Report on the investigation

of the escape of steam and hot water on board

Queen Elizabeth 2

in the mid Atlantic

resulting in one fatality

23 June 2002

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Report No 17/2003
July 2003

Extract from

The Merchant Shipping

(Accident Reporting and Investigation)

Regulations 1999

The fundamental purpose of investigating an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 is to determine its circumstances and the causes with the aim of improving the safety of life at sea and the avoidance of accidents in the future. It is not the purpose to apportion liability, nor, except so far as is necessary to achieve the fundamental purpose, to apportion blame.

NOTE

This report is not written with liability in mind and is not intended to be used in court for the purpose of litigation. It endeavours to identify and analyse the relevant safety issues pertaining to the specific accident, and to make recommendations aimed at preventing similar accidents in the future.

CONTENTS

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

CM	:	Chief mechanic
ECR	:	Engine control room
EGB	:	Exhaust gas boiler
IACS	:	International Association of Classification Societies
IS&AC	:	Information Search & Analysis Consultants
ISM	:	International Safety Management Code for the Safe Operation of Ships and for Pollution Prevention
LR	:	Lloyd's Register of Shipping
MCA	:	Maritime and Coastguard Agency
MGN	:	Marine Guidance Note
QE2	*:*	*Queen Elizabeth 2*
SI	:	Statutory Instrument
SMS	:	Safety Management System
SOLAS	:	International Convention for the Safety of Life at Sea
US	:	United States

SYNOPSIS

While on passage from New York to Southampton, two engine room crew on board the passenger cruise ship *Queen Elizabeth 2 (QE2)* were badly scalded on 23 June 2002, when boiling water suddenly discharged from a pipeline. One of the men subsequently died as a result of his injuries, the other was left seriously hurt.

On 20 June, *QE2* left New York for a 6-day transatlantic passage to Southampton. During this passage, the port auxiliary oil-fired boiler was being prepared ready for survey in Southampton. The preparation involved all the boiler mountings being removed and stripped down for inspection.

The accident happened when Edgar Villasis (motorman) and Nelson Venzal (wiper) were in the process of cleaning the port boiler main steam stop valve. Hot water and steam suddenly and unexpectedly discharged from the opened body of the valve, and covered both men.

The casualties were treated on board *QE2*, and were then airlifted to hospital as soon as the ship came into helicopter range. Edgar Villasis subsequently died.

Later inspection and testing revealed that the isolating valve to the engine room steam ring main was leaking at the time of the accident. It is thought that this led to localised heating of trapped condensate in the isolated steam line, which resulted in some of the condensate boiling and escaping through the dismantled steam stop valve.

Recommendations have been made to the vessel's owner, Cunard Line, and to the International Association of Classification Societies, regarding the provision of adequate drainage arrangements for steam pipelines to this, and future, steam systems. Additional recommendations have been made to Cunard Line to ensure that safety issues are fully recognised and addressed both by management ashore and also by engineers on board its vessels.

Photograph courtesy of FotoFlite

Queen Elizabeth 2

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *QUEEN ELIZABETH 2* AND ACCIDENT

Vessel details

Registered owner	:	Cunard Line
Port of registry	:	Southampton
Flag	:	UK
Type	:	Passenger cruise ship
Built	:	John Brown & Co Ltd, Clydebank, launched 20 September 1967
Classification society	:	Lloyd's Register of Shipping
Construction	:	Steel
Length overall	:	293.53m
Gross tonnage	:	70,327
Engine power and/or type	:	9 MAN B&W type 9L58/64 each 10625kW powering 2 GEC 44 Holland MW motors
Service speed	:	28.5 knots
Other relevant info	:	Twin screw

Accident details

Time and date	:	1545 local time on 23 June 2002
Location of accident	:	45° 02'N 36°57'W
Persons on board	:	2730
Injuries/fatalities	:	1 fatality, 1 injury
Damage	:	No damage

1.2 BACKGROUND

QE2 is a passenger cruise ship which has been in service for Cunard Line since 1968. She cruises worldwide, and operates a seasonal and regular 6½ day transatlantic crossing between Southampton and New York.

During the 2001/2002 world cruise, her first engineer, and other senior engineers, discussed a proposal to prepare the port boiler for survey at the same time it was being retubed. This proposal, however, was considered impractical because the confined space around the boiler made access to work difficult.

With Lloyd's Register of Shipping's agreement, it was decided, therefore, to delay survey of the port boiler until after it had been retubed. Retubing was started in February 2002 and completed in April.

Meanwhile, it was matter of planning and preparing for the boiler survey.

Both the first engineer and the staff chief engineer agreed that work on the boiler should begin on 17 June during sea passage from New York to Southampton. This would reduce the likelihood of disruption should something go wrong with the starboard boiler. Shutting down both boilers would have caused serious disruption to the running of hotel and engine room services on board.

Their idea was that the port boiler would be ready for survey when the vessel arrived at Southampton on 25 June 2002.

An accident occurred on 23 June, at approximately 1545, during the crossing from New York. At the time of the accident, two members of the technical department, Nelson Venzal (wiper) and Edgar Villasis (motorman), were cleaning the port boiler main steam stop valve.

The two men were badly scalded when hot water and steam suddenly and unexpectedly discharged from the opened body of the valve. Edgar Villasis died subsequently, as a result of his injuries.

1.3 NARRATIVE (TIMES UTC - 1)

Before preparing *QE2*'s port boiler for survey, the first engineer examined the steam plant drawings. Then, with the daywork engineer and engineer cadet, he isolated the port boiler feed-pump by opening its main circuit breaker and shutting the valves on the normal feed line. The emergency feed line valves to both the port and starboard boilers were also closed. The valves were wired to avoid them being opened unintentionally.

With the emergency feed lines isolated, the starboard boiler was without emergency feed. In case the pump needed to be used in an emergency, the watchkeepers asked the first engineer to unwire the valves so that the pump could be reinstated.

Later, once the port boiler feed valves had been removed, and their boiler inlets blanked, the emergency feed pump valves were unwired so that the pump was available for emergency use on the starboard boiler.

The watchkeepers then went up to the 6th deck level to isolate the live steam from the port boiler. To do this, the cross-connection steam valve between the two boilers and the engine room and hotel services supply valves, were shut and wired.

The first engineer told the 12 to 4 watchkeeper to isolate the starboard dump condenser, which supports the port boiler, and to close the cross-connection between the port and starboard dump condensers. Later, the first engineer checked and found that this had been done.

The port condenser, which supported the starboard boiler, was left online.

The first engineer had instructed the watchkeepers to drain down the port boiler.

On 17 June, he checked that the boiler was drained and depressurised, and that all necessary valves were closed and, where appropriate, wired.

He ascertained that pressure was off the boiler by opening the boiler vent valve, gauge glass drains, and by listening to the boiler blow-down line as the water was blown overboard from the boiler. He intended that the manhole doors would be removed after removal of all the boiler mountings.

From 17 June onwards, the first engineer’s team started work on the port boiler. The watchkeepers did no more work on it.

The team comprised eleven people, including the chief mechanic (CM), who supervised the Filipino contingent. This included Nelson Venzal (wiper), Edgar Villasis (motorman), Efrain Garcia and Feliciano (Felix) Nagac III.

Between 17 and 22 June, the vent valve, scum valves, three EGB suction valves, two feed check valves, and both manual feed valves and gauge glasses were removed from the boiler and taken to the workshop.

Work on the main steam stop valve cover began on the morning of 23 June. This was the last of the boiler mountings to be removed.

The first engineer told the CM that his men, in this case Edgar and Nelson, could start on this valve by removing its extended spindle fixtures and every other nut on the valve cover. He told the CM that under no circumstances should they remove all the nuts, or try to raise the cover, until he was present. He was insistent that he, the first engineer, should supervise this operation.

Meanwhile, Efrain and Felix opened up the furnace front and worked on the furnace drain valves.

At 1430, the chief mechanic reported to the first engineer that the men were ready to lift the valve cover.

The first engineer and the CM knew that the isolated steam line, leading to the valve, was not fitted with drains, and that the main stop valve was a non-return valve. The non-return valve would prevent any water from draining into the boiler unless it was disturbed off its seat.

Because of their knowledge and previous experience of conditions arising after shutdown and isolating a boiler, both men were aware that water would be present in the line, and liable to leak from the valve body cover flange once the cover was slackened off and lifted from it. They also knew that any leaking water could be too hot to touch.

As a safeguard, and on his own initiative, the CM had made a splashguard to wrap around the valve cover. Once the cover joint had been broken, any water draining from between the valve cover and body flange would be directed safely downwards out of harm's way from the men.

Before lifting the cover, the daywork engineer was instructed to stand below the valve on the 6th deck, to prevent anyone from walking into the area where the water was likely to cascade downwards.

The CM, Edgar and the first engineer, loosened the cover nuts, then, using a chain block, they lifted the cover. As they raised it, gulps of hot water poured over the valve. There was no sign of pressure in the line.

As a safety precaution, the cover was lifted by about 20mm, with the nuts still screwed on the cover studs. The time was about 1455. They stopped work for their usual teabreak: the first engineer went to the ECR and the others to the working alleyway.

Just before 1530, they all met in the working alleyway and went up to the valve to finish the job. They found that water had stopped leaking from the valve.

The weather was fine and the ship's rolling was hardly noticeable.

Using the valve spindle as a lever, they rocked the valve cover to loosen the lid off its seat. Content that it was safe to do so, they removed the remaining nuts. A small amount of water cascaded out and over the valve.

They continued to rock the valve off its seat.

By observing the drained water discharging from the boiler shell opening, exposed by the removed boiler blowdown valve, the first engineer checked to see if any remaining water had drained into the boiler shell. Having assured himself that the water was not too hot to touch, the CM lifted the valve lid and its spring out of the valve body. The only water which could then be seen in the steam line was that which was left inside the valve body around the valve seat.

