Departmental investigation into a fall from aloft aboard the CONCORDIA on 5 December 1996

Report No. 105

COMMONWEALTH DEPARTMENT OF
TRANSPORT AND REGIONAL
DEVELOPMENT

Contents

Navigation Act 1912
Navigation (Marine Casualty) Regulations
investigation into the explosion and fatality aboard the Bahamas sail training vessel CONCORDIA off New Year Is, Northern Territory, on 5 December 1996
Report No 105

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The Investigation into marine casualties occurring within the Commonwealth's jurisdiction are conducted under the provisions of the Navigation (Marine Casualty) Regulations, made pursuant to sub section 425 (1) (ea) and 425 1 AAA of the Navigation Act 1912. The Regulations provide discretionary powers to the Inspector to investigate incidents as defined by the regulations. Where an investigation is undertaken the Inspector must submit a report to the Secretary of the Department. It is Departmental policy to publish such reports in full as an educational tool.

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Summary

On 5 December 1996, the sail training ship Concordia, registered in the Commonwealth of the Bahamas, was on passage from Brisbane to Darwin in the Northern Territory. On deck, routine maintenance was being conducted by some of the students.

Shortly before 1145 on 5 December, one of the students, using a rotary grinder, was removing rust from the door of the battery locker, which was situated at deck level, in the after housing, below the wheelhouse. He paused and called over the Bosun's Mate who looked at the work before turning away and walking towards the forward housing. At that instance, the Bosun's Mate recalled being "moved" over a metre, putting her hands over her ears and hearing a noise. Another student, working on the port side about 5 metres from the bridge front, saw a dark shape, which he took to be a body, being thrown over the port rail.

The Master, who was on watch and fixing the ship's position at the time, and most of the crew heard an explosion and went to the deck. Within a very few seconds life buoys were thrown overboard, one with a smoke marker. The Master could see the student in the water close to the smoke buoy, but as he watched the student disappeared from view.

Within 3 minutes, a rescue boat was launched and was making for the smoke buoy and Concordia was turned about. No trace of the student could be found, except for a pair of shoes on the deck and some evidence of blood on the deck, on the ship's rail and near the ship's side.

The maritime rescue authorities were alerted and Concordia, assisted by a helicopter and a fixed wing aircraft, searched the area that afternoon, into the evening until 1915. The following morning the search resumed at sunrise and Concordia was later joined by a single fixed wing aircraft. The search for the student was abandoned at about 1230, and after a short service Concordia resumed passage for Darwin.

Sources of information

The Master and crew of Concordia

Australian Maritime Safety Authority

The Northern Territory Police

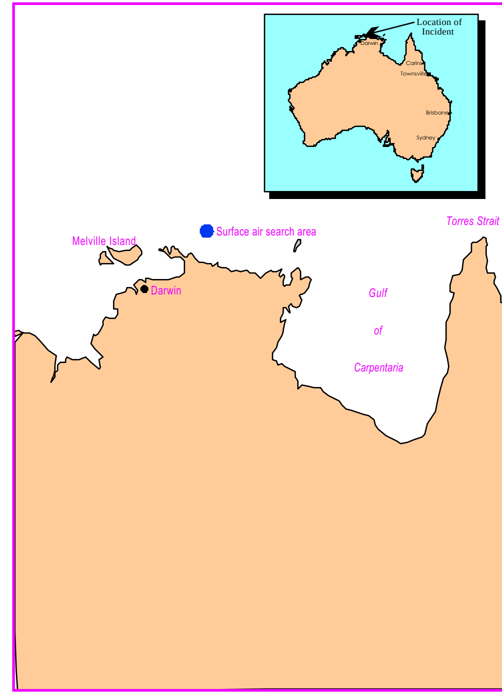
Lloyd’s Register of Shipping

Director, West Island College - Class Afloat

The Inspector gratefully acknowledges the assistance of the Australian Maritime Safety Authority and the Senior Marine Surveyor Darwin, who was appointed an investigator to conduct the field investigation.

Narrative

Concordia



Concordia was built in 1991, in Szczecin, Poland as a sail training ship and was delivered to its owners, West Island College International, in April 1992. West Island College International is a company incorporated in the Bahamas and is affiliated to West Island College of Dollard des Ormeaux, Canada.

Concordia is 58.1 m in length overall, with a beam of 9.44 m, a moulded depth of 6.2 m, and a gross tonnage of 413. The vessel was built under Lloyd's Register of Shipping survey and classed with the Society as a 100 A1 Yacht @ LMC, for sail training purposes. The vessel was also built to comply with aspects of the "Code of Safety for Special Purpose Ships", which carry more than 12 people in addition to the crew. The ship is barquentine rigged and has a 425 kW main engine driving a single screw, to give a speed of about 7 knots.

Statutory surveys are conducted on behalf of the Bahamas Maritime Authority, by Lloyd's Register of Ships and, while classed as a yacht, it operated under international cargo ship survey certificates relating to construction and equipment. On 5 December 1996 all the necessary International Statutory Certificates were valid.

The vessel is specifically designed and constructed for education at sea and fulfils the function of a floating campus offering both a mainstream curriculum, and a wide variety of international study programs.

The ship operated on a two “swing” system, working on a two semester basis. The 1996/97 voyage program was:

First semester:	San Diego - Bali	August 1996 to December 1996
Second semester:	Bali - Copenhagen	February 1997 to June 1997

The vessel has a complement of 8 professional crew consisting of a Master, two mates, two engineers, two deck ratings and a cook. On 5 December, the vessel carried 36 “special personnel”; 31 students, ranging in age from 16½ to 18½ years, three teachers, 2 guests and a director. Apart from two Australian guest special personnel, who boarded at Heron Island, and the Polish professional crew, the remaining students, teachers and the director were from Canada and the USA.

The vessel was expected in Bali on
17 December, where the students were to complete their voyage and be flown home for the Christmas holidays.

The Master in command on 5 December 1996, was an experienced sailor. He had served on a variety of sailing vessels of varying sizes including a three year period, as Mate, on an 80 m vessel. He had previously served on Concordia as Mate for about 5 months in 1995 and assumed command of the vessel in August 1996. The Master and the two watchkeeping officers all held Yacht Masters Licences issued by the Commonwealth of the Bahamas.

The Mate and Second Mate, the latter also being a medical practitioner, are both experienced seamen on sailing vessels. The Master, Mate and Second Mate maintain a four hours-on/eight hours-off watch routine, with the Master keeping the 8 to 12 watch.

The Bosun had served for six months as a deck hand and a further year as Bosun on a similar vessel to Concordia.

The Bosun’s Mate had no formal seagoing qualifications. She holds a degree in psychology and had served on Concordia in 1992 as a deck hand on its maiden voyage from Poland to Montreal. Since the maiden voyage she had held positions as “day watch officer” and bosun’s mate and had served as a deck hand on fishing vessels.

The students, in addition to their academic program, carried out basic deck duties, changing sails (including going aloft in reasonable sea conditions), chipping, painting and other similar duties.

Both the Bosun and Bosun's Mate had a supervisory role in relation to the deck work carried out by the students. The deck maintenance was the responsibility of the Mate, who would normally discuss the day's program with the Bosun or Bosun's Mate during the previous day. Normally the Bosun dealt with the maintenance and handling of the masts and rigging, while the Bosun's Mate supervised the more general scaling, painting and maintenance on deck.

