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

Investigation Report 5/04

1 September 2004

Marine Casualty

Carbon monoxide exposure of two crew members on MT SEATURBOT on 3 January 2004 in Milford Haven (UK)

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 24 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.

Issued by:
Bundesstelle für Seeunfalluntersuchung
(Federal Bureau of Maritime Casualty Investigation (BSU))
Bernhard-Nocht-Str. 78
20359 Hamburg

Director: Dieter Graf
Tel.: +49 40 3190 8300, Fax: +49 40 3190 8340
posteingang-bsu@bsh.de   www.bsu-bund.de

Table of Contents

List of Figures

1 Summary of the marine casualty

On 3 January 2004 at 09:45 h LT[1] an Motorman found the Second Engineer unconscious in the separator room on MT SEATURBOT in Milford Haven, GB. Both of them were working on the lubricating oil separator. At 09.50 h the injured man was taken to the engine control room (ECR) on a stretcher, where he regained consciousness shortly afterwards. The ambulance arrived at 09.55 h and treated the injured man with oxygen. Then the Second Engineer was carried to Withybush General Hospital. At 10.40 h the Motorman was found unconscious in the separator room and taken up to the first deck where she recovered consciousness. The Motorman was carried to the same hospital at 10.55 h. After 10.40 h a staff member of the Texaco Terminal measured a carbon monoxide (CO) content of 20 ppm in the separator room using shore equipment. Increased CO haemoglobin values of 24.3 % and 12.3 % in the two injured crew members were measured in the hospital at 11.50 h. By 20.37 h these had been lowered to approx. 1 % and below. Both crew members were then able to return to their vessel.

[1] All times stated in the Report refer to the legal time (LT) = CET = UTC+1h for Germany or UTC for GB

2 Scene of the casualty

Nature of the incident:	Marine casualty MT SEATURBOT
Date/Time:	3 January 2004, 09.45 h
Location:	Milford Haven, Texaco Marine Terminal 2
Latitude/Longitude:	φ 51°41,9' N λ 005°01,7' W
Position of vessel:	Starboard shore side 88.3° true heading

