Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Bundesoberbehörde im Geschäftsbereich des Bundesministeriums
für Verkehr, Bau und Stadtentwicklung

Investigation Report 176/05

Serious marine casualty

Engine Room Fire on Board MV LIBRA RIO GRANDE on 23.05.2005 in the Port of New Orleans

15 November 2006

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The investigation was conducted in conformity with the law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law - SUG) of 16 June 2002.

According to this the sole objective of the investigation is to prevent future accidents and malfunctions. The investigation does not serve to ascertain fault, liability or claims.

The German text shall prevail in the interpretation of the Investigation Report.

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1 Summary of the marine casualty

A fire broke out in the engine room of the Container Vessel LIBRA RIO GRANDE at about 10.20 h LT[1] on 23.05.2005. At this time the vessel was in the port of New Orleans. The fire fighting started by the crew was later taken over by the local fire brigade. It was possible to put out the fire by using CO_2 . The fire resulted in high property damage. There were no personal injuries or environmental damage.

[1] LT – Local Time - UTC minus 6 hours; all times in local time

2 Scene of the accident

Nature of the incident:	Serious marine casualty, fire in the engine room
Date/Time:	23.05.2005 / 10:20 h
Location:	New Orleans/USA

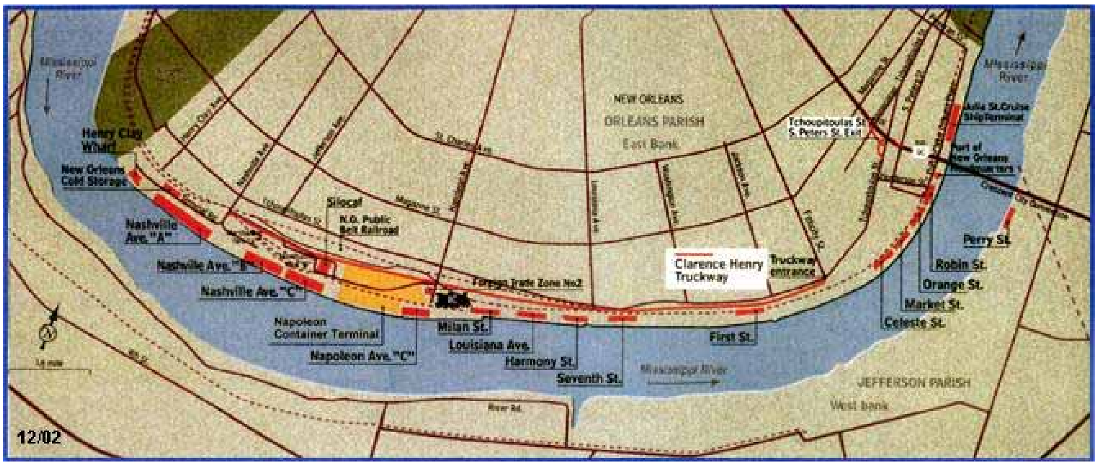

Figure 1: Layout plan of the port of New Orleans

Figure 2: Aerial photo of the port facility

3 Vessel particulars

3.1 Photo

Figure 3: MV LIBRA RIO GRANDE, ex. P&O NEDLLOYD KOWIE

3.2 Particulars

Name of vessel:	LIBRA RIO GRANDE
Type of vessel:	Container vessel
Nationality/Flag:	German/Federal Republic of Germany
Port of registry:	Hamburg
IMO–Number:	9105994
Call sign:	DBZU
Operator:	Rickmers Reederei GmbH & Cie. KG
Owner:	MS "Deike Rickmers" Schiffsbeteiligungs-gesellschaft mbH & Co. KG
Building yard/Building No.:	Stocznia Szczecinska S.A. / B 170-III/4
Classification Society:	Germanischer Lloyd
Length overall:	183.80 m
Width overall:	25.53 m
Draft at the time of the accident:	9.05 m
Gross tonnage:	16,801
Deadweight:	22,900 t
Engine rating:	13,320 kW
Main engine:	H. Cegielski-Poznan S.A. / 6 RTA 62 U
Speed:	19.5 kn
Number of crew:	22

4 Course of the accident

4.1 Course of the voyage

MV LIBRA RIO GRANDE had left the port of Houston at about 22.00 h on 21.05.2005. At 19.10 h on 22.05.2005 the vessel took the pilot for the Mississippi on board. The vessel reached the berth at Nashville Avenue Wharf in New Orleans at 03.30 h on 23.05.2005. Loading operations with shore-side cranes started at 08.00 h.