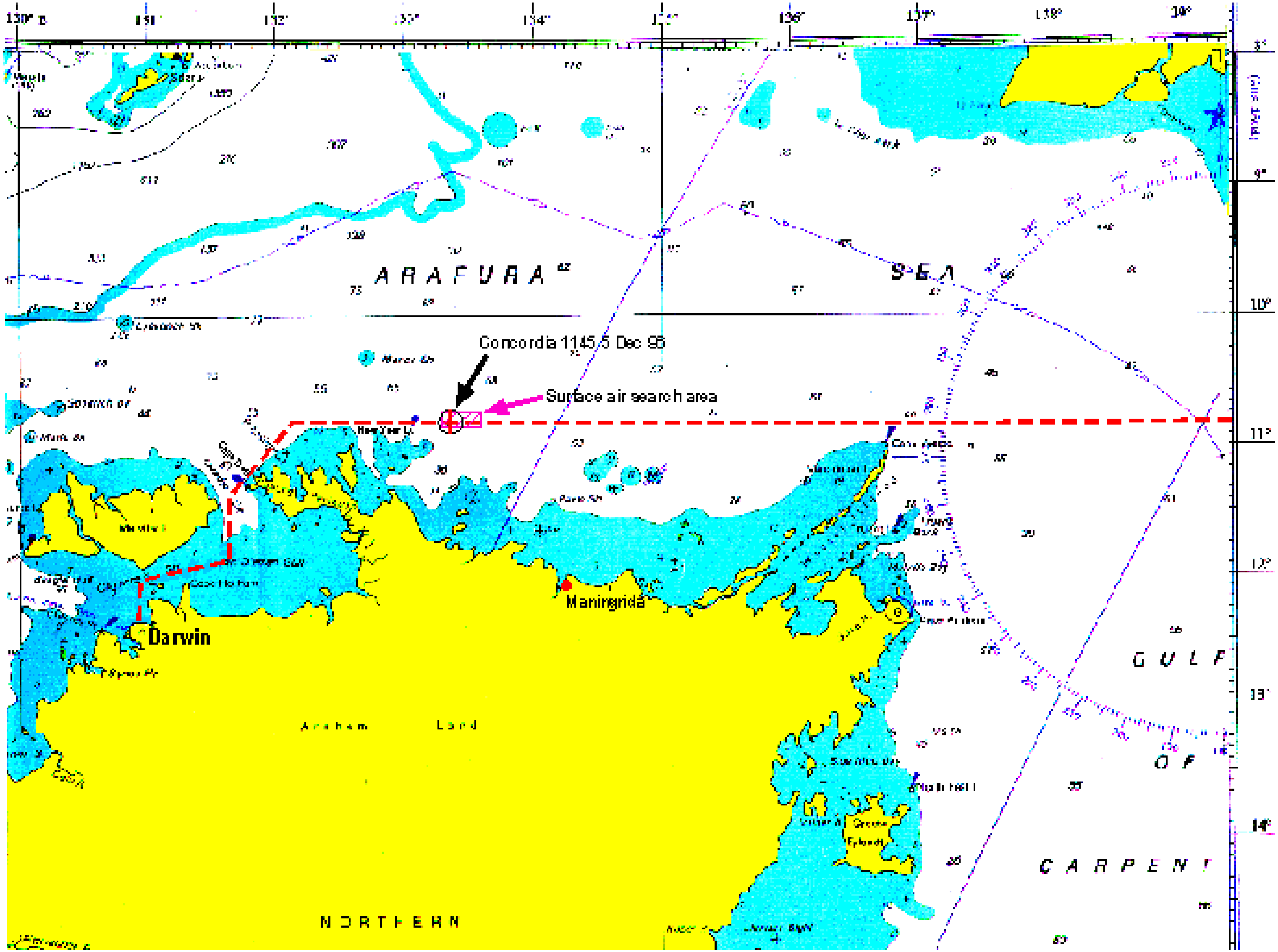
The Chief Engineer and Second Engineer were responsible for the machinery spaces and electrical power supply, including the battery lockers. The engine room and lockers, other than the deck gear lockers, were off limits to the students.

The incident

Concordia sailed from Noumea, New Caladonia, on 12 November 1996 and arrived in Brisbane, the first Australian port of call, on 17 November for a four day visit. On 21 November, Concordia embarked a pilot licensed for the inner route of the Great Barrier Reef and sailed for Heron Island and Low Isles north of Cairns. The vessel completed its transit of the inner route and disembarked the pilot at 0750 on 2 December off Thursday Island. The vessel continued on passage for Darwin under power and with no sail set.

In the afternoon of 4 December, the Mate discussed the following day's deck maintenance tasks with the Bosun's Mate. He told the Bosun's Mate to complete painting on the wheelhouse housing, rails and catwalk and then start painting the capstan and mast.

At 0800 on the morning of 5 December 1996, the vessel was in position 10° 43.5' South 133° 43' East on a westerly passage between Cape Wessel and Cape Don, about 230 miles north and east from Darwin. A work detail assembled on deck in the morning under the supervision of the Bosun's Mate. The weather conditions were good with the wind from the north, force 1 (up to 1.5 knots), no swell and about 2 octres cloud cover.



From chart Aus 4603 Australia-North coast

The work was varied and included rust scaling and painting on the main deck in the area between the wheelhouse front and the midships mess deck house. At about 1100, the work party was joined by a student, who had decided to go on watch early, to allow time for academic study in the afternoon, a common arrangement on board.

The Bosun's Mate showed the student some places on the starboard side of the bridge that required scaling and painting, areas which had been missed on the previous day. They then went to the port side of the wheelhouse housing and the Bosun's Mate indicated that the battery locker door needed rust removed from it.

The student gathered the work tools required for the task, which included an electric disc grinder with a 127 mm abrasive pad attached to the disc. The battery locker door was secured by four lugs and wing nuts, one at each side and one each at top and bottom of the door. To be able to use the grinding disc so that it could reach all parts of the lug, the door securing clip had to be loosened and lifted clear of the lug. He consulted the Bosun's Mate who told him to loosen the tightly secured wing nuts. He took a hammer and loosened the clips so they could be moved by hand. He removed all four clips from the lugs and was removing the rust using the grinder. He called the Bosun's Mate to see how efficiently the grinder removed the rust back to shiny metal. She went over to the door, which she recalled as being partially open, probably a little less than 45° (about 400 mm), looked and then made some encouraging comment on the student's efforts.

The Bosun's Mate turned away from the student towards her own work a few metres away. She later recalled that at that instance she was "moved" as if by some invisible hand over a metre, putting her hands over her ears and hearing a noise.

At this time, a second student, working on the port side about 5 m or so forward of the battery locker, heard a loud explosion and out of the corner of his eye saw a dark shape, which he took to be a body, being thrown over the rail, "as if being shot from a canon". He realised that somebody had gone overboard but, with the speed at which it happened, he did not know who it was. He took a few seconds to switch off the electric scaling equipment he was using, grabbed a life ring (life buoy) from the starboard side near the bridge front, ran aft and threw the life ring into the water. By the time he threw the ring the emergency signal was sounding and the vessel had begun to turn. This was followed almost immediately by an additional life ring with a smoke marker, which was launched by the Bosun's Mate and seen to land within a metre of the student, who was floating face down on the surface of the water with his arms outstretched.