Section from Sea Chart GB 3275

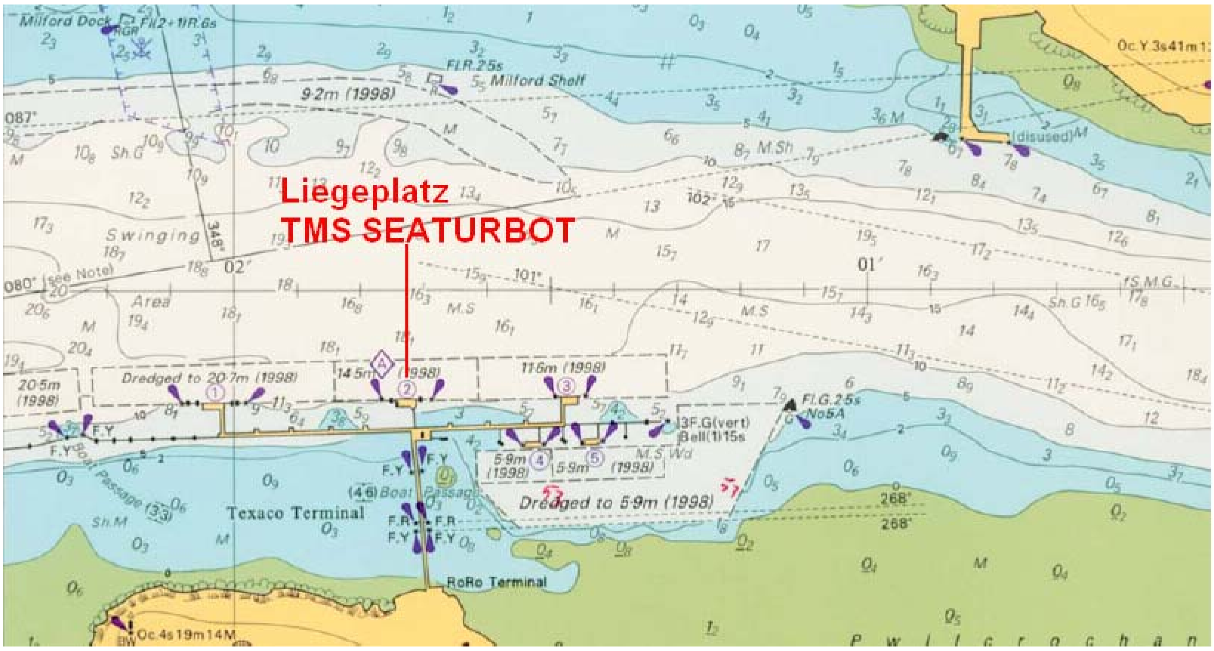

Figure 1: Sea chart

3 Vessel particulars

3.1 Photo

Figure 2: Photo of the vessel

3.2 Data

Name of vessel:	SEATURBOT
Type of vessel:	Motor Tanker
Nationality/Flag:	Germany
Port of registry:	Bremen
IMO Number:	9204764
Call sign:	DDTS
Operator:	TMS "Seaturbot" GmbH & Co KG, German Tanker Shipping
Year built:	2000
Building yard/Building number	Lindenau GmbH Kiel, No. S241
Classification society:	Germanischer Lloyd
Length over all:	177.69 m
Breadth over all:	28.04 m
GRT:	21.353
Deadweight (tdw):	32.250
Draft:	11 m
Engine rating:	8340 kW
Main engine:	MAN B&W 6 L 58/64
Speed:	15 kn
Hull material:	Steel
Hull design:	Double hull
Number of crew:	18

4 Course of the casualty

On 3 January 2004 MT SEATURBOT (see Fig. 2) was in Milford Haven to discharge gas-oil at the Texaco Marine Terminal 2 (see Fig. 1). Due to high counter-pressure on the shore side the discharge rate was low at 650 m³/h and the inert gas system was producing approx. 600 m³/h more gas than was needed in the tanks at a load of 35 %. The surplus gas was blown off via the atmosphere outlet at the aft edge of the funnel with the valve half open (see Fig. 3). Two auxiliary diesel engines each with a rating of 1030 kW, the boiler, as well as the deepwell pumps and the inert gas system were in operation to discharge the cargo. The vessel was lying with its starboard side made fast. According to the information supplied by the vessel, the wind was blowing with a force of 3 bft. from approx. 3 points from starboard. The Second Engineer and an Motorman for maintenance work were in the separator room working on the lubricating oil separator. The bearings were to be changed and a general overhaul was to be carried out. It was cold in the separator room. The engine room ventilator No. 1 was in operation and was blowing directly onto the workplace through the air ducts with the ventilator damper opened. The suction ventilator of the separator room was on, the ventilator damper was open, and none of the separators were in operation. Work began with the daily watch patrol at 08.00 h. At about 09.20 h the Second Engineer switched off the engine room ventilator No. 1 since he feared that the two crew members could catch a cold at the workplace.

At 09.45 h the alerted rescue team carried the unconscious Second Engineer by stretcher up in front of the ECR (see Fig. 4), where he regained consciousness. The shore ambulance arrived at 09.55 h, treated the injured man with oxygen in the presence of the Second Officer and transported him to Withybush General Hospital in Haverford West. After a break the maintenance work in the separator room was continued. At 10.20 h the Motorman was found unconscious in the separator room and taken to the first deck, where he regained consciousness and was then transported to the same hospital at 10.55 h.

It was now clear to the crew that this could be a case of gas poisoning. The discharge work was stopped and one auxiliary diesel was switched off. The engine room was ventilated and left by all. After the second injured person was found at 10.40 h the oxygen and hydrocarbon contents in the engine room were measured. Sufficient oxygen components were measured and no hydrocarbon components were ascertained any more. After this, according to the Master's report of 5 January 2004 and the operator's report of 23 February 2004 to the MAIB, a representative of the Texaco Terminal operator ascertained an elevated carbon monoxide level in the separator room (20 ppm, see, Fig. 5) and on the first intermediate deck (approx. 300 ppm). The provisions room (see Fig. 6), the vegetable room and the frozen food room were located there. 300 ppm were reportedly also measured in the galley. After this the inert gas system that was still running to maintain an elevated pressure in the cargo tanks was switched off on the assumption that the CO component measured had been produced by the inert gas system.

Ventilation of the engine room and gas measurements were continued over a period of 12 hours. The injured Second Engineer and the Motorman were discharged after 12 hours in hospital and returned on board. Seven other crew members were taken to the hospital for blood examinations and returned shortly afterwards.

On permission of the terminal operator the vessel was able to continue discharging without operating the inert gas system any further since the oxygen values on the cargo tanks were uncritical.

Inspectors of Messrs. ChevTex and P&I-Club conducted further measurements on the vessel using a portable measuring device for CO and H_2S (hydrogen sulphide). No leak was found in the inert gas lines. Elevated CO concentrations of 125 ppm were measured at the aft edge of the funnel where the outlet to the atmosphere of the inert gas system is located. It was suspected that the gas was carried via the engine room ventilator and the ventilator in the separator room (see Fig. 7). The outlet valve of the inert gas system opened frequently since the discharge rate was low, although the inert gas system was working with a minimum of gas produced. The gas that emerged had an elevated CO component. The Master notified all crew members during a safety meeting and gave special instructions to the officers concerning the conditions that led to the accident, including wind conditions, discharge rate, positions of the ventilator dampers (see Fig. 8).

