which many are readily soluble in water giving rise to acid mine drainage. No sulphur-bearing gases such as H_2S or SO_2 did evolve from the sample when subjected to fluids within pH1 to pH10 at run conditions. The only gas species evolving from the sample was CO2. Even at dry run conditions the sample generated three times the CO_2 background level. This amount increased by exposure to pH neutral moisture, and more so to acids. This is in part indicative of the presence of readily acid soluble carbonates as Calcite and Ankerite, known to occur in quantities less than 2% in the sample according to Tab. 1. The sample carbon content (organic + inorganic) is 2% akin to the carbonate values from Tab. 1. However, the generation of CO_2 when the sample is subjected to a base (pH 10) and also during dry conditions are not consistent with the CO_2 source being inorganic crystalline carbonates alone, or that some foreign unknown additive is buffering the system.

Based on the mineral composition it was expected that pH would become acidic when subjected to distilled water. This was not the case. Contrary, it became basic; pH rose from 6.68 to 8.67 when 1 g of the sample was subjected to 10 ml water over 24 hours.

Also, when re-measuring after two weeks the pH of the basic sample doublet #4 starting at pH 10, the pH had deceased to 5-6.

Water analyses gave high values of Ca, K, Na and Mg. Calcium would likely originate from Calcite and Ankerite and Potassium from Jarosite if these minerals were subjected to acids. However, the sample was subjected to pure water only. Calcite, Ankerite and Jarosite are not readily water soluble to give cation contents as high as those measured by CE. In addition, if Jarosite was to dissolve in pure water, pH would become acidic. Hence, an unknown additive most likely makes the solution basic. The source for readily soluble Na and Mg is also unknown. Also, if Ankerite was adding to the Calcium value, it would also imply adding Fe^{2+} to the solution. No Fe^{2+} was however detected (below detection limits of 5ppm). Potential Fe^{3+} from Jarosite would not have been detected since CE is insensitive to this particular cation species.

The density of the sample is measured to3.91 ± 0.15 g/cm^3. According to the mineral composition, as listed in Tab. 1, the sample density should be close to 4.08 g/cm^3. Due to the uncertainty of the measurements and potential concentrate batch density variations, our data fits with the theoretical density value.

Based on water analysis, GC and pH measurements it seems that the concentrated copper sample has been contaminated by foreign matter, causing contacting moisture to become basic whilst releasing CO_2. Presence of the cation species Ca^{2+}, Mg^{2+}, K^+ and Na^+, in respect to the mineral chemistry; is indicative of foreign substances have been diluting the copper concentrate at some point. This foreign substance may be exemplified by the addition of a Portlandite/bicarbonate mix as found in untreated concrete: If moist, the following type of reaction will readily occur:

$$Ca(OH)_2 + (K,Na)HCO_3 + H_2O \Rightarrow Ca^{2+} + (K,Na)^+ + CO_2(g) + 3(OH)^- + H_2O$$

The subsequently basic solution will begin corrode the ore sulphides with a resultant lowering of the pH. Though we as this stage cannot confirm directly the presence of neither Portlandite nor bicarbonate (potentially due to too poor crystallinity of these phases for good XRD measurements to be obtained) small amounts of these species would react with the concentrate according to our observations and measurements. The elevated Mg^{2+} content in the solution can however not be accounted for by this reaction. None of the known occurring Mg-bearing phases (Tab. 1) would be capable of releasing similar amounts of Mg^{2+} to a neutral aqueous solution over 24 hours. There are however small chips of whitish paint (?) and thin metal turnings in the concentrate. The rerun of the CE water analysis of 20g sample without any visually identifiable foreign matter gave however similar cation distribution and concentration as for the 1.3 g sample indicative of the chips or turnings not adding to the liquid cation content at neutral pH conditions. The use of thermodynamic modeling of this mineral system, involving equations of state and dissolution constants, would improve upon the uncertainties adhered to the present study.