The first engineer understood that the water, which had been in the steam line, was condensate from steam trapped in the line, between the boiler stop valve and the valve isolating the line from the live steam side of the system.

At that point he looked into the valve body and as far up the steam pipe as he could. Both he and the CM were then satisfied that the isolated steam line contained no water or steam.

They examined the valve seat and found it in serviceable condition and ready for survey.

The first engineer and the CM discussed what to do with the valve cover. They decided that the spindle gland should be repacked, and the valve cover joint faces cleaned off, ready for inspection by the LR surveyor.

It took about 5 minutes from lifting the cover clear until when they discussed what to do. It was then 1540.

The first engineer and the CM left Edgar and Nelson to clean the valve and the flange joint faces. The CM went down to the boiler furnace front level to check the progress of boiler work on the next deck below. The first engineer went to the ECR.

About 2 minutes later, the CM, hearing a shout from above, returned to the top of the boiler where Edgar and Nelson were working. There, he saw Nelson in a distressed state, with his boilersuit soaked in hot water. The CM told him to go to the ship’s hospital.

Edgar’s state was similar to that of Nelson, but he needed assistance to reach the hospital. The CM, assisted by Felix and Efrain, who had followed the CM from below, carried Edgar to the hospital. Edgar told the CM that water had discharged suddenly from the boiler stop valve opening.

The CM then went to the ECR. He looked shocked. His boilersuit was soaked in water from Edgar as he carried him to the hospital. He told the first engineer what had happened.

In response, the first engineer went up to the hospital immediately. He found the nurses and doctors actively treating the two casualties.

Feeling distraught and in shock, and thinking that he might have been in the way, he made his way to the engineers' office to tell the chief and staff chief engineers what had happened. He then went to examine the boiler stop valve.

He observed that the valve was still dismantled, and that about every 30 seconds, wafts of steam emitted from the opening in the valve body **(see Figure 1)**.

During that afternoon, the intermittent wafts of steam continued to discharge. Concerned that more water could suddenly discharge from the valve, the first engineer cordoned off the area around it with tape, to warn people not to get too close.

The following day, 24 June, steam was still emitting from the valve body. There was no sign of water around the valve, or on the deck level below the valve, to suggest there had been a further discharge of water since the accident.

Figure 1

Photograph of valve taken by ships staff

1.4 *QE2* STEAM GENERATION PLANT

The steam plant on board *QE2* consisted of nine exhaust gas boilers (EGBs), heated by exhaust gas from each of the nine main propulsion generators on board. The EGBs worked in combination with two oil-fired boilers, working between 5 and 6 bar gauge pressure. The fired boilers could burn light or heavy fuel or sludge.

The boilers supplied steam to the hotel services and the engine room steam ring mains. The hotel services steam ring main passed through a pressure-regulating valve **(see Figure 2)** set to 4.1 bar to supply the kitchens, air conditioning, domestic fresh water heating and swimming pool heating. The engine room ring main supplied steam at boiler pressure to the engine room **(see Diagram 1)**.

At sea, steam was normally supplied by four, five or six EGBs, depending on the load on the engines and the quantity of steam required by the ship's services. The engine room watchkeepers controlled the number of EGBs online by manually starting or stopping the EGB circulating pumps as required. This was done locally, at the starter panel by the pumps. Each EGB was either online or offline; there was no method for controlling the quantity of steam output by a single EGB **(see Figure 3)**.

Figure 2

Hotel services pressure regulating valve

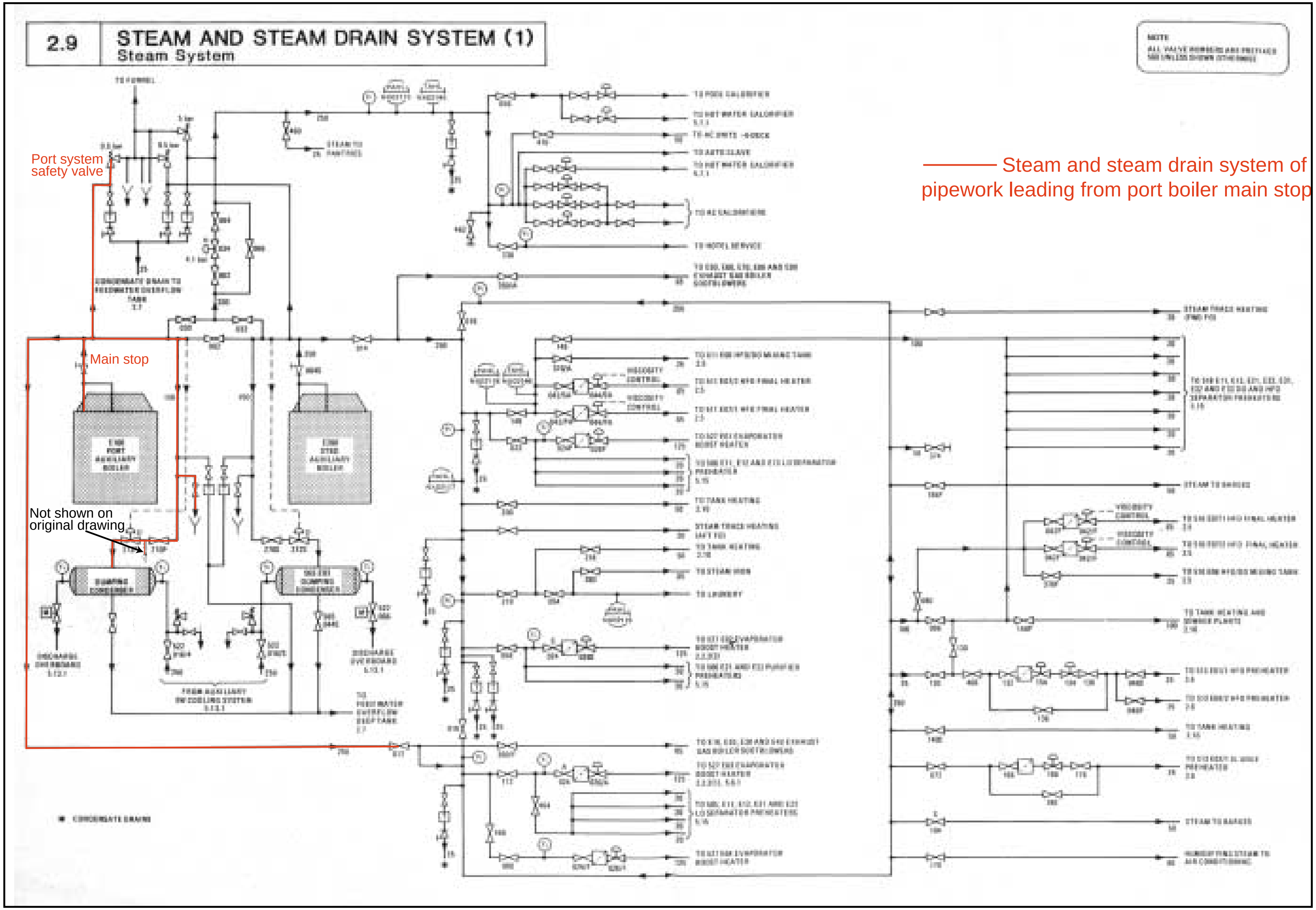

2.9
STEAM AND STEAM DRAIN SYSTEM (1)
Steam System
Port system safety valve
Main stop
Not shown on original drawing
Steam and steam drain system of pipework leading from port boiler main stop

Diagram 1

Figure 3

EGB local starter panels

If the online EGBs were producing too much steam, the system was designed to control this by using port and starboard sea water-cooled dump condensers.

Dump steam to each condenser was controlled by a pressure-regulating valve on each, set at 6.0 and 6.5 bar on the starboard and port condensers respectively **(see Figure 4)**. The condensate was returned to the feed system.

If the steam supplied by the EGBs was insufficient, one boiler would be put online to maintain steam pressure. Although two boilers could be run at the same time, one boiler online was sufficient to satisfy steam demand.

In port, the steam demand was met by one of the oil-fired boilers.

1.4.1 The exhaust gas boilers **(see Diagram 2)**

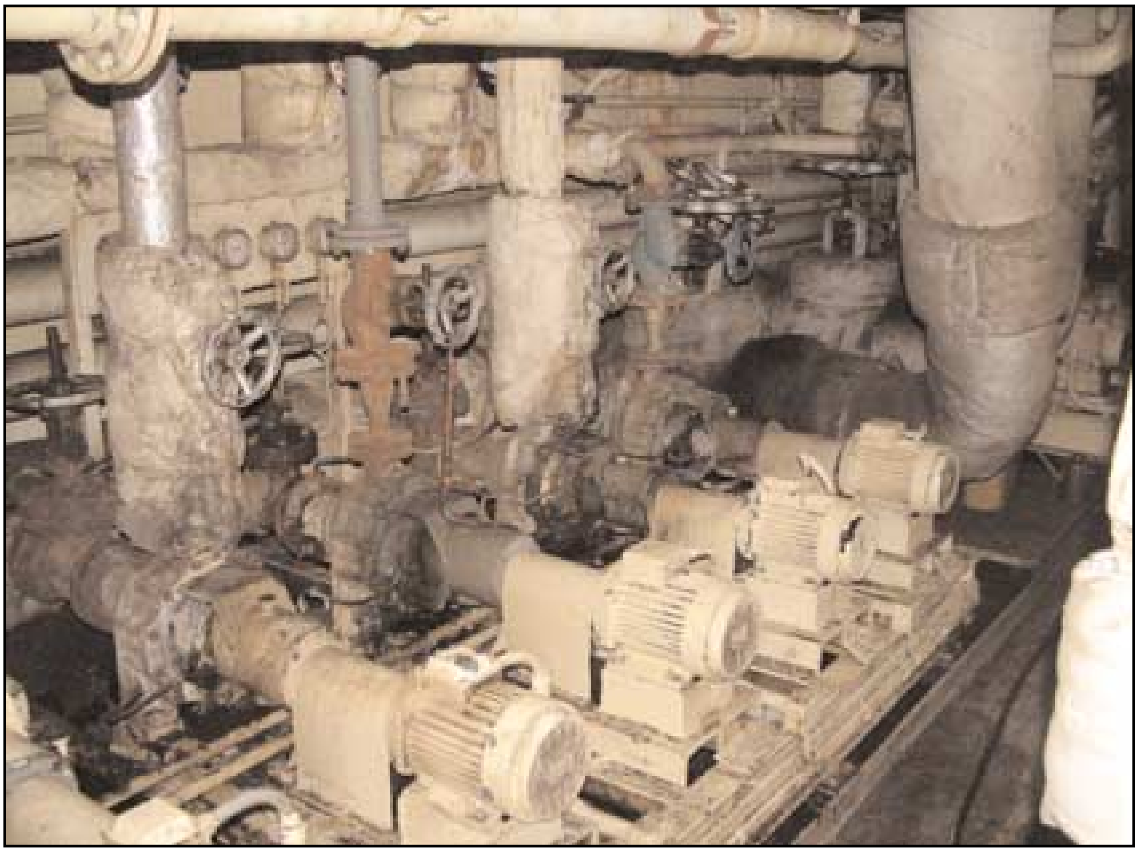
Each EGB had one feed water circulating pump **(see Figure 5)** which supplied that EGB with feed water when in service. There was also one spare pump that could supply any EGB. The EGBs were capable of being run dry, with no water circulating through them.