A third student, working on a capstan fitted between the bridge housing and the forward accommodation block, heard the explosion. He did not immediately realise what had happened but saw smoke coming from the port side and shoes and goggles upon the deck. He then realised somebody had been lost overboard.

The Master, who was in the chart room fixing Concordia's position, heard the explosion and immediately went to the wheelhouse. He saw smoke and the broken portside rail and heard a female voice shouting "man overboard". Looking astern he could see the student and his immediate impression was that he was trying to swim, but as he watched he realised he was motionless and his body could be seen to sink in the water. The vessel's "man overboard" procedure was immediately implemented. At about 1145, the GPS position was "frozen" as 10° 48' South 133° 20' East and the vessel turned and the man overboard signal sounded.   The rescue boat was launched and was in the water within three minutes of the explosion. The Master directed the boat, by VHF radio, towards the smoke float and the spot where he had last seen the body.

After a short time, when he realised that the body of the student could not be located, the Master sent a PAN PAN call on single side band radio, 2182 kHz and VHF Channel 16, When there was no immediate response he persisted in the urgency calls and activated the automatic distress signal in the SSB High Frequency radio unit.

Search (All times are for time zone UTC - 1000)

At about 1133, Concordia's Master activated an automatic distress alert on Inmarsat C, using one of the vessels two Inmarsat transceivers. The call was received on the Global Distress Circuit and passed to the United States Coast Guard (USCG) Pacific SAR Communications Centre, Alameda, California, which relayed the distress call to MRCC Australia. No details of the type of emergency were included in this first or subsequent automatic transmissions.

The Master also used the emergency frequency 2182 kHz to broadcast a series of PAN broadcasts.

Darwin Radio received the first of these at 1139 stating that the vessel had lost a man overboard in position 10° 48' South 133° 20' East. Darwin radio responded to the call, but their reply was not received by Concordia. Darwin Radio noted that the calls from Concordia were repeated every five or so minutes on 2182 kHz, but there was no acknowledgment of the response from Darwin Radio.

At 1200, the Maritime Rescue Coordination Centre received notification from Darwin of the report from Concordia. At 1203, MRCC tried to contact Concordia by Inmarsat C and when this proved unsuccessful MRCC passed the same message through Darwin Radio. At 1252, however, the Master sent a message to the MRCC via the USCG reporting the situation and requesting helicopter assistance. This was received in Canberra at 1312.

At 1312, MRCC sent an "Urgency" message to all ships, checked to establish whether there were any ships under the Australian Ship Reporting System in the area, and checked the currents and weather in the area. The Royal Australian Navy was also contacted but they had no units in the area.

Air Services Australia identified two aircraft, one fixed wing and one helicopter which were available in Darwin to respond to the search request. At 1325, MRCC sent a message to Concordia advising the Master of the aircraft details and requesting that the vessel should establish direct communications with MRCC. This message was not sent to the vessel by Inmarsat due to a bar which had been placed on that particular Inmarsat receiver.

At 1507, MRCC again attempted to establish a direct telex link through Perth Land Earth Station, but the number remained barred. An alternative number to a second receiver was used and a direct link was eventually achieved and the Master was told that the helicopter would arrive at about 1600 and that direct contact should be made with the helicopter on Channel 16 VHF.

At 1435, the helicopter left Darwin with a doctor on board. The fixed wing aircraft took of at 1450, arriving at the search area at 1529 and leaving the search area at 1815, having found no trace of the student. The helicopter arrived at the ship at 1611 and MRCC was able to make direct voice contact through the helicopter. However, the helicopter only had sufficient fuel for about one hour on station and returned to Darwin at about 1700.

Direct voice communication with the vessel was lost until contact was made through Darwin Radio at 1915.

The search had been suspended with the loss of daylight and the Master outlined his plans for the following day, accepting the offer of an aircraft to assist. After consultation with the Master about the drift being experienced, a search area for a fixed wing aircraft was established for the following day, in a square bounded by 10° 40.5’ South and 10° 55.5 South and 133° 17.5’ East and 133° 32.5’ East.

The following morning at 0656 on 6 May, another fixed wing aircraft left Darwin, arriving at the edge of the search area at 0753.

At 0800, Concordia’s Master sent a message requesting a larger search area, based on the overnight drift, estimating the position of the man overboard as 10° 52’ South 133° 30’ East. At 0832, the Master notified MRCC that Concordia would search to 1200 and then proceed to Darwin.

The aircraft searched using ½ mile track spacing until 0958 when it flew to Maningrida, a small settlement about 90 miles to the south to refuel and to allow the crew to rest. It returned to the search area at 1014 and completed its task in the area at 1245.

No sign of the student could be found and at 1227, Concordia’s Master advised that the search had been abandoned. A short memorial service was conducted on board Concordia and, from a position 10° 52.34’ South 133° 31.4’ East, the vessel resumed course for Darwin, giving an ETA of 2000 on 7 December 1996.

Darwin

The vessel arrived in Darwin just after midnight on 8 December 1996, and police and a surveyor from the Australian Maritime Safety Authority, appointed by the Inspector to investigate the accident, boarded the vessel. The Investigator conducted interviews and inspected the vessel in an investigation entirely separate from the investigation conducted by the Northern Territory Police and other interested parties.

While in Darwin the vessel undertook repairs and a new battery box was constructed from timber and positioned on the open deck.

The vessel sailed for Bali on 14 December 1996.

Comment and analysis

Source of ignition/explosion

The explosion occurred at main deck level on the port side of Concordia's after deck house in way of frame 22, below the wheelhouse. Based on the evidence of the timing of emergency messages, the explosion occurred between 1130 and 1133.

On the morning of 5 December 1996, Concordia was making good a speed of between six and seven knots with an extremely light wind on the starboard beam. The air flow which the forward motion would have created for any naturally vented or partially enclosed spaces would have been minimal.

In Darwin, the battery locker and surrounding area were inspected for any possible source of the explosion. The only possible source, considering all the evidence and the lack of burning or blast damage, was that of an accumulation of hydrogen gas within the battery locker. Hydrogen and oxygen are given off as part of the chemical reaction when batteries are charged and distilled water is broken down. This results in the potential to form an explosive mixture within any enclosed space housing batteries.

The explosion was most probably caused by sparks from the grinding machine igniting the explosive hydrogen/oxygen mixture within the battery locker. The door and the blast of the explosion hit the student with such force that he was thrown against the vessel's port side rail, which broke with the impact, and he was propelled overboard.

The battery locker door was a flat steel hinged plate with channelled edges for a soft rubber weather seal. Four hinged bolts with wing nuts were fitted to the bulkhead, corresponding with lugs welded to the door plate, which secured the door and made it weather tight. There was no hasp by which the compartment could be secured by a padlock. The door could be secured open at various angles by a retaining bar fitted on the inside of the door frame and connected to a bracket on the door itself by a bolt and securing dog.

Close examination of the battery locker door hinges showed signs of a tensile failure (necking at the point of fracture) and the door was perfectly formed in an arc shape about its vertical axis, with a displacement at the centre of the door of about 80 mm. A light grey sooty deposit was evident on the bulkhead around the wing nuts as evidence of combustion. The door sill plate, a 150 mm x 12 mm rolled steel plate, was buckled on the hinge side.

Following the explosion, the door was found in a canted position against an adjacent ladder, held only by the retaining bar; both hinges had failed. Internally, the after bulkhead structure of the battery locker was distorted, showing heavy bulging with a displacement of up to 100 mm. A small, light steel door, covering a fire hydrant 2 m aft and above the battery locker door, was found on deck with its brass hinges fractured and a large fold across its surface.