4.2 Outbreak of the fire

The vessel is equipped with three auxiliary diesel engines with coupled generators to provide electricity. They are located in the aft area of the engine room near the bulkhead to the steering gear compartment.
At the time the fire broke out the auxiliary diesel engines No. 3 (starboard) and No. 2 (centre) were running in parallel operation to generate electricity. Auxiliary engine No. 1 was on stand-by. The auxiliary diesel engines were run in heavy-oil operation. The full pressure of 0.8 to 0.9 MPa is always applied to all the auxiliary diesel engines, including those on stand-by.
Prior to the outbreak of the fire several persons had been engaged in maintenance works in the engine room. At about 10.10 h one of the crew members working in the engine room had noticed heavy oil spraying out of a diesel fuel filter of the emergency system of the auxiliary engines under high pressure and at a high temperature. The heavy fuel oil had leaked out below the filter lid. The seal had appeared to be leaky. The spray had also hit auxiliary engine 3, its turbocharger and its exhaust line. The crew member had immediately informed an engineer who was working in the nearby workshop. The engineer had hurried to the filter and tried to tighten the filter lid. This attempt was unsuccessful. About 5 minutes after the leak was ascertained the spray mist had ignited.
One of the smoke detectors mounted in the vicinity had been activated and the fire alarm had been triggered at about 10.20 h.

4.3 Fighting the fire

The engineer had run to the engine control room and stopped all fuel pumps and the auxiliary engines 2 and 3. After this he had left the engine room with the other staff in order to proceed to his muster station.
The vessel command had taken over command directly after triggering of the fire alarm and organised the fire fighting. An engineer had operated the quick-closing valves for fuel supply lines that could be remote controlled. A fire-fighting group had tried to approach the origin of the fire using respiratory protection in order to combat the fire there with portable fire extinguishers. Some of the crew had begun to close the fire dampers. At about 10.50 h the fire-fighting group had reported that due to the dense smoke in the engine room it was not possible to combat the fire. At this point in time a fire brigade of the New Orleans Fire Department had reached the vessel. The leader of the firemen had taken over the command of the fire fighting. The

Master of the vessel had handed over the plan of the ship and the documents on dangerous cargo. Apart from four officers, the crew had been called upon to leave the vessel. The officers had supported the firemen in further closing of the fire dampers and fire bulkheads. At about 11.05 h it had been decided to use CO_2 in the engine room. The crew had been mustered again on shore and after this the content of 75 CO_2-cylinders had been blown into the engine room.

The two crew members working on the filter had sustained slight injuries due to the hot fuel. They had been taken to a hospital and treated there. The injuries had proved to be so slight that the crew members had returned to the vessel in the afternoon and had remained fit for work.

At 16.45 h the firemen had declared that the fire was "under control". The fire brigade remained at the scene with two fire fighting vehicles. A regular inspection had revealed that as of 18.00 h the temperature in the engine room declined.
At 09.50 h on 24.05.2005 the fire brigade had declared that the fire had been extinguished and had left the scene. After this a gas-free condition had been produced and confirmed. At 11.00 h the representatives of the United States Coast Guard, the P&I-Club of the owner, the surveyor for the hull and engine and the classification society and others had proceeded on board.

After the fire damage had been ascertained, repairs had commenced. On 27.05.2005 the vessel had been moved by a tug to another berth. The repairs had been completed on 17.06.2005 and in the course of the following day the vessel had left New Orleans.

5 Investigation

5.1 Fuel system

The following description of the fuel system is an excerpt from the expert opinion drawn up for the Federal Bureau of Maritime Casualty Investigation (BSU) :

The auxiliary engines can be operated optionally with heavy oil or diesel oil. Fig. 4 shows the piping and instrumentation plan of the fuel supply system of the auxiliary engines.

The heavy oil system is a constant pressure system. The circulation pumps 512.13 suck from the mixing tank 512.19 and convey the heavy oil through the supply line via the pre-heater 512.17, the filters 512.81 and 512.80 to the injection pumps of the auxiliary engines and back via the return line into the mixing tank. The pressure in the supply line is kept constant at the set pressure independently of the load through the regulating valve between the supply and return lines. According to the RI plan the valve is set to a pressure of 1 MPa.