5 Investigation

The BSU was notified of the accident by the MAIB (Marine Accident Investigation Branch) on 5 January 2004 and via an article in the Lloyds List of 6 January 2004, and was only informed of the incident by the vessel operator on 3 February 2004. The BSU was not aware of the dates for the meeting at the Building yard (see Section 5.2) and the survey of the vessel (see Section 5.3). The MAIB discontinued its investigation on 26 February 2004 and supported the BSU in its investigations.

5.1 Measures taken by the crew on board

After the accident the inert gas system was subjected to a thorough examination by the vessel's command. The setting values of the fuel-air ratio at the load stages 25, 50, 75 and 100 % were checked. The values determined were identical with the operating values at the time the vessel was commissioned. The Chief changed the O_2-sensor, cleaned the main and ignition burners and checked the settings of the fuel and air dampers at 0 and 100 %. The solenoid valve of the ignition burner was changed and the height of the main burner was set at 45 mm. For better assessment of the burner and its mode of operation the Chief inspected the combustion chamber (see Fig. 9). Salt deposits were ascertained on the combustion chamber wall. A pressure test with sea water revealed two leaks in the upper area of the jacket that had been sealed by a polymer repair system of Messrs. Unitor. The places are to be welded later.

5.2 Meeting with the Building yard

A meeting to discuss the accident on MV SEATURBOT was held at the Building yard on 14 January 2004. The meeting was attended by representatives of the yard and the vessel operator. The safety organisation Seeberufsgenossenschaft (See-BG) and the classification society Germanische Lloyd (GL) were notified for information of the status and the circumstances.

The engine room ventilators port and starboard can work optionally at "delivery" or "suction". When "delivery" is pressed the air is guided via the engine room ventilators port and starboard of the funnel into the engine room and the surplus air is guided out via the dampers at the aft edge of the funnel. When "suction" is selected the air is drawn in to the engine room via the dampers and given off into the atmosphere via the engine room ventilators port and starboard of the funnel. Generally both or at least one ventilator runs at "delivery" in order to supply the main engine or auxiliary diesel, boiler system and inert gas system with the necessary combustion air. The system is only switched to "suction" in exceptional cases, for instance in order to remove CO_2 (carbon dioxide) after this has been used in the engine room to put out a fire.

The inert gas system was designed by the shipyard and the drawings were tested and accepted by the SeeBG and GL.

As additional measures a plate was to be mounted at the switch consol of the inert gas system (see Fig. 10) indicating that operation of the inert gas system was only allowed when at least one engine room ventilator was running on "delivery", and a switch condition was to be realised that did not allow any other form of operation.

5.3 Survey of the vessel by See-BG and GL

The vessel was inspected in Wilhelmshaven on 19 January 2004. In addition to the crew, representatives of the vessel operator, the See-BG and GL were present.

After inspection and repair of the inert gas system of MT SEATURBOT, the vessel's command had ascertained that the cause of the elevated CO content in the atmosphere and in the engine room had been water in the combustion chamber of the inert gas system. The water led to incomplete combustion and an increase in the CO content in the inert gas at a constant O_2-content of 3 % (see Fig. 11). The switching off of the engine room ventilator at the time of the accident meant that the auxiliary engines in port operation drew in exterior air via the louvers at the aft edge of the funnel (see Fig. 12) that was mixed with an elevated CO component.

The function test of the inert gas system did not reveal any defects. A new switching condition for the inert gas system was established. When the system is taken into operation at least one engine room ventilator must be working on "delivery". The inert gas system stops automatically when the engine room ventilator is switched off (see Fig. 13). In addition there is a portable unit for CO measurements on board. A plate with information on using the inert gas system has been mounted. The three sister vessels of the same type are to be retrofitted accordingly.

5.4 Measurements on board the sister vessel SEALING

On 20 January 2004 the operator's construction supervision conducted CO measurements using a winter gas measuring device on board SEALING with the inert gas system in operation. The measurements were as follows: at the atmosphere exit at the aft edge of the funnel 16 ppm, on the main deck inside (location of the inert gas system) with one ventilator set at "delivery" one ppm, and the second ventilator set at "delivery" 12 ppm. These measuring results were reportedly also achieved on MT SEATURBOT.

5.5 Survey by the BSU on board MT SEALING

On 19 March 2004 the BSU carried out an examination on board MT SEALING. This was attended by an inspector of the vessel operator, the Chief of MT SEALING, and one representative each of the See-BG, the GL, and Messrs. INLABCO, the firm that was to carry out the measurements.