The heavy wooden ship's side cap-rail, on the port side adjacent to the battery locker was completely fractured with one of the stanchions bent outwards. Deposits of bone, hair and flesh were taken from the rail by the attending Police Pathologist.

Surveys

Lloyd's Register of Shipping submitted that the electrical installation complied with the "Code of Safety for Special Purpose Ships" and the relevant provisions of the International Safety of Life at Sea Convention, 1974, as applicable in 1989. The battery locker was assessed on that basis, which fulfilled the Class Rules for the Classification of Ships in addition to the Yacht Rules.

In covering the requirements for precautions against shock, fire and other hazards of electrical origin, the Code requires compliance with Regulation 45 of Chapter II-1 Part D of SOLAS 74. Regulation 45.9.1 requires that "accumulator batteries shall be suitably housed, and compartments used primarily for their accommodation shall be properly constructed and efficiently ventilated". Lloyd's Register submitted that the pertinent classification and statutory requirements relating to the ventilation of the battery locker were complied with for the type of batteries originally carried.

When the vessel was built and first in operation, the battery cells were vented by an elaborate system of plastic pipes connected to a 4 mm internal diameter tube which pierced the bulkhead forward of the access door, and allowed the gas to escape to the open air. These batteries were removed and replaced by smaller batteries in about 1993, but the system of plastic pipes was not modified or reconnected and no alternative venting arrangements were made until the survey of 1995.

The battery space is only accessible by a small, 600 mm x 600 mm, door in the port side of the compartment. The only other openings in the locker were one small hole (4 mm diameter) in the external bulkhead, just forward of the door, and a hole in the after outboard deckhead, measured by the Investigator as 10 mm diameter, with a 20 mm internal diameter pipe welded outside on the deck. This latter pipe was fitted in July 1995, reportedly a requirement of the classification society surveyor, supposedly to improve ventilation of the space.

In July 1995, Concordia underwent a number of statutory flag State surveys, including its third mandatory annual survey covering safety construction. The surveys, on behalf of the Bahamas Maritime Authority, were conducted by a surveyor from Lloyd's Register. At interview in Darwin, the Master, (who was Mate in July 1995), the Second Mate and the Chief Engineer recalled that the Class Society Surveyor required the battery compartment to be fitted with "better ventilation". The Master recalled that a pipe was found in the engine room and, with the agreement of the surveyor, a hole was drilled in the deckhead and the pipe welded over the hole. According to this evidence, the survey certificate was issued to Concordia in Halifax, the port after North Sydney, only after it was confirmed the new pipe had been installed.

Lloyd's Register, however, have stated that the Society has no record of any recommendation made by the Surveyor at the time of the survey in July 1995. The Society submitted that the battery system had been altered to such an extent that the original battery type with a dedicated ventilation system had been replaced by a type which requires that any space in which they are located be provided with adequate ventilation. The Society noted that the battery arrangements had been modified and improvised in service, apparently without the application of professional standards of knowledge or expertise.

Although, in strict terms, legal responsibility for ensuring the battery compartment meets any requirements for the adequate ventilation may rest with the vessel's owners, owners, particularly small owners with minimum professional marine infrastructure, rely heavily on classification and statutory surveys to ensure compliance with rules and regulations. The fact that the modified battery arrangement had been in place when the vessel had undergone a statutory survey and Port State Inspections, but had attracted no comment, other than those alleged at survey in July 1995, indicated to the owners, Master and others that the vessel complied with requirements.

The battery supply

Three sets of batteries, the “Emergency”, “Radio” and “Fire detection system” batteries were kept in a compartment under the wheelhouse. The compartment was approximately 2.6 cu m, with a length of 1.695 m, breadth 1.42 m and a height of 1.08 m.

The large radio and emergency batteries are heavy duty, 210 ampere- hour capacity, lead acid, open venting type. Each set is connected in series/parallel to give a 400 ampere-hour capacity. The emergency battery bank (of four batteries with six cells) serves as the reserve source of energy in the event of an interruption to the main power supply. The radio battery bank, also of four batteries with six cells, is constantly in service for radio power and connected to an automatic charging system, ensuring the batteries remain in a fully charged state. In periods of low energy demand a trickle charge provides for the internal losses due to “self discharge” within the battery. The emergency lighting batteries were connected to a manual charging system. Depending on the battery cell condition and on service demand, the main charge current could vary from a few amps to 100 amps for the emergency batteries and 40 amps for the radio set.

The fire detection system batteries, consisting of two sealed “no maintenance” batteries each of six cells, provided power for the remote fire detection system and indicator board. These two batteries have a charging rate of 10 amperes. Although of a sealed type (where release of hydrogen is minimised under normal operating conditions) under conditions of overcharge or electrical abuse, significant amounts of hydrogen gas can be generated. Therefore the possible release of some hydrogen by these two, relatively small, batteries cannot be discounted.

The number of batteries carried on Concordia, and their charging capacity, is similar to the 24 volt emergency installation in many large cargo vessels.

Ventilation

Lloyd’s Register of Shipping Rules for the construction of yachts requires that “adequate” ventilation must be provided for battery compartments to avoid hydrogen accumulation. However, the ventilation requirements are not quantified.

According to Australian Standard 2676, hydrogen mixed with air in proportion between 4 per cent and 76 per cent hydrogen by volume is combustible and spaces should maintain any concentration below 2 per cent.

In the normal operation of a lead-acid storage battery, a certain amount of water is lost from the electrolyte by evaporation and gassing. Gassing takes place during charging when the electrolyte is decomposed into hydrogen and oxygen. The rate of hydrogen evolution in lead acid batteries can be determined by a number of methods, one of which is by the formula: -

$$h = 0.4191 \times n \times a,$$

where "n" is the number of cells; "h" is the hydrogen evolution in litres/hr and "a" is the charge rate in amperes.

Based on a maximum charging rate of 100, 40 and 10 amperes for the emergency, radio and fire fighting batteries respectively, a total of 1458.47 litres of hydrogen could be evolved each hour. On trickle charge this would be more in the order of 25 litres/hour.

The Institute of Electrical Engineers (United Kingdom) provides the following formula for the necessary quantity of air expelled in litres per hour (Q)

$$Q = 110 \times I \times n$$

where 110 is a constant, I is the maximum current, in amperes, delivered by the equipment during gas formation (but not less than 25% of the maximum obtainable charging current) and n is the number of cells.

Taking 25% of the maximum charging current for the three banks of batteries, the total volume of air that should be expelled is 95,700 litres, or 95.7 m^3, per hour.

Assuming an air velocity of 0.1 m/sec for natural ventilation, a ventilator of approximately 580 mm diameter would be required for both inlet and outlet ventilators.

The Australian Standards publication 2676, a “Guide to the installation, maintenance and testing of secondary batteries in buildings” in part 1 details requirements for the minimum exhaust ventilation rate in litres per second (qv):

$$qv = 0.006 \times n \times I$$

where n = number of battery cells and I = maximum output rating of the charger in amperes)

Based on this formula the required exhaust rate would be 20.88 litres/second and the diameter of the ventilator, for natural ventilation, using the formula in AS 2676 for the required area (A = 100 × qv), would need to be approximately 520 mm.