The diesel oil system is a pressure system. The circulating pumps 512.25 suck from the daily supply tank and convey the diesel oil through the supply line via the filters 512.81 and 512.80 to the injection pumps of the auxiliary engines and back via the return line into the daily supply tank. The operating pressure is regulated dependent on load by the spring-loaded pressure retaining valve in the return line. According to the RI plan this valve is set at 0.4 MPa.
In addition an release valve is arranged between the supply and return lines. If the opening pressure is exceeded, surplus fuel flows through this valve directly into the diesel oil daily supply tank and thus limits the maximum operating pressure in the diesel oil system to the pressure set at the valve. According to the RI plans, the opening pressure of the release valve is set at 0.88 MPa.

The fuel emergency starting system is a gravity system. If the power supply fails and there is a pressure drop in the main supply system, the emergency system is intended to take over the supply of diesel fuel to the auxiliary engines . This is only possible if the pressure difference between the main system and the emergency system is sufficiently large and all valves in the emergency starting system are opened.

There is only one valve and one filter between the gravity tank and the auxiliary engines. According to the RI plan the emergency system is separated from the normal system operated at a higher pressure through a non-return stop valve.

The operating pressure in the emergency system is only dependent on the difference of level between the supply tank and the auxiliary engines and the density of the diesel oil, and at approx. ≤ 0.11 MPa it is well below the operating pressure in the main system. An operating pressure above this normal operating pressure is only *possible in the pipe section between the stop valves and the check valve at the filter when the check valve is closed and one of the three stop valves fails.*