The EGBs for the four forward engine room main generator engines, Alpha, Bravo, Charlie and Delta, were supplied by water from the port boiler. The starboard boiler supplied the aft engine room main generator engines, Echo, Foxtrot, Golf, Hotel and India.

Figure 4

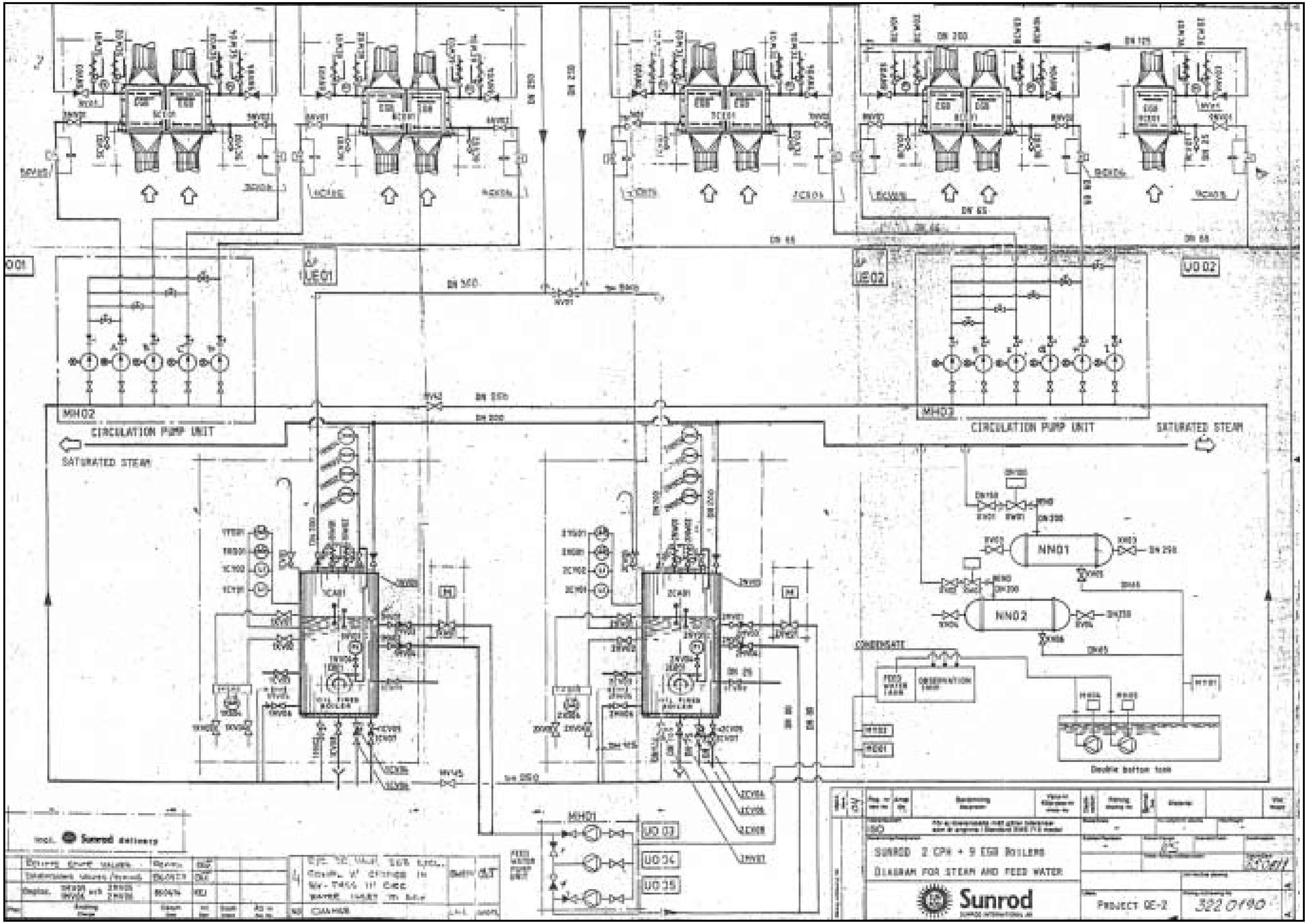
Port and starboard dump condensers

Figure 5



EGB circulating pumps

Diagram 2



Sunrod diagram for steam and feed water, showing nine exhaust gas boilers and two oil-fired boilers

The water circulated through the EGB and returned to the same boiler. Each boiler had three EGB suction valves, and one EGB return **(see Figures 6 and 7)**.

Normal operating practice was to have the cross-connecting valves open on the EGBs' return and suction lines to and from the boilers. This allowed all the EGBs in use to be run from a single boiler.

1.4.2 The oil-fired boilers

The Sunrod boilers were capable of automatic start, stop and modulation. Modulation was controlled through a feedback system which monitored the steam pressure and adjusted the fuel and air pressure to the burner assembly, thus adjusting the strength of the flame to maintain a pre-set steam pressure.

Although available, the boilers' automatic control was not used. Instead, the watchkeepers controlled the boilers manually, because it was thought that with a continuously-manned control room, a more consistent steam pressure could be achieved. In anticipation of a change in steam demand, the watchkeeper would start a boiler, either from the control room boiler panel **(see Figure 8)**, or at the local boiler control panel **(see Figure 9)**. Then, using push-buttons in the control room or on the boiler front, modulation of the burner would be set manually to match steam demand.

In addition to the safety valves on each fired boiler and EGB, there were also system safety valves, set to lift at 9.5 bar, fitted on the steam line after each boiler main steam stop. A drain was fitted beneath each set of valves **(see Figures 10 and 11)**.

1.4.3 Steam plant drainage arrangements

Two drains were fitted to the pipe leading to the port main boiler stop valve. These were:

1. <u>Fitted to the underside of the port system safety valve</u>

This was plumbed into the condensate system via a drain trap and is correctly shown in **Diagram 1**. There was a valve either side of this drain trap. The valve before the drain trap was open, and the valve after it was just off its seat. It was not possible to ascertain whether or not this drain was working.

2. <u>Fitted immediately upstream of the main isolation valve to the starboard dump condenser</u>

This was a 12mm bore drain which opened directly to bilge. It was not correctly marked on the drawing **(see Diagram 1)**, but the vessel's engineering staff knew of it. It was not open at the time of the accident as it was usually only open when the condensers were changed over.

Figure 6

Port boiler EGB suction valve

Figure 7

Mounting position for port boiler EGB suction valve

Figure 8

Control room boiler control panel

Figure 9

Local boiler control panel

Figure 10

Port system safety valves

Figure 11

Drain from below port system safety valves

1.5 CONDITION OF THE STEAM PLANT AT THE TIME OF THE ACCIDENT

Echo EGB had been isolated during the 8 to 12 watch on the evening of 22 June. This had been done so that it could cool sufficiently to allow access to a suspected exhaust gas leak from its bottom manhole door. Its circulating pump was switched off, and the suction and discharge valves shut.

Delta EGB had been isolated and drained because of water leakage into the exhaust space. This had been discovered during the 4 to 8 watch on the morning of 23 June.

At the beginning of the 12 to 4 watch on the afternoon of 23 June, Golf main generator engine was shut down, and no immediate replacement was available. The loss of Golf EGB required the use of the starboard boiler, which went online at 1220. Manual modulation of the starboard boiler was then used to maintain steam pressure at about 5 bar.

Delta main engine was started at 1530, and fully loaded by 1545. Delta EGB remained isolated and drained.

1.5.1 Post-accident inspection

MAIB inspectors first inspected *QE2* on 26 June, when she berthed at Southampton. The first engineer confirmed that the status of the valves associated with the isolation of the port boiler had not changed since the accident. During this post-accident inspection, the condition of these valves was as described below.

The following boiler mountings had been removed from the port boiler:

- The scum valve (the line was blanked) and vent valve.
- Both gauge glasses.
- The three EGB suction valves.
- The two feed inlet valves (the emergency feed line was blanked).
- The blowdown valves (the line was blanked).

The following valves were found to be shut, wired and labelled “Do not open”:

- Port boiler supply to the hotel services **(see Figure 12)**.
- Secondary EGB vapour return to port boiler **(see Figure 12)**.
- Hotel services steam supply cross-connecting valve **(see Figure 13)**.
- Port boiler supply to the engine room steam ring main **(see Figure 14)**.