5 Conclusion

No sulphur-bearing gas species was detected being emitted from the sample. The only gas species detected originating from the powderized copper ore concentrate was CO_2. This gas is released from the sample when dry, when subjected to neutral water, basic water, and in particular high gas contents, i.e., 10% CO_2, was released when exposed to acids. The known accessory presence of the carbonates Calcite and Ankerite are not likely the source of the emitted CO_2, particularly not at neutral or basic conditions. Hence the release of CO_2 at all measured lab conditions is indicative of presence of a foreign reactive substance high in Ca, Mg, K and Na with poor crystallinity since almost all XRD peaks could be attributed to phases known to occur in the concentrate. Chips of paint and metal turnings found in the concentrate are not the source for the released alkalies. The insignificant change in theoretical versus measured density points towards that only minor quantity of foreign matter may have been added at some point, unless the additive had similar (heavy) density as the concentrate, which is doubtful.

5.1 Recommendation for further work

Though outside the scope of this study, subsequent thermodynamic modeling of the lab experiment(s) would be very useful in reducing uncertainties that still persist.

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RESOLUTION A.864(20)
adopted on 27 November 1997

RECOMMENDATIONS FOR ENTERING ENCLOSED SPACES ABOARD SHIPS

THE ASSEMBLY,

RECALLING Article 15(j) of the Convention on the International Maritime Organization concerning the functions of the Assembly in relation to regulations and guidelines concerning maritime safety,

BEING CONCERNED at the continued loss of life resulting from personnel entering shipboard spaces in which the atmosphere is oxygen-depleted, toxic or flammable,

BEING AWARE of the work undertaken in this regard by the International Labour Organization, Governments and segments of the private sector,

NOTING that the Maritime Safety Committee, at its fifty-ninth session, approved appendix F to the Code of Safe Practice for Solid Bulk Cargoes concerning recommendations for entering cargo spaces, tanks, pump-rooms, fuel tanks, cofferdams, duct keels, ballast tanks and similar enclosed spaces,

NOTING FURTHER the decision of the Maritime Safety Committee at its sixty-sixth session to replace appendix F referred to above with the recommendations annexed to this resolution,

HAVING CONSIDERED the recommendation made by the Maritime Safety Committee at its sixty-sixth session,

1. ADOPTS the Recommendations for Entering Enclosed Spaces Aboard Ships set out in the Annex to the present resolution;

2. INVITES Governments to bring the annexed Recommendations to the attention of shipowners, ship operators and seafarers, urging them to apply the Recommendations, as appropriate, to all ships;

3. REQUESTS the Maritime Safety Committee to keep the Recommendations under review and amend them, as necessary.

ANNEX

RECOMMENDATIONS FOR ENTERING ENCLOSED SPACES ABOARD SHIPS

PREAMBLE

The object of these recommendations is to encourage the adoption of safety procedures aimed at preventing casualties to ships personnel entering enclosed spaces where there may be an oxygen deficient, flammable and/or toxic atmosphere.

Investigations into the circumstances of casualties that have occurred have shown that accidents on board ships are in most cases caused by an insufficient knowledge of, or disregard for, the need to take precautions rather than a lack of guidance.

The following practical recommendations apply to all types of ships and provide guidance to seafarers. It should be noted that on ships where entry into enclosed spaces may be infrequent, for example, on certain passenger ships or small general cargo ships, the dangers may be less apparent, and accordingly there may be a need for increased vigilance.

The recommendations are intended to complement national laws or regulations, accepted standards or particular procedures which may exist for specific trades, ships or types of shipping operations.

It may be impracticable to apply some recommendations to particular situations. In such cases, every endeavour should be made to observe the intent of the recommendations, and attention should be paid to the risks that may be involved.

1 INTRODUCTION

The atmosphere in any enclosed space may be deficient in oxygen and/or contain flammable and/or toxic gases or vapours. Such an unsafe atmosphere could also subsequently occur in a space previously found to be safe. Unsafe atmosphere may also be present in spaces adjacent to those spaces where a hazard is known to be present.

2 DEFINITIONS

2.1 *Enclosed space* means a space which has any of the following characteristics:

.1 limited openings for entry and exit;

.2 unfavourable natural ventilation; and

.3 is not designed for continuous worker occupancy,

and includes, but is not limited to, cargo spaces, double bottoms, fuel tanks, ballast tanks, pump-rooms, compressor rooms, cofferdams, void spaces, duct keels, inter-barrier spaces, engine crankcases and sewage tanks.