It should be noted that for the required airflow in either case, an inlet ventilator of equivalent size must also be provided. There was no inlet for air to the battery locker aboard Concordia. The two openings in Concordia’s battery locker (the 4 mm pipe in the bulkhead and a 10 mm diameter hole in the deckhead) would have allowed no effective

Door deformed in an arc shape about its vertical axis, displacement about 80 mm

Port side main deck battery locker door

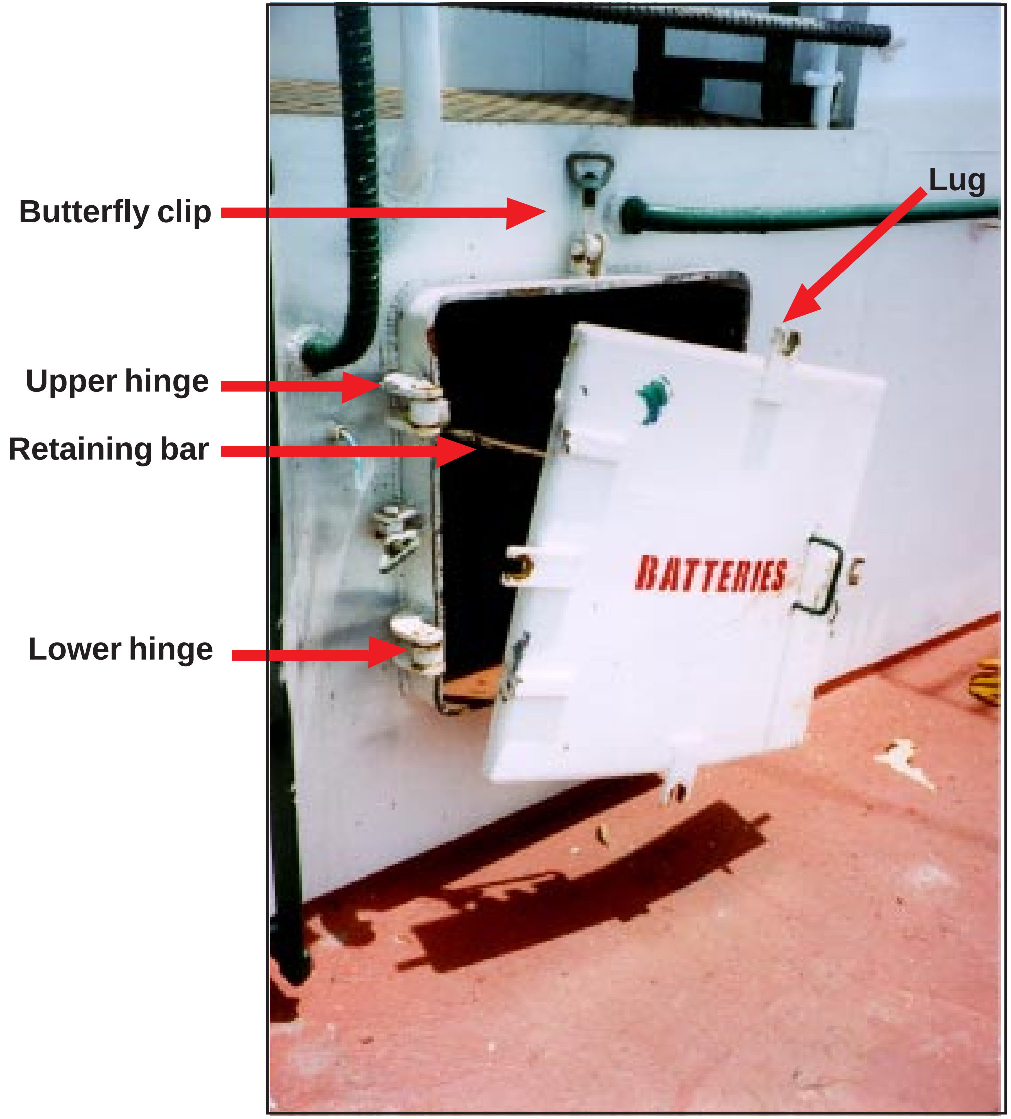
ventilation and was totally inadequate to maintain a safe atmosphere inside the battery compartment.

The Institute of Electrical Engineers publication "Regulations for the Electrical and Electronic Equipment of Ships with Recommended Practice for their Implementation" under Section 14 (Batteries) paragraph 14.12 (5) states that:

> *"Batteries in compartments or boxes connected to a charging device with a maximum power output of more than 2 kW should be ventilated by mechanical exhaust."*

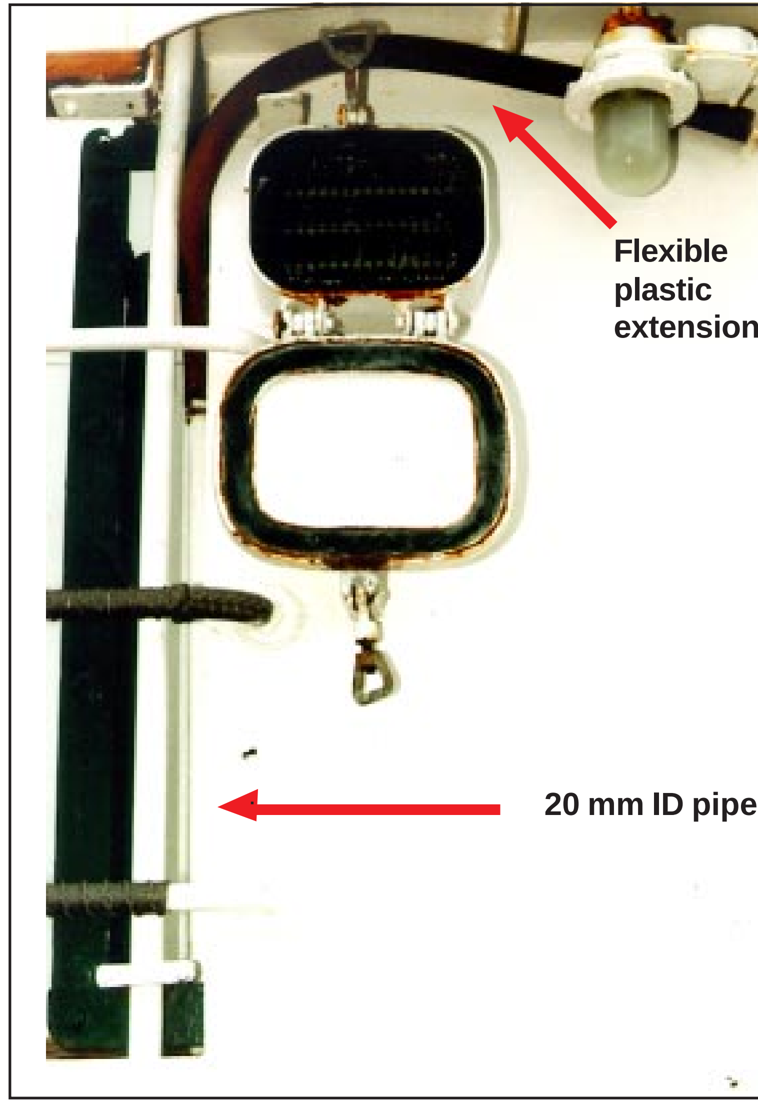
The maximum output of the charger for the emergency batteries was 100 amps at 24 volts, ie. 2.4 kW. The IEE publication thus indicates that mechanical ventilation should have been fitted.