- EGB circulating pumps main suction from the port boiler **(see Figure 15)**.
- Feed pump suction and discharge valves (port feed pump primary, secondary and cross-connection to the emergency feed line and starboard cross-connection to emergency line) **(see Figure 16)**.

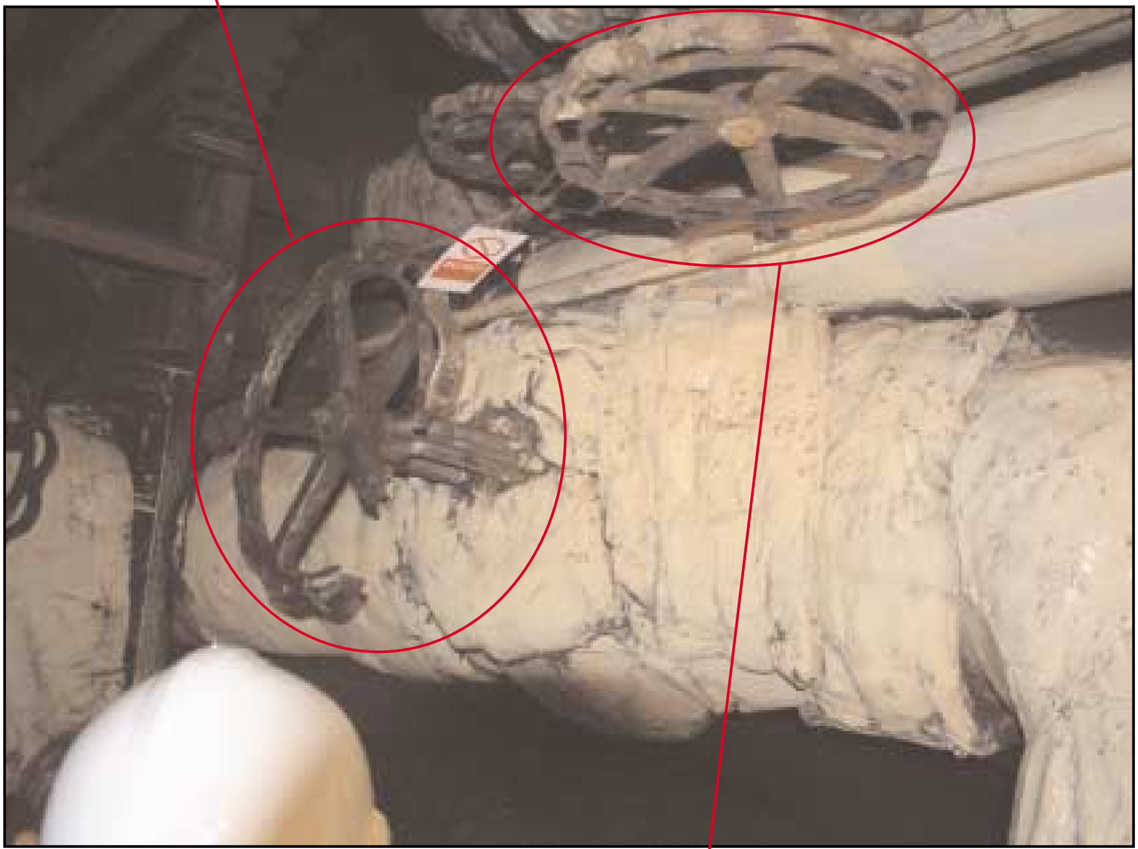
The following valves were found to be shut, but not labelled or wired:

- Starboard dump condenser steam inlet **(see Figure 17)**.
- Primary EGB vapour return to port boiler valve.

The inspectors found that the vertical length of pipe leading from the port boiler to the engine room steam ring main isolating valve (as shown in **Diagram 3** showing temperatures), was hot above this valve. The figure shows the temperatures of the pipe wall taken with a calibrated hand-held non-contact temperature sensor. The ambient temperature in the space at the time of these measurements was 41° to 46°C. The temperature readings indicate that the ring main isolating valve was passing steam in the reverse direction of flow, and that the level of hot condensate was up to the expansion bellows, some 6.5 metres above the top flange of the valve. The pipe was 250mm nominal bore.