2.2 *Competent person* means a person with sufficient theoretical knowledge and practical experience to make an informed assessment of the likelihood of a dangerous atmosphere being present or subsequently arising in the space.

2.3 *Responsible person* means a person authorised to permit entry into an enclosed space and having sufficient knowledge of the procedures to be followed.

3 ASSESSMENT OF RISK

3.1 In order to ensure safety, a competent person should always make a preliminary assessment of any potential hazards in the space to be entered, taking into account previous cargo carried, ventilation of the space, coating of the space and other relevant factors. The competent person's preliminary assessment should determine the potential for the presence of an oxygen-deficient, flammable or toxic atmosphere.

3.2 The procedures to be followed for testing the atmosphere in the space and for entry should be decided on the basis of the preliminary assessment. These will depend on whether the preliminary assessment shows that:

.1 there is minimal risk to the health or life of personnel entering the space;

.2 there is no immediate risk to health or life but a risk could arise during the course of work in the space; and

.3 a risk to health or life is identified.

3.3 Where the preliminary assessment indicates minimal risk to health or life or potential for a risk to arise during the course of work in the space, the precautions described in 4, 5, 6 and 7 should be followed as appropriate.

3.4 Where the preliminary assessment identifies risk to life or health, if entry is to be made, the additional precautions specified in section 8 should also be followed.

4 AUTHORIZATION OF ENTRY

4.1 No person should open or enter an enclosed space unless authorised by the master or nominated responsible person and unless the appropriate safety procedures laid down for the particular ship have been followed.

4.2 Entry into enclosed spaces should be planned and the use of an entry permit system, which may include the use of a checklist, is recommended. An Enclosed Space Entry Permit should be issued by the master or nominated responsible person, and completed by a person who enters the space prior to entry. An example of the Enclosed Space Entry Permit is provided in the appendix.

5 GENERAL PRECAUTIONS

5.1 The master or responsible person should determine that it is safe to enter an enclosed space by ensuring:

.1 that potential hazards have been identified in the assessment and as far as possible isolated or made safe;

.2 that the space has been thoroughly ventilated by natural or mechanical means to remove any toxic or flammable gases, and to ensure an adequate level of oxygen throughout the space;

.3 that the atmosphere of the space has been tested as appropriate with properly calibrated instruments to ascertain acceptable levels of oxygen and acceptable levels of flammable or toxic vapours;

.4 that the space has been secured for entry and properly illuminated;

.5 that a suitable system of communication between all parties for use during entry has been agreed and tested;

.6 that an attendant has been instructed to remain at the entrance to the space whilst it is occupied;

.7 that rescue and resuscitation equipment has been positioned ready for use at the entrance to the space, and that rescue arrangements have been agreed;

.8 that personnel are properly clothed and equipped for the entry and subsequent tasks; and

.9 that a permit has been issued authorizing entry.

The precautions in .6 and .7 may not apply to every situation described in this section. The person authorizing entry should determine whether an attendant and the positioning of rescue equipment at the entrance to the space is necessary.

5.2 Only trained personnel should be assigned the duties of entering, functioning as attendants, or functioning as members of rescue teams. Ships' crews should be drilled periodically in rescue and first aid.

5.3 All equipment used in connection with entry should be in good working condition and inspected prior to use.

6 TESTING THE ATMOSPHERE

6.1 Appropriate testing of the atmosphere of a space should be carried out with properly calibrated equipment by persons trained in the use of the equipment. The manufacturers' instructions should be strictly followed. Testing should be carried out before any person enters the space, and at regular intervals thereafter until all work is completed. Where appropriate, the testing of the space should be carried out at as many different levels as is necessary to obtain a representative sample of the atmosphere in the space.

6.2 For entry purposes, steady readings of the following should be obtained:

.1 21% oxygen by volume by oxygen content meter; and

.2 not more than 1% of lower flammable limit (LFL) on a suitably sensitive combustible gas indicator, where the preliminary assessment has determined that there is potential for flammable gases or vapours.