The vessel was built to the same design as MT SEATURBOT and two other vessels of the operator. It was to be investigated how the CO levels of 300 ppm in the provisions room, 20 ppm in the separator room, probably measured approx. two hours after the accident in Milford Haven on MT SEATURBOT, and the CO levels of 16 ppm at the outlet to the atmosphere as well as 12 ppm on the main deck inside, measured on 20 January 2004, could be achieved on MT SEALING. The MAK value[2] lies at 30 ppm (30 ml/m^3). Even 1,000 ppm CO in the air breathed can cause severe toxic syndromes. The influence of CO doses that lead to a CO haemoglobin content of about 20 to 50 % in the blood cause, for instance, headaches, giddiness and failure of muscle force. Approx. three-and-a-half hours after the accident 24.3 % CO haemoglobin was measured in one of the injured crew members in the hospital.

All the air inlets and outlets on MT SEALING in the way of the superstructures and the engine were examined together with the Chief, photos were taken, and the measuring points were specified. At the time of measuring the wind was blowing 5 points from starboard at a force of 6 bft. The vessel was lying with the port side fast. The inert gas system was running at 20 % load and the gas was given off into the atmosphere entirely via the I.G. outlet at the aft edge of the funnel. Both engine room ventilators were set to "suction" for the scenario in order to produce the least favourable conditions artificially (normal operation "delivery").

During the accident on MT SEATURBOT the inert gas system was not working soundly due to the leak discovered in the cooling system and the ventilation system in the engine room since the engine room ventilator was switched off. After the accident elevated CO concentrations of 125 ppm were measured at the inert gas exit at the aft

[2] Maximal allowable concentration

edge of the funnel on MT SEATURBOT. The boiler system and the auxiliary diesel were not supplied with air as planned, since the engine room ventilator was switched off. These sources were not examined and there were no exhaust gas measurements at the time of the accident. According to the emission test the auxiliary diesel engines installed on board each produce between 11 ppm CO at full load and 216 ppm CO at idling speed. Incomplete combustion with elevated CO output would have been possible here too due to the deficient air supply. CO gases were emitted into the atmosphere that were ultimately the cause of the CO poisoning of the two crew members. According to the DWD Survey Report it is very probable that clearing of the air heavily interspersed with CO components in the funnel area of SEATURBOT was impeded due to the weather conditions. Thus it cannot be ruled out that under unfavourable weather conditions emitted gas can be drawn in again, for example via the air conditioning system and the air inlets in the engine room. Sufficient ventilation is then crucial in order to avoid dangerous gas concentrations.

Measuring results:

10:36 h:	0 ppm	Main deck inside inert gas system, measuring point approx. 50 cm high
10:42 h	0 ppm	Dry provisions room, measuring point head height
10:48 h	0 ppm	Galley, measuring point 85 cm high
12:00 h	60 ppm	Outlet to atmosphere of inert gas system, measuring point in the bars
12:06 h	0 ppm	Lubricating oil separator, measuring points on the ground
12:10 h:	Both engine room ventilators set to delivery.	
12:20 h	0 ppm	Port cowl engine room ventilator measuring point directly behind the protective grating
12:26 h	0 ppm	Measuring point 1 m behind the exit to the atmosphere, inert gas system
12:45 h	0 ppm	Sounding pipe sludge tank separator room

The engine room ventilators each have a capacity of 100,000 m³/h. The inert gas system produced approx. 740 m³/h. A mobile measuring device of SEALING showed 0 ppm CO component and 20.7 % oxygen component in the interior spaces during the measurements conducted by Messrs. INLABCO.

5.5.1 Expert opinion by Schmitt und Fintelmann (INLABCO) GmbH

The measurements were conducted with a Dräger gas trace hand pump with Dräger test tubes carbon monoxide 2/a (for details of measuring points and conditions on the spot see Section 5.5).

The expert certified that on the basis of the results of the survey conducted on MT SEALING on 19 March 2004 with fault-free operation of the inert gas system and with the engine room ventilation switched on (100,000 m^3/h), contamination with a carbon monoxide concentration harmful to health could be ruled out.

5.6 Ship's plan and arrangement of the air inlets and outlets in the way of the superstructures

Fig. 19 shows a side view through the air inlet and outlets in the way of the superstructures on MT SEATURBOT and the three sister vessels of the same design, as well as the position of the engine control room, the inert gas system, the provisions and cold stores, the galley and the separator room. The ventilation systems of the engine room, accommodations and galley are separated from each other.

The engine room ventilators are located on the port and starboard sides of the funnel (see Fig. 14). The outlet to the atmosphere of the inert gas system is below the louvers (see Fig. 12). The air inlet for the air conditioner in the accommodations is on the port side superstructures (see Fig. 15). The after edge of the superstructures in the midship area accommodate the ventilator dampers for the galley (see Fig. 16), laundry and sanitation facilities. At the top edge of the funnel (see Fig. 17) are the outlets to the atmosphere for the main engine, the auxiliary diesel engines and the boiler system. The inert gas line (see Fig. 18 and 15) leads along the port side superstructures below the supply air for the air conditioning system to the tanks forward.