In submission, the owners stated that the assumptions made about the venting capacity should give consideration to the additional air exchange capacity created by the 600 mm x 600 mm battery locker door.



Port side main deck battery locker door

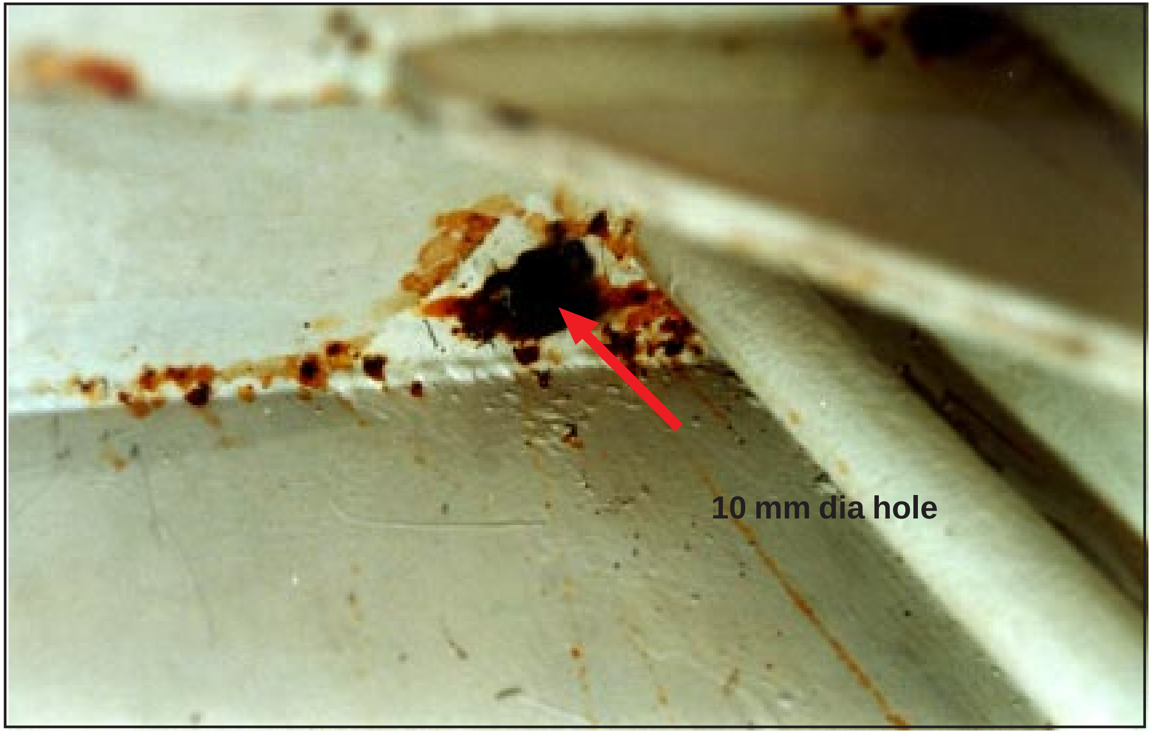
However, the Inspector cannot accept this submission. Opening the battery locker door, even if left open for some time, would not necessarily remove the explosive mixture as ventilation would depend upon the direction and force of the ship generated breeze and no through draft could be created, there being no opening on the opposite side. The IEE standards indicate that mechanical ventilation would have removed any dangerous atmosphere. The concept is to maintain a safe atmosphere at all times, not just when deliberate access was required.



Portside outside wheelhouse

Although built to class yacht rules, and the battery locker apparently surveyed as such, the certificates issued by the Bahamas Maritime Authority are those for a cargo vessel. The Cargo Ship Safety Construction Certificate was also issued under the Safety of Life at Sea Convention, although Concordia is not a Convention vessel. Lloyd's Register Rules and Regulations for cargo ships of Concordia's size (Chapter 2-1.9.5) requires effective natural ventilation or, if this cannot be achieved, a mechanical ventilation system.

There is, in the Inspector's opinion, something of an anomaly in a vessel classed as a yacht being issued with cargo ship certificates. Should the vessel's construction survey treat it as a yacht or a cargo vessel? It is clearly evident that the rigid application of the less onerous class rules for yacht construction was inappropriate for the number, capacity and charging rate of the batteries actually carried. The generation of hydrogen is a function of the number of cells and the charge rate, not the type of vessel construction.



Locker deckhead

The risk posed by a gaseous atmosphere within the battery locker had been present since the vessel was built, more particularly when the original batteries, with their venting system, were replaced by new batteries in 1993 and no effective ventilation was installed.

Lloyd's Register maintains that the original battery arrangements (the venting by way of plastic tubing) were not inherently unsafe or unsuitable for their intended purpose and that inappropriate rules were not applied during construction. However, the provision of plastic tubing to assist in the removal of hydrogen gas directly from the battery cells, in the Inspector's opinion, has no bearing on the ventilation of the battery locker.

The total battery capacity and charging rate show that, in Concordia, dangerous levels of hydrogen were generated without adequate ventilation. In the absence of such ventilation, the space within the enclosed bridge/wheelhouse structure was unsafe.

Maintenance

The maintenance of the batteries on board Concordia came under the Chief Engineer's general area of responsibility. The Second Engineer carried out weekly inspections of the batteries (more frequently if necessary), including a check on the electrolyte level. No record was kept of these inspections, however the two engineers confirmed that the last inspection had been made on 24 November, while at Heron Island.

Both engineers were asked by the Investigator to describe the precautions they took when entering the battery space and checking the batteries. They were also asked what hazards existed. Both emphasised that the confined space could become very hot and that there was a risk from the battery acid. It was only after a number of questions relating to entry to the locker, when heat continued to be offered as the prime reason to allow the space to vent, did the Chief Engineer show awareness of the possible dangers of explosion.

In the Inspector's opinion, the danger of the evolution of hydrogen gas seems to have been only remotely recognised and nobody on board seemed to appreciate or equate an abstract concept with the actual danger in terms of the safety of the vessel.

Passive defences

The battery locker door was marked with the word "BATTERIES" in large red letters. An internationally recognised warning sign, indicating corrosive acid and the dangers of corrosive acid burns, was fitted on the internal bulkhead.

There were no warning signs prohibiting naked lights and smoking. Such signs are not required under the classification society's rules for yachts, although they are required under the same society's rules for cargo ships

Additionally, such a warning is a requirement where the rules of Institute of Electrical Engineers are adopted as a standard. At Section 14.10 (4) it states;

> *"A permanent notice should be exhibited prohibiting naked lights and smoking in battery compartments."*

No other measures, such as hazard signs to warn of the risk of explosion, or means to prevent entry to the locker, were put in place.

Ship organisation

The general operation of the ship was effective and overseen in a professional manner with safety of personnel as the main consideration. The students, under supervision, tended sails including, in appropriate conditions, laying aloft to set or furl sails. Students were only allowed in the accommodation and on deck and were not allowed in the engine room or locker spaces.

The professional crew are responsible for the sailing of the vessel and overall safety. The students, in addition to academic work directed by teaching staff, undertake seamanship duties and follow a watch pattern. All on board attended frequent emergency musters and drills, including “man overboard”, fire and abandon ship, these were held at least once each week. The response to the man overboard situation on 5 December was immediate and professional.