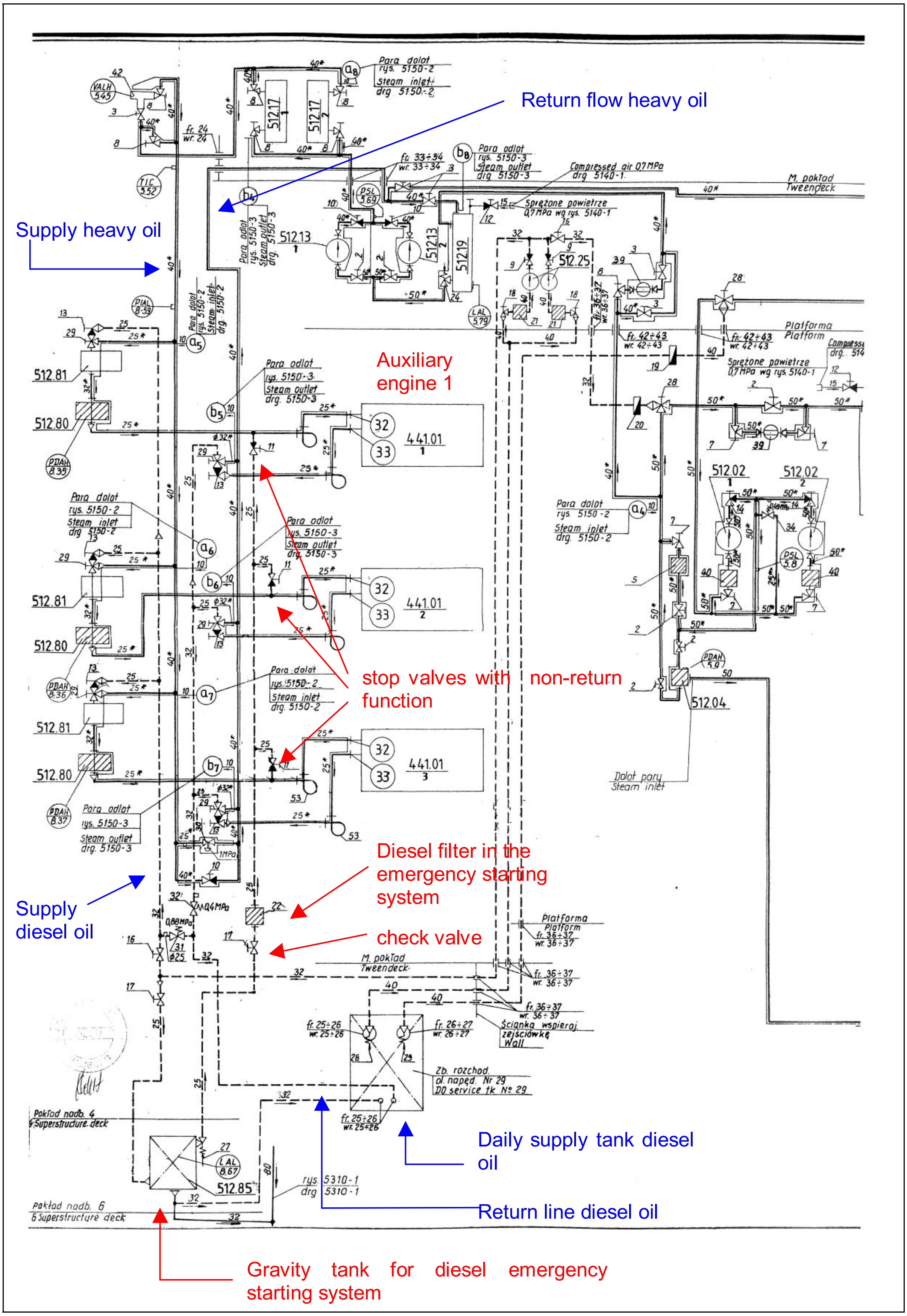

Figure 4: Piping and instrumentation plan of the fuel system of the auxiliary diesel engine

5.2 Findings on board

Directly after the fire, investigations into the cause of the fire were started by the representatives of the US Coast Guard and a surveyor from BMT Salvage LTD who was acting on behalf of the hull underwriter.

At the start of the investigation it was ascertained that the stop valves to the emergency starting system at auxiliary engines 2 and 3 that were running at the time the fire broke out were closed. The valve at auxiliary engine 1 that was on stand-by was open.

The components of the emergency starting system (the stop valves with non-return function and the filter) were removed and dismantled. It was ascertained that the cones on the spindles of all the subject stop valves were secured with a wire and that the cone was thus strongly restricted in its movability (see Fig. 5 and 6). There was no spring on the spindle. Evidently there was no non-return function as the valve cone was carried with the spindle and raised from its seat when the valve was opened. Thus all the stop valves at the separating point from the normal system to the emergency system did not correspond to the specification of the piping plan. The crew had been unaware of this circumstance.
The investigators had the impression that the securing of the cones with wire on the spindle had not been carried out by the original manufacturer. The crew were unable to provide any information in this respect.

Figure 5: Cone secured with wire

Figure 6: Wire removed and cone drawn off

On the basis of the fact that the stop valve on auxiliary engine 1 was open and the line of the emergency starting system did not seal through the non-return function of the stop valve, heavy oil flowed into the emergency starting line at a pressure of 0.8 to 0.9 MPa. The emergency system itself was only designed for a much lower pressure. During the investigation on board the investigators ascertained that the check valve behind the diesel filter of the emergency starting system was closed. That is why the pressure could not be reduced via the gravity tank and was applied to the diesel filter. The seal on the diesel filter did not withstand the pressure and the heavy oil escaped, finely atomised. Among other objects it also struck the auxiliary engine 3 close by.

After dismantling of the diesel oil filter it was diagnosed that the seal was completely burnt out. Two other filters of the same type were opened for purposes of comparison. It was ascertained that a T-shaped rubber material had been used for the seal. The filters were designed for contact with diesel oil, a temperature of 35 to 40°C, and a pressure of 0.4 MPA.

Figure 7: Diesel oil filter in the emergency system

5.3 Classification and acceptance of the pipe system

The piping system of LIBRA RIO GRANDE, like the entire vessel, is built and accepted in accordance with the Rules for Classification and Construction of Germanischer Lloyd (GL). The fuel system activity is based on the GL Regulation on "Piping systems, fittings and pumps" (I Part 1 Chapter 2 Section 11) as a component of the classification and building regulations. In this, systems for conveying liquid or gaseous substances are divided into three pipe classes. The classification is based on the pressures and temperatures occurring. The lowest qualitative requirements made of materials have to be satisfied for classification in pipe class III. This class includes e.g. pipe systems for liquid fuels that are carried at pressures ≤ 7 bar (0.7 MPa) and temperatures ≤ 60°C.
The emergency starting system of the auxiliary engine corresponds to pipe class III due to the low requirements made because of the medium transported.

The normal piping system suitable for heavy oil operation corresponds to pipe class II. Here pressures ≤ 16 bar (1.6 MPa) and temperatures ≤ 150°C can occur. This also covers operation with diesel oil in normal operation on the grounds of the lower requirements made here regarding pressure and temperature.

Piping systems of pipe class II and their components such as fittings and flanges are subject to higher requirements concerning the materials allowed, their workmanship, and testing.
According to the classification and building regulations of GL I Part 1 Chapter 2 Section 11-B-4.2.1, all pipes of pipe classes I and II must be examined by an surveyor prior to installation. Fuel lines with a calculated pressure above 3.5 bar are

included in this examination, independently of the pipe class. As the calculated pressure in the emergency system lay below 3.5 bar, no examination was necessary here.