Figure 12

Secondary EGB vapour return to port boiler

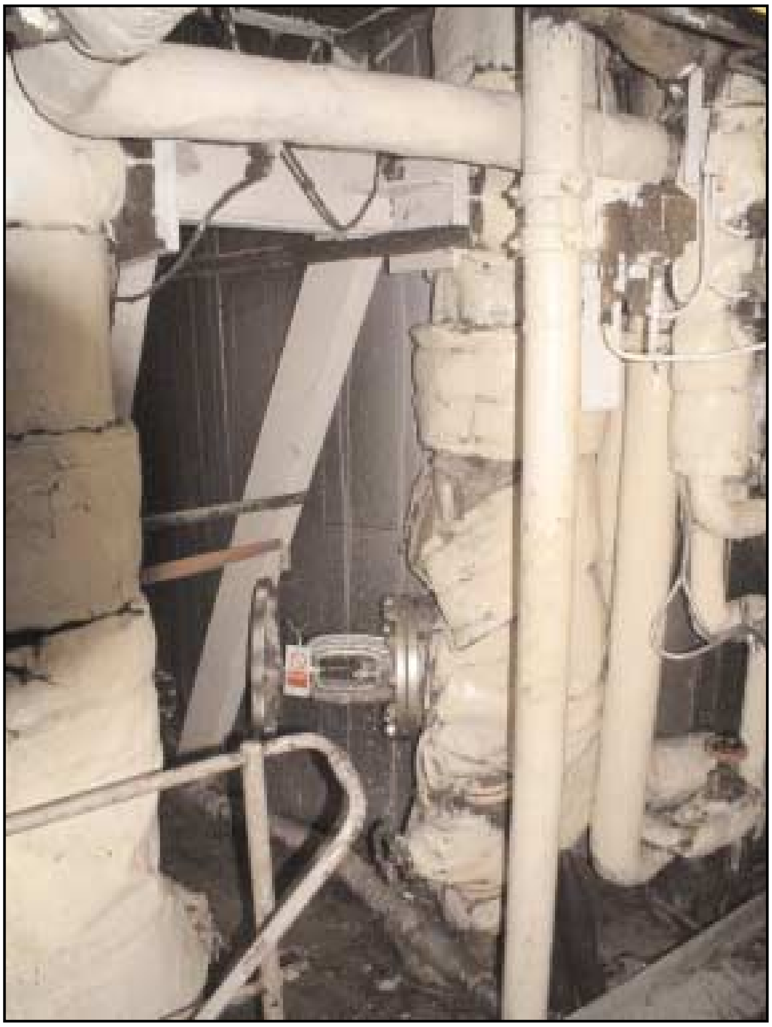


Port boiler supply to the hotel services

Figure 13

Hotel services steam supply cross-connecting valve

Figure 14

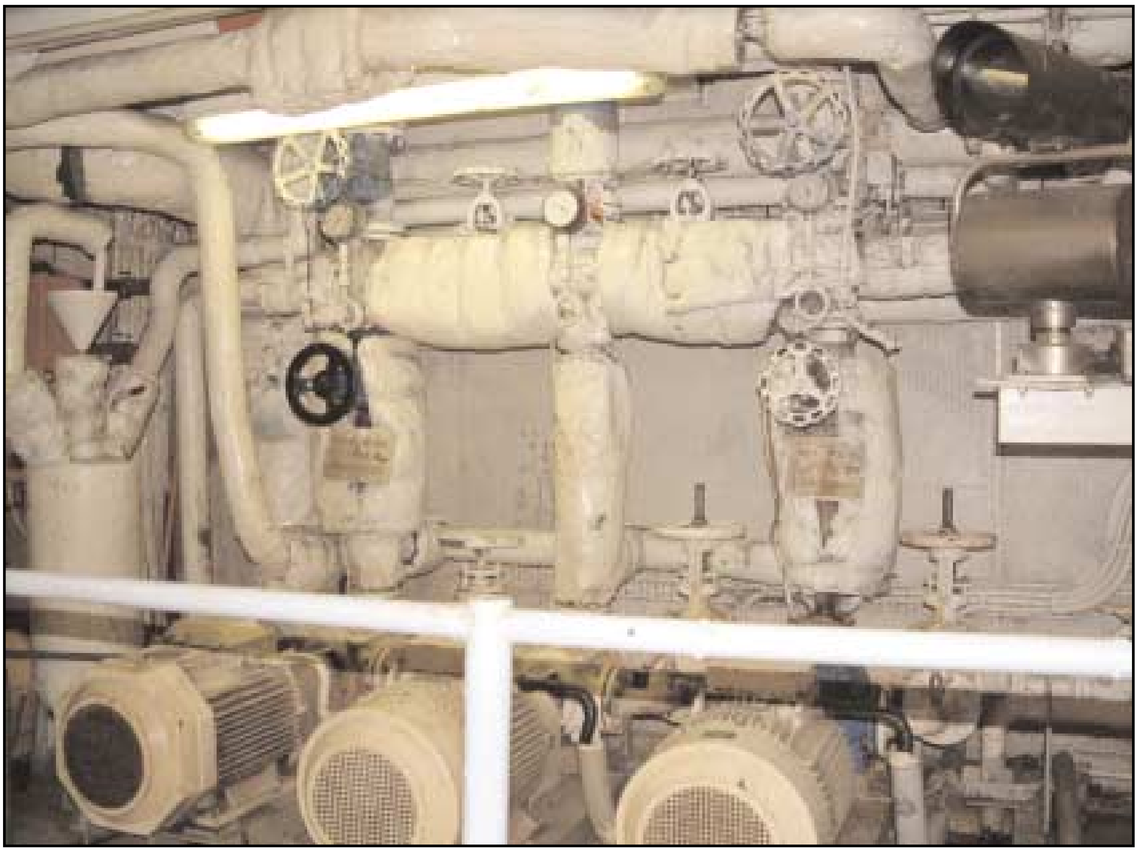


Port boiler supply to the engine room steam ring main

Figure 15

EGB circulating pumps main suction from the port boiler

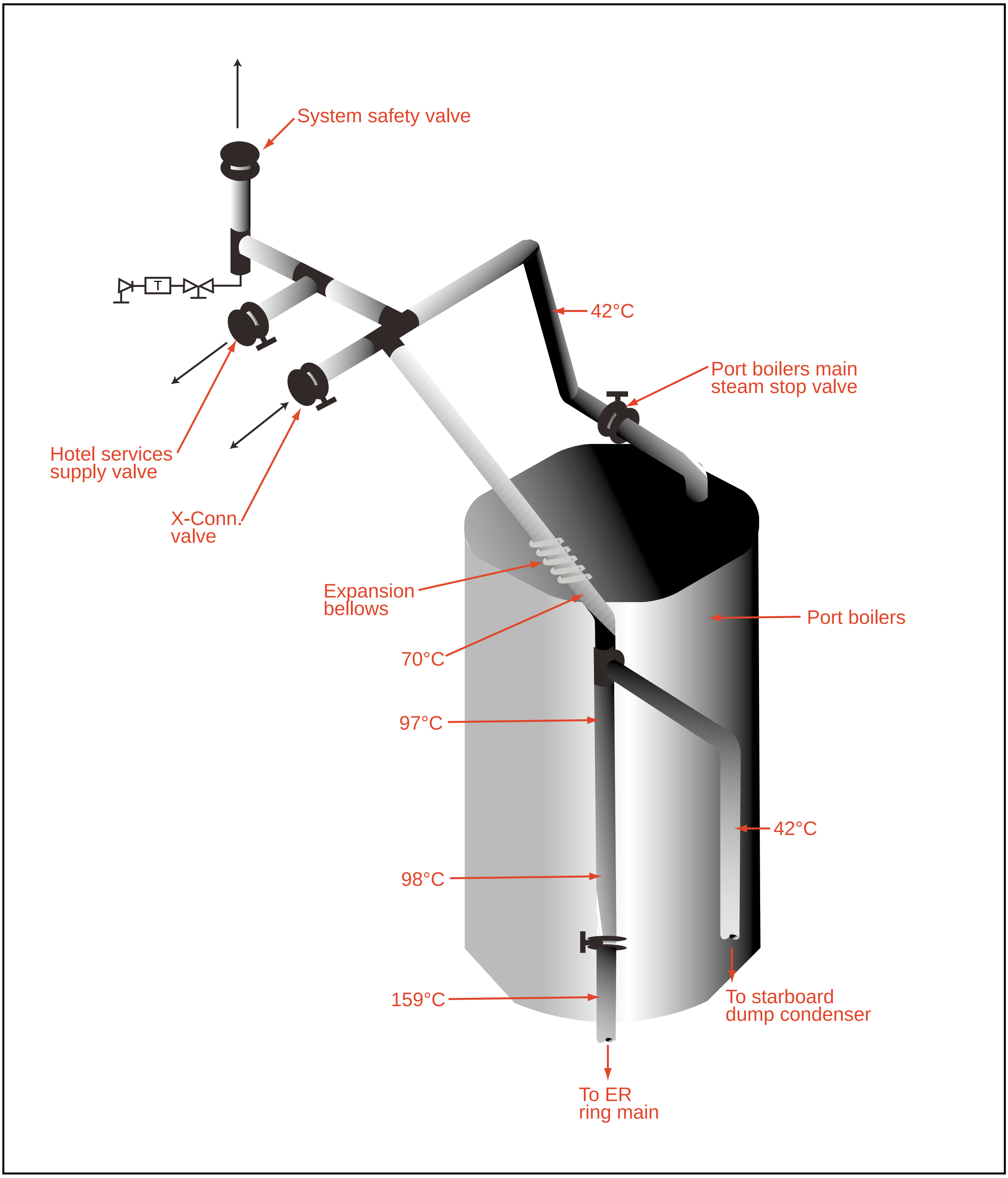
Figure 16



Feed pump suction and discharge valves (port feed pump primary, secondary and cross-connection to the emergency feed line and starboard cross-connection to emergency line

Figure 17

Starboard dump condenser steam inlet



3-dimensional sketch showing layout of port oil-fired boiler, steam pipework and temperatures

1.5.2 Mandatory requirements for draining of steam pipe systems on *QE2,* or UK Class I passenger ships

1. The Merchant Shipping Passenger Ship Construction – ships of Classes I, II and II(a) Regulations 1998. Regulation 67(2) – Steam pipe systems:

   Effective means be provided for draining every steam pipe so as to ensure that the interior of the pipe is kept free of water and that water hammer action will not occur under any conditions likely to arise in the course of the intended service of the ship.

2. SOLAS chapter II-1 – Construction – Structure, Subdivision and Stability, Machinery and Electrical Installations, Regulation 33 – steam pipe systems.

   Regulation 33(2) – requires that:

   Means shall be provided for draining every steam pipe in which dangerous water hammer action might otherwise occur.

3. Lloyd's Register's Rules and Regulations for the Classification of Ships. Part 5 Main and Auxiliary Machinery, January 1991; and

   5.2 – *drainage, requires that the slope of the pipes and the number and position at the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam piping system when the ship is in normal trim and is either upright or has a list of up to 5°.*

These above requirements are designed to ensure that steam pipe installations on board ships have facilities to ensure that steam pipelines can be safely drained of water condensate.

The steam pipe system examined by inspectors on board *QE2* did not satisfy these requirements.

1.6 SAFETY MANAGEMENT SYSTEM

1.6.1 Engineering officers

The engineering officers on board *QE2* comprised the following:

<u>Chief engineer</u>: responsible for managing the safe operation and maintenance of all technical equipment on board the vessel. He held a Class 1 Certificate of Competency.

<u>Staff chief engineer</u>: responsible for the delegation of work, and the management of technical staff. The staff chief engineer reported to the chief engineer and held a Class 1 Certificate of Competency.

Ship's services manager: responsible for managing the safe operation and maintenance of the ship's domestic and passenger services, including the hotel services. He reported to the staff chief engineer and held a Class 1 Certificate of Competency.

First engineer: responsible for management of all engine room auxiliary plant maintenance. He reported to the staff chief engineer and held a Class 1 Certificate of Competency.

Three second engineers: each responsible for a sea watch, with either a third engineer or a junior engineer. Each watch also had two technical ratings assigned to it.

One third engineer and three junior engineers: three of which were assigned to sea watches, with the remaining one assigned to main engine maintenance with the fourth engineer.

There was also a hotel services engineer, a deck service engineer, an accommodation service engineer and a cadet.

The technical ratings assigned to the engine room auxiliary plant consisted of a chief mechanic, a mechanic, three motormen and five wipers.

The technical staff on *QE2* had a great deal of experience on the vessel, many having sailed on her for a number of years.

1.6.2 The engineering department's ship-to-shore liaison

For technical matters, the chief engineer reported to and liaised with the director - technical operations.

The director, in turn, reports to the vice president, marine and technical operations. He is the line manager for other technical superintendents assigned to vessels in Cunard's fleet. Specific duties and responsibilities include: ensuring that all technical operations carried out on board company ships, are performed in accordance with the safety and environmental policy statement. He is also the technical superintendent for his assigned ship(s).

He assists the vice president, marine and technical operations, in the management of technical operations across the company fleet, standardisation of departmental practices and development of policies and procedures. He also acts as the marine and technical operations representative for inter-departmental technical matters, as designated by the vice president, marine and technical operations. He maintains an overview of the technical operations of all company vessels.

1.6.3 Routine ship-to-shore reporting requirements

The reporting line, what needs to be reported and when, is recorded in Cunard's Safety Management Policy and System Manual.

There are four routine ship-to-shore reports:

1. A monthly report of minutes of the ship safety and environmental control committee meeting is submitted to the safety and environmental manager. The report includes an SMS review and accident figures.

2. A non-conformity report and statement of corrective action is written within 48 hours of occurrence. The report is distributed to the vice president (marine and technical operations); vice president (hotel operations) (public health matters only); the director (marine operations); the director (hotel operations); the director (technical operations); and the designated person.

   Included in the report are comments on audit reports, port and flag state inspections, US public health reports, etc.

3. Within 24 hours of an occurrence, a report of a critical equipment defect, or incident report, is written. This report is forwarded to the vice president (marine and technical operations), director (marine operations), and the designated person.

   Included in this report are accident reports, accounts of dangerous occurrences, oil spills that reach the water, fires, collisions, groundings and strandings.

   Also reported are machinery or material casualties which do, or may, cause significant disruption to passenger comfort or safety, or may affect the safety or manoeuvrability of the ship.

4. The chief engineer's report is submitted weekly to the vice president (marine and technical operations); the director (marine operations), the director (technical operations) and the technical superintendent. At the time of the accident, the technical superintendent also served as the director of technical operations.

   This report must contain at least information on the chief engineer's inspection of the ship, including inspection of safety equipment and machinery. The report includes operation and maintenance matters concerning the main plant and ship and hotel services.

1.6.4 Specification of work to be carried out at refit

Work, which the engineers consider needs to be carried out at refit, is recorded in what is known on board as the "first engineer's database". Work submitted by the first engineer, or through him by less senior engineers, is considered by the staff and chief engineers.

They decide whether or not the work should be completed at refit. If so decided, the work is added to the refit specification, together with a priority notation. “Priority one” indicates that the work must be completed.

“Priority two”, and the lowest, “priority three” notations, indicate that the work to be carried out is optional, depending on time, costing and management needs.