5.7 Inert gas system

The inert gas system bears the designation 108 Moss Hamworthy KSE HKSEM. The Technical Manual No. 130574 supplies the following performance data:

TECHNICAL DATA

Performance Generator System

Nominal capacity:	3.750 Nm³/h
Delivery pressure generator outlet:	Approx. 1200 mm WG at 100 % capacity
Normal oxygen content:	1 - 4 % by volume
Turndown ratio:	4 : 1

Oxygen content adjustable down to approximately 1,0 % by volume.

Gas composition by volume at O_2 = 3 % by volume *)

CO	= Max. 100 ppm
NO_x	= Max. 150 ppm
SO_2	= Max. 1 ppm
CO_2	= Approx. 14 %
N_2 + Ar	= Balance
Soot	= Bacharach 0

Gas temperature at cooling tower, outlet: Maximum 3 - 5°C above cooling water inlet temperature. Carry over of water droplets less than 1 g/kg dry gas.

*) Guaranteed through all points in the operating range.

Consumption

Fuel oil
(Inert gas at 3 % by volume O_2 by combustion of ambient air).

Capacity:	Approx. 277 kg/h
Without preheating:	Marine Distillate Fuels, according to ISO 8217:1996(E). Category DMA or DMB

Seawater

Capacity (Cooling tower):	Approx. 220 m³/h
Pressure (Cooling tower):	Approx. 2 bar g at plant inlet
Temp. increase through plant:	Approx. 13°C

5.7.1 Operation of the inert gas system

The operation of the inert gas system is regulated in the procedural instruction in the Quality Manual of the SEATURBOT and its sister vessels. The following rules are laid down for discharge operation:

The use of the inert gas system is always necessary when

- the flashpoint of the cargo lies beneath 60° C and the vessel > 20,000 tdw,
- it is required by port or charterer regulations (e.g. in Immingham),
- the cargo is heated to a temperature that is higher than the flashpoint of the cargo minus 5°C.

The inert gas system is to be made ready at least 15 min. before the start of the use of the inert gas system by the engine (order to the Chief Engineer).

- After the engineer has reported that all is clear the system is to be regulated and monitored from the cargo office.
- Have control strips written (O_2-content and pressure).
- The O_2-content of the system must lie below 5 % (SOLAS requirement!). If the O_2-content exceeds the maximum limit there is an

alarm and a valve guides the faulty inert gas into the atmosphere. The engineer on watch must check the system.

- Set the pressure in accordance with the experience of the vessel's command (e.g. to 0.8 bar overpressure) and in accordance with the external circumstances (e.g. season).
- Measurements to monitor the O_2-content in the cargo tank must be conducted and logged regularly.

The following must be noted:

If the nature of the cargo requires the use of the inert gas system, extreme care must be taken that no underpressure occurs in the tank. The pump must be operated in such a way that the inert gas quantity exceeds the loading rate by 25 %.

In the event of failure of the inert gas system the discharge operation is to be broken off at once. The Chief Engineer is to be notified immediately. If he is unable to ascertain that the system can be restored within an appropriate period, the Terminal must be informed and the further action to be taken agreed. Special care should be taken to ensure that the discharge operation can be continued under the safety conditions stipulated in ISGOTT[3], Chapters 7.10 and 10.6.7 with written agreement of the Terminal.

During discharge all tank apertures are to be kept closed!

5.8 Building regulations, building yard and ventilation system

The See-BG approved the plans for the ventilation systems in the engine rooms and superstructures. These were implemented by the Lindenau yard and the vessel was then surveyed by GL.

The overpressure in the engine room may not exceed 50 Pa. The maximum exhaust air speed in the waste air apertures must be less than 6 m/s. There are two lockable supply air ducts in the separator room and a non-lockable waste air duct. The air volume flow rate is 2.77 m^3/s at an overall air flow rate of 55.56 m^3/s in the engine room.

The air conditioning system operates independently of the air flow in the engine rooms. It must also be ensured that no air-conditioned room is connected to the CO_2-fire extinguishing system of the vessel. The mechanical supply air results from 10 m^3 room capacity multiplied with the air change rate of 9/h. The mechanical used air results from 4 m^3 room content multiplied by the air change cycles of 15/h. The air conditioning system cannot be operated with recirculating air.

The separator room is supplied from the engine room ventilators, and the provisions room and the galley from the air conditioning system. The frozen food and vegetable room is not connected to the air conditioning system.

[3] International Safety Guide for Oil Tankers & Terminals

5.9 Official expert opinion by DWD

The BSU requested the business unit Marine of Germany's National Meteorological Service (DWD) to analyse the weather conditions prevailing between 09.45 h and 10.40 h on 3 January 2004 in the port area (Texaco Terminal 2) of Milford Haven (UK).

5.9.1 Basis of the data

Due to the international exchange of weather data, the DWD has hourly measuring and observation values from official weather stations of the British Weather Service available for the region and the period to be assessed. In addition recourse was made to vertical soundings of the radio sounding stations Camborne (Cornwall) and Valentia (Republic of Ireland) at 00 and 12 UTC (3 January 2004).