All pipes are to be tested after installation on board in accordance with I Part 1 Chapter 2 Section 11-B-4.3. Piping for fuels are to be tested with not less than 1.5 times the calculated pressure, but at least with 4 bar overpressure. The BSU was unable to ascertain to what extent these tests had been carried out at the time the vessel was commissioned.

The components of the fuel system are subject to inspection within the context of maintaining the class. The scope of the inspection depends on the provisions specified in Part O - Classification and Inspection - here Section 3 C 1. According to this, the fuel systems are also accepted in the annual inspections within the scope of the inspection of the engine room. Generally a visual inspection is carried out. The piping and fittings of the auxiliary engines are only expressly named for renewal of class III and thereafter for vessels older than 10 years. Here the components are to be inspected and tested in the condition recorded as directed by the surveyor.
The various pipe classes are not distinguished in any of the possible inspections.

The BSU did not check to what extent the fuel system of the auxiliary engines had been checked within the scope of the annual inspections.

5.4 Expert opinion on behalf of the BSU

One of the stop valves was handed over to the BSU by the vessel operator at the beginning of November 2005.
The BSU charged its expert, Prof. Dipl.-Ing. Diederichs, to examine the stop valve.
The examinations conducted are described in the following excerpt from the expert opinion drawn up:

The valve to be examined was handed over to the Undersigned together with the report by the insurance expert, dated 08 June 2005, and the accident report by the US Coast Guard.

Photo 2 (Fig. 8) shows the valve in the condition on delivery. The valve was dismantled and all parts were cleaned with a cleaning agent. The coats of paint on the housing were removed mechanically in order to make any marks visible. Photo 3 (Fig. 9) shows the valve after dismantling and cleaning.

The cast and mechanically applied marks ascertained after completion of cleaning of the valve body are shown in Photo 4 (Fig. 10).

The valve was assembled to carry out tightness testing and to measure the valve lift. The fastening screws of the top part were pre-tightened with a torque of approx. 90 Nm in accordance with DIN 2507.
A valve lift of 18 mm was ascertained in this assembled condition.

For the tightness test the valve was closed with a torque of approx. 12 Nm using the hand wheel, filled with water and subjected to a hydraulic pressure of 4 MPa. No drop in pressure could be ascertained after five (5) hours. The point at which the pressure drops was determined by actuating the hand wheel in stages of approx. 20°.

There was no drop in pressure up to turning the hand wheel through approx. 150°. Beyond this turning angle a drop in pressure could be ascertained.

The flow inspection was carried out with water at 18°C. With a norm pressure of 1 MPa pressure difference, a flow rate of V_{100} = 22 m^3/h corresponding to $k_{V,100}$ was determined for the valve opened 100%.

A maximum axial play of 2 mm and a maximum possible inclination of ± 3° was ascertained on the cone fixed on the spindle by steel wire with a diameter of 2 mm.

After the securing wire had been removed, the spindle and the bore of the valve cone were measured. The measuring results are listed in Figure 5 (Fig. 11).

At the close of the examinations the material of the valve body was identified. The analysis data revealed a heat-resistant material GS – 22 CrMo 5 4 (material No.: 1.7354). This material is used to produce steel castings (fittings, flanges etc.) in chemical apparatus, steam boiler facilities or heat engines.

Figure 8: Valve in the condition on delivery

Figure 9: Valve in dismantled and cleaned condition

Figure 10: Markings on the valve

1) Test number PRS
2) Acceptance stamp PRS
3) Test stamp flow test
4) Valve size
5) Acceptance stamp quality verification
6) Nominal width ND and nominal pressure NP
7) Material code C 22.8
8) Flow direction for guaranteed tightness