This reporting and recording system is not documented in the SMS.

1.6.5 ISM audits

The last internal safety audit undertaken before the accident was between 21 and 23 September 2000. The UK Maritime and Coastguard Agency (MCA) undertook an external audit between 6 and 9 November 2000.

The external auditors found that the SMS complied with ISM Code requirements, with the exception of six minor non-conformities and observations. These related to Section 7.0 of the Code, that is, development of plans for shipboard operations.

The auditors also remarked that Cunard had developed procedures which reflected good operational practice. The crew displayed practical familiarity with the procedures.

Referring to Section 10 of the Code: Maintenance of the Ship and Equipment; the external auditors were concerned about Cunard’s application of the risk assessment requirements outlined in MGN 20 and associated SI (1997 No 2962) - The Merchant Shipping and Fishing Vessels (Health and Safety at Work) Regulations 1997. The auditors advised that risk assessments were incomplete, and not subject to review to ensure their continued relevance.

They also remarked that the current planned maintenance system was separated into two distinct systems for deck and engineering. However, there were defects in the recording and monitoring systems on board, which did not line up with either system.

Cunard responded to the auditors’ findings. It confirmed that the safety management system (known as SMS 2000) provided a means for anyone on board the ship to be able to inform the company, via safety committees, feedback forms, etc, of any relevant risks to health and safety arising out of, and in connection with, their respective jobs.

Cunard devised an action plan to fully comply with MGN 20 and associated SI (1997 No 2962). In its view, this compliance would ensure a continued review of the SMS. In particular, relevance of risk assessments undertaken, policies, procedures, protection equipment, checklists, forms, and records would be reviewed.

When necessary changes were identified, the company would act to ensure these were made. The SMS would be updated accordingly.

An audit followed up any outstanding issues as required. A manager was assigned to maintain an oversight of the company's ships' safety officers and their duties under the Code of Safe Working Practice for Merchant Seamen. This manager provided input and advice on all navigational and marine matters, in the absence of the director, marine operations and safety.

1.7 TESTING OF THE LEAKING STEAM VALVE

The purpose of this test was to ascertain whether the valve isolating the port steam line, leading to the port boiler from the hotel and engine room steam ranges, was leaking, and, if so, to what extent.

The test was undertaken under controlled conditions at Weir Engineering Services, Leeds.

Results of the test showed that the valve had been leaking. It was found that 2.5ml per minute and 1.5ml per minute of water leaked past the 7.2 and 6.1 bar gauge respectively.

Examination of the valve seal faces showed a build-up of precipitates from condensing steam leaking across the valve.

1.8 ASSESSMENT OF CIRCUMSTANCES OF SUDDEN DISCHARGE OF WATER FROM THE OPENED UP PORT BOILER STOP VALVE

Dr George Munday of IS&AC consultants, and Professor Geoffrey Hewitt, emeritus professor of Imperial College, London, considered the possible circumstances leading to the sudden discharge of hot water from the boiler stop valve.

A summary of the consultants' findings follows; the full report can be obtained by writing to the MAIB.

The consultants' findings showed that the source of water discharge was that which was contained in the vertical pipe above the leaking isolating valve in question. Steam from the live side of the steam plant leaked past the valve into the column of water in the vertical pipe.

The cooling and leakage process leading to the discharge was in three phases:

1. Phase one; loss of superheat. This would have occurred over about 1 minute from the time the pipeline was isolated from the live steam range.

2. Phase 2; cooling with falling pressure and the consequent build-up of large quantities of condensate in the vertical pipeline, introduced through the leaking valve over the 5 days from shutdown to the opening up of the port boiler stop valve.

3. Phase 3; final depressurisation. By that time, the vertical leg, and the pipe leading down to the dump condenser, were full of water. Leakage rate across the valve will be determined by the pressure drop across it at the time.

   When the system was depressurised at the time the boiler stop valve cover joint was broken, the leakage across the valve increased. Dependent upon the relative magnitude of all the variables involved, it is possible that the cooling controlled leakage during the previous 5 days was succeeded by a leakage rate which caused the vertical leg to fill up over a much shorter period.

   This resulted in delayed, but significant, flow of condensate after depressurisation was completed.

   The consultants also considered it was quite probable that the depressurisation would also result in phase changes, which could lead to a sudden eruption of steam under the condensate layer lying above the leaking valve in the vertical leg.

   To enable a complete quantification of causation, both aspects would require further theoretical studies and/or experimental tests.

   In their conclusions, the consultants considered that the mechanism which best explained the cause of the sudden discharge of water, was the leaking of steam from the live steam side of the plant across the closed isolating valve.

   Their analysis of the evidence indicates that the flow rate figures, calculated from the leakage tests carried out in Leeds, cannot represent the condition of the valve at the time of the accident. The leakage rates must have been substantially higher.

   For these higher leakage rates, it is possible to quantify a mechanism involving the build-up of condensate in the pipelines during a lengthy cooling period, then followed by rapid depressurisation. This would explain the circumstances of the rapid discharge.

   Further questions remain: these require further investigation to understand the detail of the processes which took place in the cooling of the condensate in the pipeline, the behaviour of the two phase system during the depressurisation phase, and the possible evolution of steam within the condensate layer during depressurisation.

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 SCOPE

Two engine room crewmen were injured while working on the port boiler main stop valve. One of them subsequently died.

About 40 minutes after they lifted and removed the valve cover from the valve body, there was an unexpected and sudden discharge of hot water and steam from the valve body opening.

The consultants' report of the reason for this discharge, and the factors leading to it, are discussed in the section below.

2.3 CAUSE OF THE ESCAPE OF STEAM AND HOT WATER

In the previous section, the consultants have clearly defined the process which led to the discharge. A major factor, which instigated and continued the process, was the steam leakage across the isolating valve.

The consultants considered the leakage must have been substantially more than that found during the leakage tests. The reason for this discrepancy is unclear. However, the precipitate found on the valve seals would have effectively reduced the orifice of leakage. It is possible that most of the deposit occurred between the time the port boiler stop valve was opened for maintenance, and when the steam plant was shut down completely to remove the valve for inspection after the accident.

Another scenario is that the valve was leaking, but was not fully closed. The inspectors found the valve closed. However, they have no reason to doubt the statements of those interviewed, who confirmed that the valve had not been disturbed since it was wired closed.

The leaking valve was a major factor which led to the accident. Had it not been leaking, the accident would not have happened. The accident highlights the value of having double valve isolation: a feature not uncommon in steam plant systems.

Such a safeguard would have reduced the risk of leakage, and certainly reduced it to below the leakage rate the consultants considered to be sufficient to cause the sudden discharge.

2.4 FACTORS LEADING TO THE ACCIDENT

2.4.1 Procedures used to isolate the port side of the steam plant

With the port boiler shut down, the steam pipelines leading to the boiler main stop valve from the hotel and engine room service lines had been isolated from the live side of the steam plant. The first engineer and chief mechanic were aware that condensate would have been in this pipeline.

Procedures for working on boilers and adjoining steam plant are well documented in marine engineering textbooks and codes of safe working practice. Knowledge of the procedures is tested in examinations for marine engineering Certificates of Competency.

When opening up a section of steam plant, precautions must be taken to avoid the risk of scalding. The section must be isolated from the live side of the plant, vented to atmosphere, and drained of condensate.

The first engineer was responsible for planning and supervising the operation.

In so doing, he discussed and planned the operation with the chief mechanic, watchkeepers and the daywork engineer. The plan was to shut down and isolate the port boiler from the live steam side of the steam plant, then to prepare the boiler for survey by removing the boiler mountings.

Six days before the accident, the boiler was shut down. The first engineer warned engine room personnel of his intentions, keeping them fully informed while his team worked on the steam plant.

He recognised the need to avoid the risk of scalding. To isolate the live steam from the port side of the plant, he ensured that the necessary steam valves were closed. To deter anyone from opening them, he wired up the valves' handwheels and labelled them "do not open".

Before the boiler mountings were removed, the boiler was drained and vented, and blanks were fitted to inter-connecting pipelines, such as feed and blowdown lines. This action avoided the possibility of feedback of hot water and steam from the live side of the plant.

The main boiler stop valve was the last of the port boiler valves to be opened up. As personnel worked on the boiler mountings, this valve remained shut, thus ensuring two-valve separation between the boiler and the live side of the steam plant. Consequently, the chance of steam and condensate leaking into the boiler, and the risk of personnel being scalded while working on it, was reduced significantly.

Once work started on the port boiler stop valve, the risk of scalding increased. At that time, just one valve separation existed between the workers and live steam. Based on past experience of working on the boiler, they knew that the isolated steam pipe would contain condensate. There would be sufficient condensate to flow out of the boiler main stop valve body once its cover had been slackened off.

To work on the valve safely, measures had to be taken to ensure that there was no pressure on the pipeline, and that any condensate which could spill over was drained away before the men started work on it.

To drain the pipeline, they followed standard engineering practice, which is described in MCA's Code of Safe Working Practice section 22.4.3. This was to slacken off the main boiler stop valve cover, allowing condensate to drain away safely. They, thus, assured themselves that any pressure in the pipeline had been removed before the valve cover was lifted clear of the valve body.

In anticipation of hot condensate discharging from the broken cover joint, the chief mechanic fitted a shield around the valve body: a method of protection that he had used before when working on the boiler stop valves.

Once satisfied that the pipeline adjacent to the boiler stop valve was fully drained, work began on cleaning the valve.

Despite the first engineer following what could be considered to be an acceptable procedure, two men were seriously scalded by hot water.

2.4.2 The port boiler supply to the engine room steam ring main isolating valve

A number of valves, like the one that was found to be leaking, are fitted in the steam plant. The first engineer was unaware that this isolating valve had been leaking; there were no records indicating that it had been.