In addition to the evaluation of the available measuring and observation documents from the area to be assessed, the scientific analysis of the overall weather situation and its development provided a major basis for preparing the expert opinion.

5.9.2 Weather situation

In the morning of 3 January 2004 a weakly pronounced trough of low pressure crossed the Irish Sea and the area around Milford Haven and carried stable, layered, very damp and relatively mild ocean air masses into the area forming the subject of the examination. This finding was supported by the vertical soundings of the neighbouring radio sounding station in Cornwall and Southern Ireland. Weak intermediate high-pressure influence was only able to make itself felt in the second half of 3 January 2004 and in the night from 3 to 4 January 2004. However, this was not completely free of interference.

5.9.3 Wind and weather conditions

Throughout the entire morning of 3 January 2004 the Observation Station in Milford Haven reported south-east winds of force 4 to 5 bft. On occasions wind force 6 bft. was also registered. The air temperature at a height of 2 m was 6°C for the period between 07.00 h and 12.00 h. The atmospheric humidity was over 95 %. At times 100 % was measured too. With an overcast sky and deep lower cloud boundaries between 30 and 100 m drizzle of varying intensity occurred repeatedly. The visibilities were very poor and fluctuated between 2 and 3 km. With relatively strong drizzle visibility may also have dropped below 1,000 m for short periods.

The vertical soundings available show very stable layering for the Milford Haven area. The first inversion in the atmosphere was over 1000 m high, however. The radio balloons also show an isothermal line, in other words temperature remaining constant with the height for the bottom decametre, which probably made a vertical air exchange difficult to say the least.

5.9.4 Summary

The analysis of the weather data available and the vertical soundings of 3 January 2004 indicated that exchange of the vertical air mass was impeded at the scene of the accident, despite the relatively strong winds.

Following a thorough analysis of the documents available to us it is therefore probable that clearing of the air heavily interspersed with CO components in the funnel area of MT SEATURBOT was impeded due to the weather.

6 Analysis

The arrangement of the air inlet apertures and the apertures to the accommodations and engine rooms is based on empirical values in ship building. The International Code (IBC) and the Code (BCH) for the construction and equipment of ships carrying dangerous chemicals in bulk require special observation taking into account loading lines and tank venting lines.

According to IBC, BCH and the Accident Prevention Regulations for Enterprises engaged in Ocean Navigation (UVV-See) at least two licensed gas detector units must be carried to detect gases. One gas detecting unit that operates in accordance with the test tube method must have 10 test tubes each for measuring carbon monoxide, carbon dioxide, nitrous gases, oxygen and qualitative gas display. The test tubes were quickly used up on board. The measurements were continued with shore-based equipment.

According to the special GL regulations for tankers, the spaces to be rendered inert must be equipped with facilities for pressure monitoring and connections for monitoring the tank atmosphere as well as with appropriate excess pressure/underpressure safeguards. Appropriate measuring devices for measuring oxygen and hydrocarbon gases and vapours are to be provided. The faulty combustion with the elevated CO components (the leak in the cooling line in the combustion chamber of the inert gas system) was not identified with this equipment (see Figs. 10 and 11).

The safety circuit in which at least one engine room ventilator in the inert gas operation is set at "delivery" has now been realised on the vessels WELS and SEATURBOT. Mobile measuring devices for carbon monoxide is now in use on all the vessels of the operator following the accident on SEATURBOT. The surveyor of Messrs. INLABCO certifies that with sound running of the inert gas system and the engine room ventilation switched on (100,000 m^3/h), contamination with a carbon monoxide concentration harmful to health can be ruled out.

It was not possible to clarify how the CO values of 300 ppm measured in the area of the provisions and cold stores and the galley occurred. The frozen food store and vegetable room are not connected to the air conditioning system. The provisions store is connected to the air conditioning system that is supplied with air from the port side at the aft edge of the superstructures (see Fig. 15). The galley is supplied via ventilator dampers at the aft edge of the superstructures (see Fig. 16). During the survey on board SEALING by the BSU no CO components were measured in the spaces under the most unfavourable conditions (both engine room ventilators set to "suction") with the inert gas system running. The CO component emitted was 60 ppm directly next to the outlet to the atmosphere. The max. value given by the manufacturer lies at 100 ppm.

More could be done on the ship-building side to reduce accident risks of this kind by structural measures. Carbon monoxide components can be measured and reported by installing sensors. The toxic gas is emitted from all internal combustion engines (e.g. main engine, auxiliary diesel, boiler and inert gas system) that burn diesel or gas-oil. The gas mixes well with air, having almost the same specific weight as air, and is odourless and colourless. Effective ventilation in the way of spaces is vital (see above regarding the switch condition of the ventilators in inert gas operation) in order to avoid poisoning.