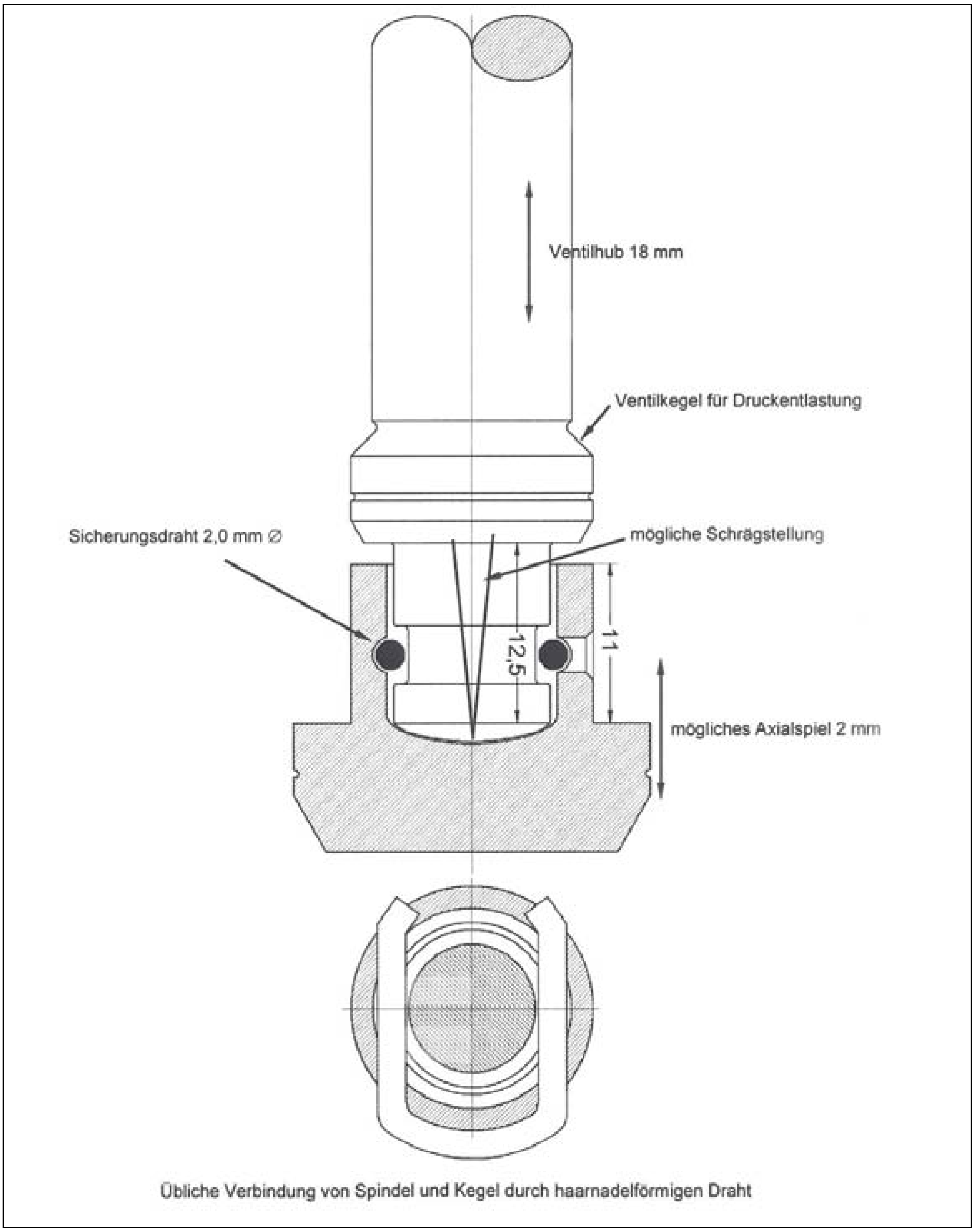

Figure 11: Dimensions on the valve

Ventilhub	-	Valve lift
Ventilkegel für Druckentlastung	-	Valve cone for pressure relief
Sicherungsdraht	-	Securing wire
mögliche Schrägstellung	-	Possible slanting position
mögliches Axialspiel	-	Possible axial play
übliche Verbindung von Spindel und Kegel durch haarnadelförmigen Draht	-	Customary connection of spindle and cone with hairpin-shaped wire

As a result of the examinations the author of the expert opinion comes to the following conclusions:

- *The valve corresponds to the standard EN 736 – 1 and is a standard commercial, manually operated through-way stop valve with a 45° sloping seat and a relief valve for the gland seal. A return flow check (non-return valve) through a freely sliding cone is neither envisaged nor structurally possible, as the spindle lift of 18 mm is greater than the pin length of the spindle (12.5 mm) in the cone.*
  So that the valve is not a stop valve with a return flow safeguard (non-return stop valve) in accordance with the shipside documents.