These valves were known to leak from time to time. For example, a similar valve had been removed from a section of steam pipeline, overhauled, and then retained as a spare. It was stored in the boiler area of the engine room.

The inspectors found that the vertical section of pipeline, leading up from the leaking isolating valve, was full of hot water to the level of the steam branch line leading to the starboard dump condenser. The water temperature was near to boiling point at atmospheric pressure. The pipe surface temperature of this section is shown in **Diagram 3**.

As the boiler stop valve cover joint was about to be broken, the first engineer's immediate concern was the hazard of overflowing condensate which lay in the short vertical pipe section, adjacent to the boiler stop valve.

He had made a prudent and conscientious effort to ensure that his men would be working safely on the boiler stop valve. He followed what could be considered acceptable procedures.

However, the weakness in the procedure was that he did not satisfy himself that the isolating valve in the vertical leg was not leaking. He could have done this by measuring the temperature of the pipe. However, it is a matter of speculation as to what he would have done to mitigate the situation had he discovered the leakage.

He may have abandoned working on the boiler stop valve, closed it up, and shut the plant down at a convenient time to repair the leaking valve.

On the other hand, with the knowledge that hot water remained in the vertical pipe above the leaking valve he may have decided to continue work on the boiler stop valve.

Given that he could not have expected a sudden discharge of hot water from the opened valve some 40 minutes after being satisfied that the pipework adjacent to the valve was drained of water, it would have been a reasonable decision for him to make.

At the request of the MAIB, well qualified and experienced consultants undertook careful research and analysis to find possible reasons for the sudden water discharge. Their findings confirm that it was an unusual and unexpected event, and probably outside the experience of most marine steam engineers.

A lesson from this accident is found in the importance of having steam plant which can be easily drained of condensate. The fact was that the steam plant on *QE2* could not be easily drained, a condition which handicapped any well intended safe operation of the plant.

The drainage facilities are discussed in the next section.

2.5 DRAINAGE FACILITIES ON STEAM PIPELINES

Strategically-placed drain valves fitted on steam pipes ensure that pipes can be safely vented to atmosphere, and water completely removed before the pipeline is opened up.

Equally important is the need to ensure efficient and thorough drainage before, and during, start up of steam plant. When steam is turned on to a line, condensate should not be allowed to accumulate, otherwise it will be carried along with the steam flow and will collide with bends, valves and other obstacles in the pipeline. This phenomenon is termed “water hammer”. Water hammer can, and has, caused serious injury to personnel, because pipe fittings fail suddenly and violently.

Water hammer has occurred on board *QE2* with serious effect. For example, a senior engineer on board reported to the inspector that, some time before this accident, steam was put into a line containing condensate. Consequently, because of water hammer, a pipe elbow section blew out in the air-conditioning heater steam line.

The regulations outlined in Section 1 are designed to ensure that steam pipe installations on board ships have facilities to ensure that steam pipelines can be safely drained of water condensate. The steam pipe system on board *QE2,* examined by inspectors, did not satisfy these regulations.

Over a 6-month period between 1986 and 1987, the vessel was refitted in Bremerhaven, Germany. The purpose of the refit was to re-engine the vessel with a diesel electric propulsion system. The propulsion system replaced the original steam turbines and related steam plant. The installation was approved over a 2-year period preceding the refit, and into the period of the refit itself. Records indicate that Cunard, Lloyd's Register of Shipping, and the Department of Transport Marine Directorate (now known as the MCA), approved line drawings of the new steam plant installation. The date of approval of the drawings preceded the start of installation.

Drainage points are shown on the drawings. However, it is standard practice for surveyors to make judgments as to where the drains should be placed, once the pipe system has been fitted on board the ship. On site inspection as to where the drains should go, is considered the most practical means of ensuring efficient drainage of pipe sections etc.

The small number of drains which were fitted to the system were not in the right places to effect good condensate drainage.

It is more than 15 years since the steam pipe system was installed, therefore, it is a matter of speculation as to why the drains were not fitted. At the time of the refit, the work on the vessel was programmed to a very tight schedule of 6 months. A larger part of the surveyor effort by MCA and Lloyd's Register surveyors, and Cunard's superintendence of the work, concentrated on the installation of the propulsion plant, and the structural changes to the hull to accommodate it.

It is possible that the MCA, LR and Cunard paid less attention to the detail of the new steam plant pipeline installation, and concentrated more on what was, at the time, perceived to be the most important part of the refit: that is, the new propulsion plant installation. As a result of this, the need to ensure effective drainage facilities was missed.

But the situation does highlight the importance of careful superintendence and survey at refit to ensure that essential safety features, such as condensate drains, are properly installed.

The fact is that, engineers on board *QE2* inherited a legacy which hindered safe operation of the steam plant.

In their post-accident examination of the steam plant, the inspectors found that the isolated steam line, leading to the port boiler, was fitted with two drain lines. One was fitted below the system safety valve, but at the top of the line: useful as a vent, but incapable of draining the line.

The second drain was fitted immediately before the dump condenser. This had remained shut throughout the period of shutdown. Had it been left open, condensate in the line down to the dump condenser would have drained into bilge.

However, the 4-metre vertical section of pipe, between the ring main isolating valve and the point where the line to the dump condenser branched off, would not have been drained of any condensate.

The first engineer had experience of having to work on EGB vapour lines with leaking steam isolating valves. Not being able to vent off steam pressure, because of the absence of drains in the vapour lines, posed difficulties. On breaking a pipe flange, the steam pressure in the line could be so great as to render it unsafe to work on the plant at that time. The work would have to be delayed until the steam plant, or parts of it, could be shut down and allowed to cool.

The ship's engineers were unable to fit drains to the steam plant because of the requirement to use coded welders. It would have needed at least one working day to fit drains to the EGB lines. To shut the plant down for such a period would have caused serious disruption to the workings of the vessel.

The first engineer reported that he had discussed the problem with the chief engineer on board at the time. However, the chief engineer could not recall that the subject was discussed.

The first engineer recorded, on the first engineer's electronic database, the need for the drains. However, there was no record to indicate any decision or request had been made to include the work in the worklist for the next refit, which was due in December 2001. Consequently, an opportunity was lost to examine, more closely, the deficient drainage arrangement of the steam plant.

The notice of the need for drains in the EGB vapour lines, was the spur which could have encouraged a fundamental examination of the drainage facility on the steam plant as a whole. Such an examination could have enabled an assessment of the inadequacy of the facility, and the consequent impact on safe operation.

A safety assessment could have highlighted the need to remedy the situation at the earliest opportunity, and, possibly, thereby prevented a tragic accident such as this.

Such a risk assessment, however, can only succeed if it is underpinned by the knowledge of the possible consequences of not fitting drains.

It was stated earlier that steam pipes opened up to a steam supply must be drained. It has also been discussed that effective drainage of the plant was not possible.

Yet for more than 15 years since its installation, engineers have been prepared to open up undrained sections of steam plant leading into steam supply lines.

Irrespective of any leakage past the valve isolating the port boiler from the live steam side of the plant, condensate is bound to settle in the vertical section of the isolated pipeline.

Engineers on board accepted as normal the operation to open up the valve and allow condensate into the steam supply line. One senior engineer, who had spent most of his seagoing career on the vessel, advised the inspector that they had always done it “that way”.

“That way” was contrary to safe practice, as is clearly stated in MCA’s Code of Safe Working Practice, Section 22.4.4:

“before a section of steam pipe is opened to a steam supply all drains should be opened. Steam should be admitted very slowly and the drains kept open until all water is expelled”

To be effective, a safety risk assessment of any operation must be underpinned by a fundamental knowledge of safety issues. In this case, the engineers needed to appreciate the importance of ensuring thorough and efficient drainage.

Complacency was a possible reason why engineers operated the steam plant without suitable drainage. The ship’s engineers are competent people. Those questioned were found to be knowledgeable of the dangers of water hammer. But, because they had experienced no serious mishap for many years, they were prepared to operate the steam plant without suitable drainage.

The first engineer’s concern about lack of drains on EGB vapour lines stemmed from the practical difficulties of repairing leaking steam valves. The concern was unrelated to the overall safety of the plant.

A safety assessment of the steam plant could have realised the need for written procedures for its opening up and shutting down, a need for a more formal risk assessment, and the use of permits when working.

2.5.1 The Safety Management System

Cunard Management had a positive commitment to ensuring the safety of passengers and crew. It continually reviewed the SMS. In particular, the relevance of risk assessments undertaken, policies, procedures, protection equipment, checklists, forms, and records were reviewed.

The SMS documentation described clearly defined ship-to-shore reporting lines. This encouraged the reporting of incidents and concerns about the safety of any shipboard operations.

Management responded positively to this accident, previous incidents, MAIB investigations, and MCA's audit reports.

So why then did the accident happen, despite evidence which showed that the vessel had the ingredients of an effective safety management system and a management committed to ensuring its success?

Firstly, with regard to drainage of the steam pipe system, staff on board accepted the inadequacy of steam pipe drainage. To them it was a technical issue, rather than one of safety. The lack of drains was seen as a problem of disruption of the ship's operation, and the consequent inconvenience to passengers.

The "first engineer's database" was considered to be a list of maintenance and safety related items which needed to be addressed at refit.

With regard to the maintenance items, however insignificant they may seem, staff must be mindful of any safety issues that could be involved.

Marine engineers sometimes, incorrectly, consider many maintenance issues to be divorced from safety, and not to be part of the synergy of the SMS.

They become preoccupied with the need for maintenance to ensure least disruption of the operation. However, this preoccupation is sometimes undertaken at the expense of addressing overlapping safety issues.

Consequently, despite clearly established ship-to-shore reporting lines, shore-management is not always aware of safety issues on board.

With respect to Cunard's management of maintenance issues, a problem with drainage was identified, but consideration of it was not carried through to a higher management level ashore. Consequently, management was handicapped in achieving a fully proactive role to remedy the unsafe situation.