At the time of the accident the lubricating oil separator was being serviced. The lubricating oil separator is close to a lockable waste air duct. Instead of closing the supply air duct so as not to work in the supply air current, the engine room ventilator was switched off. Thus the engine room and separator room could no longer be ventilated sufficiently. The performance of the engine room ventilator might possible have sufficed to reduce the air contaminated with CO to a contamination level that is not dangerous for humans.

6.1 Cause of the casualty

As a result of the engine room ventilator being switched off and the underpessure in the engine room generated by this CO gases emitted into the atmosphere by the internal combustion engines (auxiliary diesel, boiler, inert gas system) were able to return back to the separator room. This was the cause of the accident involving the CO poisoning of the two crew members.

The weather situation prevailing at this time promoted the accident, so that sufficient mixing of the CO emissions with fresh air by means of vertical exchange of air volumes was impeded. The auxiliary diesel engines were able to produce 11 - 216 ppm CO components each in normal operation and the inert gas system not operating soundly produced a CO emission of 125 ppm, elevated by 25 %. It should be taken into account here that the outlet to the atmosphere if the IG system (see Fig. 12) is located in the direct vicinity below the ventilator dampers (louvers) at the aft edge of the funnel, while the exhaust gas outlets of the other internal combustion engines are arranged above the ventilator dampers at the upper edge of the funnel (see Fig. 17). In addition the ventilator dampers were slanting downwards. As a result a stronger intake of the inert gases emitted from the outlet to the atmosphere of the IG system appears more probable than intake of the exhaust gases from other internal combustion engines from the exhaust pipes lying above the louvers. In addition to the fact that the engine room ventilation was not operated in accordance with provisions, identified as the cause of the accident, and the weather situation that promoted the casualty, in this respect the ship's design is also to be considered as a factor promoting the accident.

7 Safety recommendations

The BSU recommends owners, operators and crews of all vessels that emit carbon monoxide gases to ensure sufficient ventilation in spaces and to install carbon monoxide detectors in superstructures and engine rooms.

Equipping vessels that emit carbon monoxide with carbon monoxide detectors in the way of superstructures and engine rooms should be specified and regulated in the national and international codes and be included in the construction and testing provisions of the classification societies.

Shipyards, the safety organisations and classification societies should recognise weak points in ship designs and plan inspection by applying better risk analysis methods in order to make sources of danger visible already at the design stage and minimise them by structural measures.

If the occurrence of one or more dangerous substances in the air at the workplace cannot be ruled out safely, the operator or the crew of the vessel must determine whether the levels fall below the maximum admissible concentration (MAK)[4], the technical guideline concentration (TRK)[5] or the biological workplace tolerance value (BAT)[6], or whether the trigger threshold is exceeded. The overall effect of various dangerous substances in the air at the workplace must be assessed (cf. § 18 Gefahrstoffverordnung - Monitoring Obligation; Dangerous Substances Regulations).

Operators of vessels are advised to replace the measuring of gases with a test tube method by other and faster procedures if possible, or to supplement these in order to allow permanent measurement that is not limited to the number of test tubes available.

[4]Maximum admissible concentration (MAK) is the concentration of a substance in the air at the workplace at which employee health is generally not impaired.
[5]The technical exposure limit (TRK) is the concentration of a substance in the air at the workplace that can be achieved by the state of the art.
[6]Biological tolerance value (BAT) is the concentration of a substance or its product of conversion in the body or the resulting deviation of a biological indicator from its standard, at which employee health is generally not impaired.

8 Sources

- Investigations
  - Maritime and Coastguard Agency (MCA)
  - Marine Accident Investigation Branch (MAIB)
  - See-Berufsgenossenschaft (See-BG) (German Safety Organisation)
  - Classification Society Germanischer Lloyd (GL)
  - On-board survey of SEALING by the BSU

- Written declarations/comments
  - Accident Report by the See-BG and the injured persons
  - Command of SEATURBOT, SEALING
  - Inspection of German Tanker Shipping GmbH & Co. KG (GT)
  - Manufacturer of the inert gas system Hamworthy KSE Moss AS
  - Building yard Lindenau GmbH

- Oral information
  - supplied by the manufacturer of the air conditioning system Imtech Schiffbau-/Dockbautechnik

- Expert opinion/technical contribution
  - Official weather expert opinion by the Germany's National Meteorological Service (DWD) Business unit Marine (Seewetteramt)
  - CO measurement and expert opinion by Schmitt und Fintelmann (INLABCO) GmbH

- Sea charts and vessel particulars Federal Maritime and Hydrographic Agency (BSH), British Admiralty Chart GB 3275