If these conditions cannot be met, additional ventilation should be applied to the space and re-testing should be conducted after a suitable interval. Any gas testing should be carried out with ventilation to the enclosed space stopped, in order to obtain accurate readings.

6.3 Where the preliminary assessment has determined that there is potential for the presence of toxic gases and vapours, appropriate testing should be carried out using fixed or portable gas or vapour detection equipment. The readings obtained by this equipment should be below the occupational exposure limits for the toxic gases or vapours given in accepted national or international standards. It should be noted that testing for flammability does not provide a suitable means of measuring for toxicity, nor vice versa.

6.4 It should be emphasized that pockets of gas or oxygen-deficient areas can exist, and should always be suspected, even when an enclosed space has been satisfactorily tested as being suitable for entry.

7 PRECAUTIONS DURING ENTRY

7.1 The atmosphere should be tested frequently whilst the space is occupied, and persons should be instructed to leave the space should there be a deterioration in the conditions.

7.2 Ventilation should continue during the period that the space is occupied and during temporary breaks. Before re-entry after a break, the atmosphere should be re-tested. In the event of failure of the ventilation system, any persons in the space should leave immediately.

7.3 In the event of an emergency, under no circumstances should the attending crew member enter the space before help has arrived and the situation has been evaluated to ensure the safety of those entering the space to undertake rescue operations.

8 ADDITIONAL PRECAUTIONS FOR ENTRY INTO A SPACE WHERE THE ATMOSPHERE IS KNOWN OR SUSPECTED TO BE UNSAFE

8.1 If the atmosphere in an enclosed space is suspected or known to be unsafe, the space should only be entered when no practical alternative exists. Entry should only be made for further testing, essential operation, safety of life or safety of a ship. The number of persons entering the space should be the minimum compatible with the work to be performed.

8.2 Suitable breathing apparatus, e.g. of the air-line or self-contained type, should always be worn, and only personnel trained in its use should be allowed to enter the space. Air-purifying respirators should not be used as they do not provide a supply of clean air from a source independent of the atmosphere within the space.

8.3 The precautions specified in 5 should also be followed, as appropriate.

8.4 Rescue harnesses should be worn and, unless impractical, lifelines should be used.

8.5 Appropriate protective clothing should be worn particularly where there is any risk of toxic substances or chemicals coming into contact with the skin or eyes of those entering the space.

8.6 The advice in 7.3 concerning emergency rescue operations is particularly relevant in this context.

9 HAZARDS RELATED TO SPECIFIC TYPES OF CARGO

9.1 Dangerous goods in packaged form

9.1.1 The atmosphere of any space containing dangerous goods may put at risk the health or life of any person entering it. Dangers may include flammable, toxic or corrosive gases or vapours that displace oxygen, residues on packages and spilled material. The same hazards may be present in spaces adjacent to the cargo spaces. Information on the hazards of specific substances is contained in the IMDG Code, the Emergency Procedures for Ships Carrying Dangerous Goods (EMS) and Materials Safety Data Sheets (MSDS). If there is evidence or suspicion that leakage of dangerous substances has occurred, the precautions specified in 8 should be followed.

9.1.2 Personnel required to deal with spillages or to remove defective or damaged packages should be appropriately trained and wear suitable breathing apparatus and appropriate protective clothing.

9.2 Bulk liquid

The tanker industry has produced extensive advice to operators and crews of ships engaged in the bulk carriage of oil, chemicals and liquefied gases, in the form of specialist international safety guides. Information in the guides on enclosed space entry amplifies these recommendations and should be used as the basis for preparing entry plans.

9.3 Solid bulk

On ships carrying solid bulk cargoes, dangerous atmospheres may develop in cargo spaces and adjacent spaces. The dangers may include flammability, toxicity, oxygen depletion or self-heating, which should be identified in shipping documentation. For additional information, reference should be made to the Code of Safe Practice for Solid Bulk Cargoes.