- *A return flow safeguard could not be ascertained even at a low turning angle of the hand wheel. The play ascertained in the tightness test is necessary to ensure the tightness of the valve closed in cold condition when the operating temperature rises and the components (valve body, spindle) expand to varying degrees.*

- *In valves of this kind fixing the cone with steel wire is certainly customary, but generally a hairpin-shaped wire is used for this purpose (see Fig. 11). With the pressed-in wire made of heat-resistant material the valve cone was fixed securely.*

- *It is evident from the marking on the housing - see Photo 4 (Fig. 10) that the valve with nominal width ND 25 is made of cast steel and in accordance with DIN 2401, Part 2, is licensed for a nominal pressure NP 40 (40 bar).*

  - *The material quality specified in DIN 2401 was confirmed by the examination.*

  - *The K_V–value of 20.2 stated on the valve was confirmed by the flow measurement.*

  - *The valve is provided with quality verification and was accepted by the Polish Classification Society PRS.*

- *A stop valve of this kind without return flow safeguard should be installed in such a way that the arrow cast on the valve body points in the direction of the pressure gradient so that in closed condition the high pressure acts beneath the cone and in the opened condition the gland is screened against the high pressure by the relief valve.*

- *It is not known in what direction the valve was installed. However, it is to be assumed that in all probability the arrow on the valve body was erroneously considered to be the marking of a non-return stop valve and that the arrow pointed in the direction of flow, i.e. in the direction of the higher pressure.*

- *Judging by the thickness of the coat of paint that had to be removed on cleaning of the valve in order to make the marks visible, it is to be assumed that the valve was installed already when the vessel was built.*

- *The emergency starting system was clearly allocated to pipe class III in accordance with Chapter 2 - Section 11 of the GL building regulations. According* *to Table 11.3 all fittings in this pipe class must show quality verification 2.2 in accordance with EN 10204. The valve body shows quality verification 2.2.*

6 Analysis

6.1 Fire fighting

According to the documents presented to the BSU the fire fighting measures carried out by the crew were well organised and led to the target. The fire was brought under control with the support of the fire brigade and put out.

6.2 Cause of the fire

The cause for the outbreak of the fire was the installation of stop valves that were not provided with the intended non-return function. This led to heavy oil standing under a pressure of approx. 1 MPa flowing in to the emergency start line. The high pressure in turn was the cause of the failure of the seal on the diesel oil filter of the emergency system. The heavy oil escaped here in spray form. The fact that this spray hit the hot parts of the auxiliary engine 3, its turbocharger and exhaust pipe, started the fire.

The vessel operator did not submit any documents showing maintenance work on the stop valves. In the opinion of the BSU-surveyor the wrong stop valves were installed already when the vessel was built.

The operator did not have any data sheet or other documents on the stop valve found. There was only a reference to the producer on board LIBRA RIO GRANDE. According to this the manufacturer is ZUChi A from Kielce in Poland. The building yard of the vessel does not exist any more in the meantime.

It was not possible to ascertain how long the valve was open and how long the diesel filter of the emergency system was subjected to the high pressure before the filter yielded. No statements about actuating the stop valves could be obtained on board.

6.3 Operating the stop valves

In the expert opinion by BMT Salvage LTD. it is opined that the cause of the outbreak of the fire was in fact the opened valve. It would be good engineering practice to close all stop valves, irrespective of whether they were provided with a non-return function if the relevant system was not being used or was on stand-by. At the time of the accident the emergency starting system installed on LIBRA RIO GRANDE had neither been in use nor on stand-by.
The Federal Bureau of Maritime Casualty Investigation (BSU) does not share this opinion. Emergency systems especially should always be ready for operation. The stop function of the valve at the interface normal system/emergency starting system only serves to close piping sections during maintenance work. In order to have full operability of the emergency starting system it is necessary to keep all the valves in the further course of the piping system open. In so far the closed check valve in front of the filter of the diesel emergency system was an error and co-causal for the outbreak of fire, as the high pressure of the heavy oil could not be passed on over the gravity diesel tank.

It is further stated in the expert opinion for the BSU:

In the connection of piping systems with different operating pressures an appropriate valve position must fundamentally ensure that no closed pipe section results in which an operating error or the leakiness of a valve allows the pressure to rise uncontrollably above the structurally intended operating pressure.
As in the present case valves without a backflow safeguard were installed, these valves should have been closed and for safety reasons the check valve at the filter should have been operated in the open position.