Safety meetings to raise awareness of and to discuss potential dangers were held occasionally, as deemed necessary. The last such meeting had been held about mid November, when the topic discussed had been the appropriate dress, protective equipment, safety harnesses and adequate competency in the use of machinery or power tools.

The Mate assigned the work for the day to the Bosun’s Mate in very general terms. The task was to complete painting the deck housing, mostly on the starboard side. He gave no thought to the possibility of somebody removing rust with a grinder in the vicinity of the battery locker and, even if he had, the Inspector is not confident that he would have appreciated the risk. The Master stated that the main engine, the vessel’s generator and two grinders being used at the same time made it impossible to detect the exact location of where the grinding was taking place.

The Bosun’s Mate understood the batteries to be no more dangerous than a car battery. Both the Chief and Second Engineers had to be prompted by the Investigator to consider the production of hydrogen from the batteries. The Inspector believes that neither the student involved, nor the Bosun’s Mate could be expected to fully appreciate the potential danger and explosive energy that could be generated by the accumulation of hydrogen from the ship’s batteries.

The Master submitted, “all of the professional crew were aware of the danger of the evolution of hydrogen gas. However, they could not be aware of the accumulation of hydrogen as they were under the impression that the locker was properly ventilated.”

The danger, although always present, was invisible and was not that encountered in the students’ normal routine associated with working on the exposed deck or when aloft. Painting and scaling of the battery locker door was an infrequent event.

In the Inspector’s opinion, there was a general lack of awareness by all on board, either by oversight or lack of perception, of the potential dangers associated with the battery locker. The Investigator found that there was a lack of appreciation of the consequences of the release of hydrogen in such an enclosed space and of the attendant hazards.

Search

The search operation involved three different time zones; Concordia was keeping UTC -10 hours; USCG at Alameda California and the MRCC, Canberra kept UTC; Darwin was on UTC -0930.

The emergency occurred in a very remote area of the Australian coast, the closest centre of any size and with suitable resources was Darwin, 170 miles to the west-south-west. The response by the search and rescue services was immediate and consistent with the emergency. In all the three aircraft were airborne for 14 hours and were in the search area for 7.3 hours, a measure of the remoteness of the search area.

Concordia was not visited by an AMSA surveyor while in Brisbane and it is evident that whoever acted as the vessel’s agent did not supply a copy of the Australian Ship Reporting System guidelines. This scheme is mandatory for vessels to which the Navigation Act applies.

A master is required to furnish a sailing plan and report daily to the MRCC in Canberra. Had Concordia been following this scheme, the response to the emergency situation would have been considerably more rapid. Time was lost in passing messages through the USCG California and in the delay in making direct contact with MRCC.

However, these delays had no bearing on the outcome of the search.

Overview

In attempting to balance hindsight with the practicalities of the situation as faced by those responsible for the operation and safety of a vessel, the Inspector applies six tests of safety management.

1. Were the risk factors identified or identifiable?

   The risk posed by hydrogen given off from batteries is specifically recognised in Lloyd's Register's Classification Rules for Ships. The rules require adequate ventilation and warning notices prohibiting smoking and naked flames. However, the class rules for yachts, under which Concordia was constructed, only require "adequate" ventilation and have no requirement for any warning notices, despite Concordia's battery capacity and the number of people carried. The risk is such that it is specifically recognised in the regulations of the Institute of Electrical Engineers.

2. Was the equipment in use fit for the purpose?

   The equipment in this case refers to the locker in which the batteries were housed. The locker was an integral part of the ship's structure but was provided with no effective ventilation, neither natural nor mechanical. The battery locker was inherently unsafe and not fit for its intended purpose.

3. Were the systems and procedures on board effective to maintain safe operation?

   There was no effective venting system and no simple lock to secure the battery space to prevent inadvertant access. These factors, together with the lack of appreciation of the risk, resulted in unsafe operation.

4. Were the individuals involved fit, competent and effective?

   The Master and crew held the necessary qualifications. All on board were apparently fit, competent and effective in relation to the normal running of the vessel, but these attributes did not extend to the particular circumstances attending this tragic accident. In terms of training, the level of awareness and appreciation of the risks by the professional staff on board was not at such a level to prevent the accident in the absence of other defences.

5 Were defences and emergency procedures effective?

There were no effective defences to guard against the risk of fire/explosion in the battery locker. There was no effective ventilation, no signs warning of the danger of explosion and the locker was not secure against inadvertent opening.

The emergency procedures as conducted by the Master, Concordia's crew, the academic staff and students had established an effective, well understood and well drilled system.

6. Was there a management system to monitor performance?

In terms of the vessel's owners, there was no such system which would have prevented this accident. There was total acceptance of classification society standards as providing the safety bench mark by the owners, Master and professional staff, and, according to the Class Society, they were not notified of the equipment change involving the replacement of the original batteries.

In the case of the classification society, if the Master's recollection of the 1995 survey is accurate, the absence of any record of the requirements made by the surveyor in 1995 suggests a breakdown in communication.

Conclusions

These conclusions identify the different factors contributing to the incident and should not be read as apportioning liability or blame to any particular individual or organisation. The following factors are considered to have contributed to the loss overboard and death of the student from Concordia:

1. A spark from the grinder being used by the student ignited the hydrogen air mixture causing an explosion within the battery locker.
2. The student took the full force of the blast, which threw him through the vessel's port side rail and thence overboard, resulting in his death.
3. The ventilation of the battery locker was totally inadequate and no objective assessment of the ventilation requirements had been made, after the original batteries were replaced. However, the changed battery arrangement was in place in the survey of July 1995 and the inadequate ventilation should have been apparent to the survey authority.
4. There was no safety sign warning of the hazard of explosion due to the build-up of hydrogen gas.
5. There was a lack of perception of the potential dangers presented by the enclosed battery locker and by the accumulation of hydrogen gas.
6. The application of the Classification Society Rules for the Construction of Yachts, to a battery installation of this size and charging capacity, was inappropriate.
7. The Owners, Master and Officers seem to have placed too great a reliance on the Society to act as a de facto company superintendent in matters of ship safety standards, indicating a seemingly common misunderstanding of the role of classification societies.

Submissions

The provisions of sub-regulation 16 (3) of the Navigation (Marine Casualty) Regulations require if a report, or part of a report, relates to a person's affairs to a material extent, the Inspector must, if it is reasonable to do so, give that person a copy of the report or relevant part of the report. Sub-regulation 16(4) provides that such a person may submit written comments or information relating to the report.

The final draft of the report, or parts of thereof, was sent to the Master, Owners, the Assistant Bosun, the College representatives and Lloyd's Register.

Master

A number of submissions were received from the Master, some of which have been incorporated into the text. In addition the Master commented:

Ventilation

Please note that the new battery locker (as was the old), was constructed under the supervision of Lloyd's Register, whom we rely on for their expertise, does not meet your requirements. Moreover, the new battery locker, after reference to several guidelines, was constructed under the supervision of the AMSA surveyor. According to your more recent standards for ventilation, requiring 580 mm intake and 580 mm exhaust ports, your surveyor's requirements have changed. It is clear that there is a marked discrepancy between you and Lloyd's Register.

All of the professional crew were aware of the danger of the evolution of hydrogen gas. However, they could not be aware of the accumulation of hydrogen as they were under the impression that the locker was properly ventilated. Even the professional surveyors had difficulties in establishing how a properly ventilated locker should be constructed.