9.4 Oxygen-depleting cargoes and materials

A prominent risk with such cargoes is oxygen depletion due to the inherent form of the cargo, for example, self-heating, oxidation of metals and ores or decomposition of vegetable oils, animal fats, grain and other organic materials or their residues. The materials listed below are known to be capable of causing oxygen depletion. However, the list is not exhaustive. Oxygen depletion may also be caused by other materials of vegetable or animal origin, by flammable or spontaneously combustible materials, and by materials with a high metal content:

.1 grain, grain products and residues from grain processing (such as bran, crushed grain, crushed malt or meal), hops, malt husks and spent malt;

.2 oilseeds as well as products and residues from oilseeds (such as seed expellers, seed cake, oil cake and meal);

.3 copra;

.4 wood in such forms as packaged timber, roundwood, logs, pulpwood, props (pit props and other propwood), woodchips, woodshavings, woodpulp pellets and sawdust;

.5 jute, hemp, flax, sisal, kapok, cotton and other vegetable fibres (such as esparto grass/Spanish grass, hay, straw, bhusa), empty bags, cotton waste, animal fibres, animal and vegetable fabric, wool waste and rags;

.6 fishmeal and fishscrap;

.7 guano;

.8 sulphidic ores and ore concentrates;

.9 charcoal, coal and coal products;

.10 direct reduced iron (DRI)

.11 dry ice;

.12 metal wastes and chips, iron swarf, steel and other turnings, borings, drillings, shavings, filings and cuttings; and

.13 scrap metal.

9.5 Fumigation

When a ship is fumigated, the detailed recommendations contained in the Recommendations on the Safe Use of Pesticides in Ships* should be followed. Spaces adjacent to fumigated spaces should be treated as if fumigated.

10 CONCLUSION

Failure to observe simple procedures can lead to people being unexpectedly overcome when entering enclosed spaces. Observance of the principles outlined above will form a reliable basis for assessing risks in such spaces and for taking necessary precautions.

* Refer to the Recommendations on Safe Use of Pesticides in Ships, approved by the Maritime Safety Committee of the Organization by circular MSC/Circ.612, as amended by MSC/Circ.689 and MSC/Circ.746.

APPENDIX

EXAMPLE OF AN ENCLOSED SPACE ENTRY PERMIT

This permit relates to entry into any enclosed space and should be completed by the master or responsible officer and by the person entering the space or authorized team leader.

General

Location/name of enclosed space...

Reason for entry...

This permit is valid from:................hrs Date..................

to :................hrs Date...................

(See note 1)

Section 1 - Pre-entry preparation

(To be checked by the master or nominated responsible person) Yes No

- Has the space been thoroughly ventilated ? ❐ ❐
- Has the space been segregated by blanking off or isolating all connecting pipelines or valves and electrical power/equipment ? ❐ ❐
- Has the space been cleaned where necessary ? ❐ ❐
- Has the space been tested and found safe for entry ? (See note 2) ❐ ❐
- Pre-entry atmosphere test readings:

  - oxygen.......................% vol (21%) By:....................
  - hydrocarbon.............% LFL (less than 1%)
  - toxic gases.................ppm (specific gas and PEL) Time:................

  (See note 3)

- Have arrangements been made for frequent atmosphere checks to be made while the space is occupied and after work breaks ? ❐ ❐
- Have arrangements been made for the space to be continuously ventilated throughout the period of occupation and during work breaks ? ❐ ❐
- Are access and illumination adequate ? ❐ ❐

	Yes	No
● Is rescue and resuscitation equipment available for immediate use by the entrance to the space ?	❒	❒
● Has a responsible person been designated to be in constant attendance at the entrance to the space?	❒	❒
● Has the officer of the watch (bridge, engine room, cargo control room) been advised of the planned entry ?	❒	❒
● Has a system of communication between all parties been tested and emergency signals agreed ?	❒	❒
● Are emergency and evacuation procedures established and understood by all personnel involved with the enclosed space entry ?	❒	❒
● Is all equipment used in good working condition and inspected prior to entry ?	❒	❒
● Are personnel properly clothed and equipped ?	❒	❒

Section 2 - Pre-entry checks

(To be checked by the person entering the space or authorized team leader)