Management needs to review its system of reporting technical operational matters through the management chain, with regard to the type of information reported and recorded. This will assure it that any safety issue which may arise from technical matters has been properly considered by senior engineers.

A second issue with the SMS is the unsafe working practices which evolved because of acceptance of lack of drainage.

The SMS documentation contained procedures to operate and maintain the boilers. However, there was no specific advice on procedures, or the need for formal risk assessment, for isolating or opening up of steam pipelines adjacent to the live steam range.

In consultation with shore-management, SMS procedures were developed by ship's staff. However, as discussed earlier in this report, if staff do not appreciate the safety issues of an operation, any risk assessment of it will be flawed.

Management must be fully satisfied that all the hazards of an operation have been considered before accepting the control measures likely to overcome them.

Evidence on board shows that safety reviews were taking place. It is management's responsibility to assure that all potential safety benefits have been highlighted in the review.

The "first engineer's database" can be used as a platform to convince management that safety issues have been considered. But, whatever platform is used, management needs to know whether or not there is a safety issue overlapping the maintenance request.

With any maintenance request, the reasons why the request has been turned down should be recorded.

Management can learn from the lessons of this accident. Drainage facilities on the steam plant should be reviewed, and action taken to ensure that the plant can be drained safely. The plant must be designed so that maintenance work can be done safely and successfully, with minimum time pressures and disruption to essential steam supplies.

SECTION 3 - CONCLUSIONS

3.1 SUDDEN DISCHARGE FROM THE OPENED PORT BOILER STOP VALVE

The following are the safety issues which were identified as a result of the investigation. They are not listed in any order of priority:

1. A major factor which instigated and continued the process that led to the sudden discharge of steam and water, injury, and loss of life, was the leakage across the isolating valve. [2.3]

2. The thermodynamic process, in the vertical pipe above the closed but leaking valve which led to the discharge, was in three phases:

   - Loss of superheat over about 1 minute from the closing of the valve.
   - Cooling with falling pressure and the consequent build-up of large quantities of condensate in the vertical pipeline, introduced through the leaking valve over the 5 days from shutdown to the opening up of the port boiler stop valve.
   - Final depressurisation. By that time, the vertical leg, and the pipe leading down to the dump condenser, were full of water. When the system was depressurised at the time the boiler stop valve cover joint was broken, the leakage across the valve increased. Dependent upon the relative magnitude of all the variables involved, it is possible that the cooling-controlled leakage during the previous 5 days was succeeded by a leakage rate which caused the vertical leg to fill up over a much shorter period.

   This caused delayed, but significant, flow of condensate after depressurisation was completed. This resulted in overflow of steam and water from the vertical pipe and its discharge from the port boiler stop valve. [1.8]

3.2 DRAINAGE FACILITY OF THE STEAM PIPELINES

1. Condensate in the steam pipelines produced on shutdown and start-up could not be removed to prevent the possibility of water hammer and catastrophic failure of pipelines and valves. [2.5]

2. LRS Rules, SOLAS, and United Kingdom Merchant Shipping Regulations, were not adhered to, in that the steam plant installations could not be drained efficiently. [2.5]

3. The general arrangement drawings of the steam pipelines connecting the EGB and fired boilers to the hotel services ring main and machinery space steam distribution system, were approved by the Department of Transport (MCA), LRS and Cunard. [2.5]

4. These drawings did not indicate the positions of drain valves to enable efficient drainage. [2.5]

5. It is normal practice for surveyors to identify efficient drainage positions on site and during installation of plant. [2.5]

6. The small number of drains fitted were placed incorrectly and did not effect good condensate drainage. [2.5]

7. It is a matter of speculation as to why supervision of the installation of the drains was ineffective in ensuring efficient drainage. [2.5]

   It is possible that, at the time of the re-engineering project in 1986-87, Cunard's superintendents, LRS and the Department of Transport (MCA) surveyors concentrated their efforts mainly on the major part of the project. That was, the installation of the new propulsion plant and the major structural alteration. This effort was at the expense of ignoring the relatively small, though important, detail of ensuring that steam pipeline installation was capable of being drained efficiently. [2.5]

   The situation highlights the importance of careful superintendence at refits to ensure that essential safety features, such as condensate drains, are properly installed. [2.5]

8. The vertical section of pipe leading up from the isolating valve was found to be full of condensate and near to boiling point at atmospheric pressure. It was not possible to drain the condensate from the section. [2.5]

9. The engineers on board the vessel inherited a legacy of an unsafe steam plant, which hindered safe operation of the steam plant. [2.5]

3.3 PREPARING THE PORT BOILER FOR SURVEY

1. The first engineer followed standard and acceptable procedures when preparing the port boiler for survey. [2.4.1]

2. The daywork team working to open up the port boiler stop valve, used reasonable procedures to ensure that any steam pressure in the pipeline had been removed before the valve's body cover was lifted clear. [2.4.1]

3. In anticipation of hot condensate discharging from the opened valve, reasonable precautions were taken to avoid the possibility of scalding. [2.4.1]

4. The first engineer was unaware that the valve isolating the live side of the steam plant from the port boiler was leaking. There were no records to indicate that it had been. [2.4.2]

5. The valve was one of a number of similar valves in the steam pipeline which were known to leak from time to time. [2.4.2]

6. To repair the isolating valve, or fit new drains in the steam pipeline connecting the EGBs and fired boilers to the steam service lines, requires the whole steam plant, or parts of it, to be shut down, with serious disruption of the ship's operation and hotel services. [2.5]

3.4 MAINTENANCE OF THE STEAM PIPELINES AND VALVES

1. The engineers were, to some extent, aware of the importance of having drains in the steam line and the consequential operational difficulties caused by their absence. [2.5]

   Leakage of isolating valves in the steam pipelines leading from the EGBs was a regular occurrence, which posed safety problems. Because drains were not fitted to the pipelines, the steam pressure in them was so great as to render it unsafe to work on the steam plant unless it, or parts of it, were shut down, which resulted in serious disruption to the working of the vessel. [2.5]

   Fitting drains to the steam pipelines required specialised welders and at least one working day to complete the work. The engineers considered that the disruption this work would cause to the operation of the ship was unacceptable. [2.5]

2. The chief engineer, in discussion with senior engineers, recommends to shore-management a list of work that he thinks should be included in the dry dock specification. What goes in this worklist is dependent, to some extent, on the judgment of senior engineers. The reason why the fitting of drains to the EGB pipeline was not undertaken is uncertain. [2.5]

3. The first engineer recorded, on the first engineer's electronic database, the need for the drains. However, there was no record to indicate any decision or request that the work be included in the worklist for the next refit, which was due in December 2001. [2.5]

4. By not taking up the concern of the need for drains to be fitted to the EGB steam pipelines, engineers and management lost an opportunity to make a fundamental examination of the drainage facility of the steam plant as a whole. Such an examination could have realised the fact that, because drainage was ineffective, the steam plant was unsafe. [2.5]

5. Contrary to safe working practice, senior engineers were prepared to open undrained sections of the steam plant into the live steam lines. [2.5]

   The reason why engineers were willing to allow condensate to enter the live steam side of the plant was, possibly, in part due to a lack of knowledge, and also complacency, because they had not experienced any serious mishap during their time on board. [2.5]

6. An effective safety assessment is dependent on the recognition of hazards arising during an operation. If engineers do not appreciate the hazards of inefficient drainage of steam pipelines, then any safety assessment will not realise the importance of good drainage and the precautions that must be taken. The safety assessment will, therefore, be flawed. [2.5]

3.5 THE SAFETY MANAGEMENT SYSTEM

1. Management had a positive commitment to ensuring the safety of crew and passengers. [2.5.1]

2. Management had developed procedures that reflected good operational practice. The crew displayed practical familiarity with the procedures. [2.5.1]

3. Management continually reviewed the SMS. In particular, the relevance of risk assessments undertaken, policies, procedures, protection equipment, checklists, forms, and records were reviewed. [2.5.1]

4. The SMS incorporates a ship-to-shore management reporting system. With regard to the reporting of technical issues, the information which is reported to shore-management is left, to some extent, to the professional judgment of the senior engineers. [2.5.1]

   In this respect a problem with drainage was identified, but consideration of it was not carried through to a higher management level ashore. Consequently, management was handicapped in achieving a fully proactive role to remedy the unsafe situation. [2.5.1]

5. With respect to Cunard's management of maintenance issues, the SMS was vulnerable because management waited for ship's staff to highlight safety issues as they perceived them. In so doing, it was handicapped in achieving a fully proactive role in avoiding any unsafe situation which could have led to a dangerous incident. [2.5.1]

SECTION 4 - RECOMMENDATIONS

Cunard Line is recommended to:

1. Fit drains to the steam pipe installation of the fired and exhaust gas boiler steam plant so that efficient means of draining condensate can be achieved.

2. Review the system of reporting technical operational matters through the management chain, with regard to the type of information reported and recorded. Management will then be assured that any safety issues which may arise from these technical matters have been properly considered by senior engineers.

3. Ensure that the Safety Management System facilitates engineers' continued awareness of the importance of efficient drainage of steam pipelines when shutting down or starting up of steam plant. Management must be assured that all hazards have been identified in the formal safety assessment of the work to be undertaken.

4. Satisfy itself that any steam plant installation on board any of its current and future vessels can be efficiently drained of condensate.

5. Encourage engineers and management to take account of any overlapping safety issues when considering technical issues arising on board its vessels.

International Association of Classification Societies, through Lloyd's Register of Shipping and the Maritime and Coastguard Agency is recommended to:

6. Provide advice to remind shipbuilders, classification societies, owners, surveyors, superintendents and engineers, of the need to ensure that efficient draining of steam pipelines on board vessels is available in accordance with mandatory requirements.

Marine Accident Investigation Branch
July 2003