Overview, in reference to securing the battery locker:

Even on the new battery locker there was no suggestion from Lloyd's Registry nor AMSA to place a lock on the compartment to secure the battery space to prevent accidental access.

Owners

Submissions were received from the Managing Director on behalf of the Owners;

The Owners made a number of submissions which have been incorporated into the text. In addition they submitted:

"My recollection of the testimony and following review of the recorded tapes of [the Assistant Bosun's] report, indicated that neither the mate, nor [the Bosun's Mate] specifically pointed out the rust on the slotted lugs which form part of the battery locker hatch. On the contrary, [the Bosun's Mate] reports that she did not recall showing [the student or asking [him] to work on the hatch.

During the interrogation of the engineers, a translator was used to ensure that both questions and responses were understood. The police interrogator asked general and leading questions which, in another context, might have evoked freer responses. A question such as "Are you aware of any dangers associated with the handling of batteries?" was answered by a simple "yes". If I recall correctly, the inspector was looking for a response that showed a measure of recognition of the inherent dangers of hydrogen gas but didn't receive a response until he asked "Are there any dangers associated with the emission of hydrogen gasses during charging?" to which the answer was "yes". I see no reason to conclude that only after prompting by the investigator did the Chief Engineer express "some awareness of the possible dangers of explosion. This in my opinion, is an incorrect interpretation of the Chief's responses.

Inspector's comment:

The Managing Director was not present during the interview with the investigator. The report accurately reflects the evidence. His recollection may be confused with the interview conducted by the Police, at which he was present.

Other topics covered by the submission include:

Ventilation

It would appear, assuming the formulae and calculations submitted are correct, that were the Institute of Electrical Engineers (Australia) recommended practice for implementation of electronic equipment applied, (the Concordia's charger output was, maximally 100 amps at 24 volts or 2.4 kW) the Concordia would have , during maximum charging, exceeded the 2 kW level by .4 kW. It should be noted that this system for charging is manually activated by authorized personnel only, whose practice is to open the hatch fully during charging for the 100 amp system. Consequently, the assumptions made about venting capacities should give consideration to the additional air exchange capacity created by the hatch opening.

Passive defences

This section, dealing with passive defences, makes reference to rules and regulations applied and the offers a scenario under which a hypothetical class might prescribe different rules and regulations. It must be made clear that that the Concordia was built, was and is classed, by Lloyd's Register, as a 100A1 yacht. The vessel met, and continues to meet every class regulation or rule. The vessel met, and continues to meet all of the rules and regulations pertaining thereto.

In simple terms, the Concordia is not a passenger ship and never has been. It is, in my opinion, facile to choose a class rule which applies to another type of vessel and make the assumption that, were it applied in this case, it might ... and only might have changed an outcome. Since you have addressed this report to the owners' office, the owners wish to make abundantly clear that they have, throughout design, construction and operation, complied fully with class requirements and further, have had U.S. and Canadian Coast Guard Safety Inspections. While it is true that we had not posted warning signage recommended by the Institute of Electrical Engineers, the owners deferred to the independent expertise of a class society, Bahamian Registry requirements and two demanding Coast Guard authorities. While in Darwin, and during the investigation, the assembled expertise (Lloyd's Surveyor, A.M.S.A Surveyor and a third independent Surveyor hired by the owner) could not find a single reference in their bibliography of rules, regulations and guidelines that prescribed battery locker size, battery locker venting systems or battery locker signage.

Overview 5:

This statement is clearly made in error. The Classification Society's rules were both appropriately and completely applied. If the writer is suggesting that the Classification Society should modify its rules for 100A1 yachts, then I suggest that it be written that way.

Overview 6:

There appears to be a consistently ignored element in this report, that being, the prescribed regulations of and inspections by the Bahamas Maritime Authority. Indeed, and contrary to your statement in # 6, there is a system provided by the owners to prevent such an accident. That system was and is to engage respected and qualified expertise to ensure a safely constructed and operated vessel. There are five witnesses to the surveyor's requirements for renewal in 1995. There was, in my opinion, no breakdown in communications. If the classification society did not record the prescribed action, it does not, in my opinion, have anything to do with how well the communication was made or received. It was an expert's requirement, made as the appointed representative of the Classification Society. The owners willingly complied.

General

As owners, we cannot offer scientific expertise and, therefore, cannot speculate as to cause. However, it would seem that little has been said of the batteries themselves. Is there something to be said about the amount and frequency of charging, normally required, when they are never or seldom used? Is there a place for such a statement in the conclusions?

The Managing Director, on behalf of the Owners concluded:

I am not comfortable that I have exhausted nor understood nor even accept all of the scientific assertions. This part might better be answered by the Classification Society.

We are interested in establishing and acting upon those measures that can be taken to avoid any future accidents of this nature. To be sure, no Class Society and no Safety Authority has been able to say, with *any degree of certainty, what must or should be done. At our own initiative, awaiting further "expert" advice and regulations, we have moved the battery locker to the open mizzen deck, re-routed conduit and plastered the aerated plywood box with all the appropriate signage.*

Lloyd's Register

Lloyd's Register made a number of submissions which have been incorporated into the text. In addition they submitted:

Following very thorough investigation, we are satisfied in this office that the alterations to the battery arrangements were not carried out under LR survey and were not brought to our attention by the Owners representative as required under the Classification Regulations.

We also believe that the pertinent classification and statutory requirements were complied with for the type of installation originally fitted. While the comments in the report may be appropriate to the arrangements found on board following the incident, they are not considered to be so in respect of the arrangements approved by our surveyors during construction. In particular, we are unable to agree with the Inspector's comment that the risk posed by the gaseous atmosphere within the battery locker had been present since the vessel was built. We do not consider the original battery arrangements were inherently unsafe or unsuitable for their intended purpose, or that inappropriate Rules were applied during construction and we have seen no evidence of this.

We have striven, without success, to ascertain if there could be any basis in fact, which might account for the statements of the Master and Second Mate as to the survey in Canada in July 1995. In particular, we have verified that our Surveyors were not involved with modifications to the battery or battery room arrangements. Lloyd's Register believes your report is incorrect in this respect. Therefore having investigated this matter comprehensively with our Surveyors and with respect to our own records, we are satisfied that there was no breakdown in communications within LR and we were not advised by the Owners of any modifications to the battery room arrangements, as required by the applicable Rules and Regulations, in 1995 or at the time of the incident.

As these modifications affected arrangements covered by the Classification Rules, notification of changes to the battery arrangements should have been given to LR by the Owners as provided for in our published

Classification Regulations, Part 1, Chapter 2, Section 3.4.6, as printed on Lloyd's classification certificates given to owners which states:

"Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval, and such alterations are to be carried out to the satisfaction of LR's Surveyors."

Failure of an Owner to comply with this requirement is in contravention of the Classification Regulations. SOLAS contains a corresponding provision in Chapter 1, Regulation 11.

Ship details

Name	Concordia
IMO Number	1001269
Flag	Bahamas
Classification Society	Lloyd’s Register
Type	Yacht
Builder	Colod Co Ltd, Szczecin, Poland
Year	1992
Owner	West Island College International, Nassau, Bahamas
Gross tonnage	413
Net tonnage	123
Summer draught	4.037 m (approx)
Length overall	58.1 m
Moulded breadth	9.44 m
Engine	MAN/DEMP 12 cyl
Engine power	313 kW
Crew	39