	Yes	No
● I have received instructions or permission from the master or nominated responsible person to enter the enclosed space	❒	❒
● Section 1 of this permit has been satisfactorily completed by the master or nominated responsible person	❒	❒
● I have agreed and understand the communication procedures	❒	❒
● I have agreed upon a reporting interval of.......................minutes	❒	❒
● Emergency and evacuation procedures have been agreed and are understood	❒	❒
● **I am aware that the space must be vacated immediately in the event of ventilation failure or if atmosphere tests show a change from agreed safe criteria**	❒	❒

Section 3 - Breathing apparatus and other equipment
(To be checked jointly by the master or nominated responsible person and the person who is to enter the space)

	Yes	No
● Those entering the space are familiar with the breathing apparatus to be used	❒	❒
● The breathing apparatus has been tested as follows:		
- gauge and capacity of air supply	....	
- low pressure audible alarm	....	
- face mask - under positive pressure and not leaking	....	
● The means of communication has been tested and emergency signals agreed	❒	❒
● All personnel entering the space have been provided with rescue harnesses and, where practicable, lifelines	❒	❒

Signed upon completion of sections 1,2 and 3 by:

Master or nominated responsible person..................... Date................. Time................

Responsible person supervising entry .... Date.................. Time................

Person entering the space or authorized team leader .... Date................... Time................

Section 4 - Personnel entry
(To be completed by the responsible person supervising entry)

Names	Time in	Time out
....	....	....
....	....	....
....	....	....
....	....	....

Section 5 - Completion of job
(To be completed by the responsible person supervising entry)

● Job completed Date.......................... Time.......................

● Space secured against entry	Date............................ Time.......................
● The officer of the watch has been duly informed	Date.............................
Time.........................	

Signed upon completion of sections 4 and 5 by:

Responsible person supervising entry .... Date................... Time................

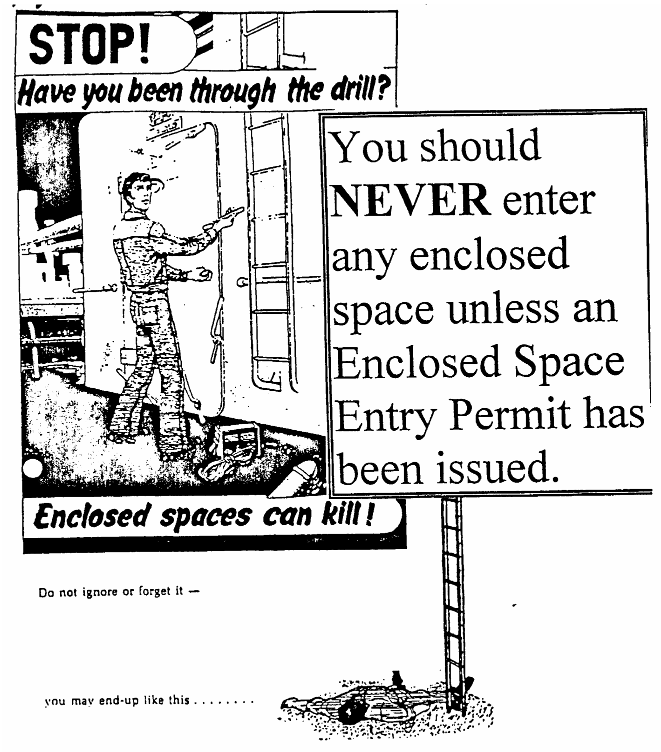
THIS PERMIT IS RENDERED INVALID SHOULD VENTILATION OF THE SPACE STOP OR IF ANY OF THE CONDITIONS NOTED IN THE CHECKLIST CHANGE

Notes:

1 The permit should contain a clear indication as to its maximum period of validity.

2 In order to obtain a representative cross-section of the space's atmosphere, samples should be taken from several levels and through as many openings as possible. Ventilation should be stopped for about 10 minutes before the pre-entry atmosphere tests are taken.

3 Tests for specific toxic contaminants, such as benzene or hydrogen sulphide, should be undertaken depending on the nature of the previous contents of the space.


STOP!
Have you been through the drill?
You should NEVER enter any enclosed space unless an Enclosed Space Entry Permit has been issued.
Enclosed spaces can kill!
Do not ignore or forget it —
you may end-up like this ....

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