It is further stated:

By installing a non-return stop valve it should be ensured that if there is a loss of pressure in the main supply system, the emergency starting system can automatically take over the supply of the auxiliary engine with fuel. This is only possible if

- *the connecting valves between the two main systems and the emergency starting system are also executed with a backflow safeguard and are open.*
- *the shut-off valve at the filter is open and the spring-loaded quick-closing valve at the tank is open.*

Accordingly we have here a safety system that is based exactly on the function of a non-return stop valve and that can activate itself automatically as such. In the opinion of the BSU, especially in the case of vessels like LIBRA RIO GRANDE whose automatic systems allow 24 hour watch-free engine operation, it makes no sense if in the case of a blackout valves must be opened by crew members who might possibly not be on hand initially in order to allow the auxiliary engine to start, or if automatic starting is prevented by closed valves. Possible delays in manning the engine room thus endanger the entire ship's operation.

No damage to the injection pumps is to be feared from the fast change of operating fuel, as on the one hand the pumps are designed for this and on the other hand the diesel oil becomes mixed with the heavy oil and is thus warmed.

6.4 Connecting different pipe classes

All constituent parts of a pipe system must satisfy the requirements made by their categorisation in one of the pipe classes. This statement is "state of the art" according to a representation by Germanischer Lloyd. The said requirement is not stated notably in the classification and building regulations, however.
The components of a pipe system of pipe class II must satisfy the requirements of the quality verification 3.1 B according to EN 10204 (DIN 50 049). The stop valves found satisfied these requirements. In so far they were installed in accordance with the state of the art.
The BSU is of the opinion that the classification and building regulations should expressly contain a reference to the fact that when pipe classes of different ratings are connected, a component that satisfies the requirements of the higher class must be used at the transition point/interface.

6.5 Actions taken

At the shipyard and its successor company altogether 16 vessels of type B 170-III were built between 1995 and 2003. LIBRA RIO GRANDE is the fifth ship of the series. As it could not be ruled out that such wrong stop valves were installed on the sister vessels too, BSU contacted GL. Germanischer Lloyd announced the following steps in a letter:

- *For the vessels of the subject building series we shall include an appropriate note for our surveyors in our Register (Fleet-Online) that within the context of the next survey the function of the three installed non-return fittings in the emergency start-up line is to be examined and that this is to be noted in the survey statement.*

  In the event of malfunctions a corresponding Condition of Class will be entered in the class certificate that states that within a given period the existing fittings must be replaced by suitable non-return stop valves.

  The function test can be carried out during ongoing machine operation by opening the stop valves briefly one after the other. If the emergency starting line of the relevant auxiliary engine warms quickly, this is a clear indication of a malfunction.

  Moreover the vessel command will be instructed to attach a warning plate stating that the check fitting in the emergency starting line between the diesel oil supply tank and the diesel oil filter must be blocked in the "open" condition.

- *Based on the results of the examination of the events on MV DEIKE RICKMERS* (ex. LIBRA RIO GRANDE)*, we shall inform the owners/operators of the further vessels of this newbuilding series about the measures we have taken (checking the function of non-return fittings at the next survey) and draw their attention to a possible elevated risk in the event of faulty operations in conjunction with a request that they forward this information on board the vessels.*

7 Safety recommendation(s)

For the operation of piping systems the Federal Bureau of Maritime Casualty Investigation (BSU) recommends to the crews of vessels that

- when connecting piping systems with different operating pressures it must basically be ensured by appropriate valve positions that no closed pipe section results in which the pressure can rise uncontrollably above the structurally designed operating pressure due to an operating fault or leakiness of a valve.

- the valve positions for pipe sections to be kept open be secured and labelled so that changes can be clearly recognised.

The Federal Bureau of Maritime Casualty Investigation (BSU) recommends to the classification societies that they include a statement in the classification and building regulations that all components of a pipe system must correspond to the same pipe class and that the requirements of the higher class must be fulfilled at the interfaces between two systems of different pipe classes.

8 Sources

- Written statements/comments
  - Vessel Command
  - Vessel Operator
  - Classification Society
- Expert opinion by BMT Salvage Limited
- Expert opinion by Prof. Dipl.-Ing. Diederichs
- Photos/drawings
  - Figure 1: Layout plan of the port of New Orleans
  - Figure 2: Aerial photo: P&O Ports North America
  - Figure 3: Hasenpusch, Maritime Photo-Productions and Agency
  - Figure 5 and 6: United States Coast Guard
  - Figure 7: BMT Salvage Limited
  - Figures 4, 8, 9, 10, 11: Expert opinion Prof. Dipl.-Ing. Diederichs