- Documents
  - Accident Prevention Regulations for Enterprises engaged in Ocean Navigation (UVV-See)
  - Guidelines and leaflets (See-BG)
  - International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC)
  - Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (BCH)
  - International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC)
  - Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (GC)
  - Special Regulations for Tank Vessels (GL)
  - Dangerous Goods Regulations
  - Vessel files See-BG, BSH

The photos relate to the survey of 19 March 2004 on board MV SEALING

Figure 3: Inert gas outlet

Figure 4: Engine control room

Figure 5: Separator room

Figure 6: Provisions room

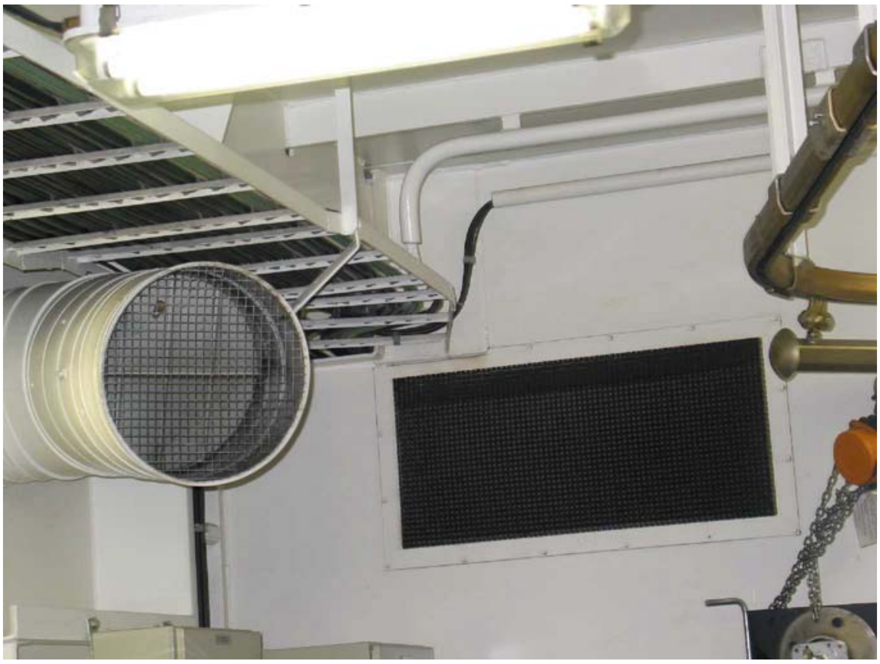

Figure 7: Ventilator separator room

Figure 8: Aft edge of funnel

Figure 9: I.G. top with lid for combustion chamber

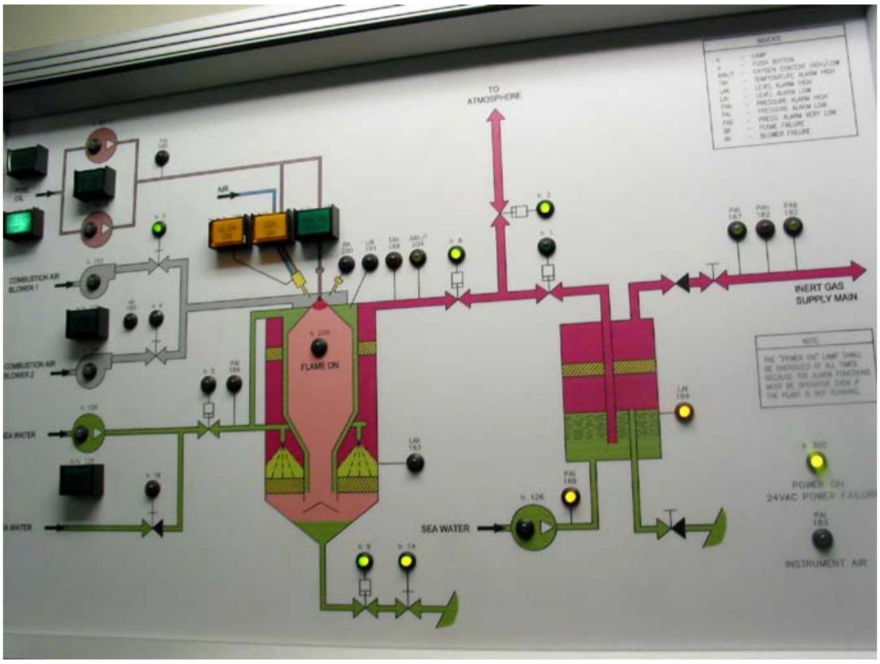

Figure 10: Switch consol inert gas system

Figure 11: Displays I.G.

Figure 12: I.G. outlet and louver

Figure 13: Switch cabinet engine room ventilator

Figure 14: Portside engine room ventilator

Figure 15: Air inlet air conditioner, provisions room with I.G. line running beneath

Figure 16: Air inlet, galley

Figure 17: Funnel, top

Figure 18: I.G. line outboard

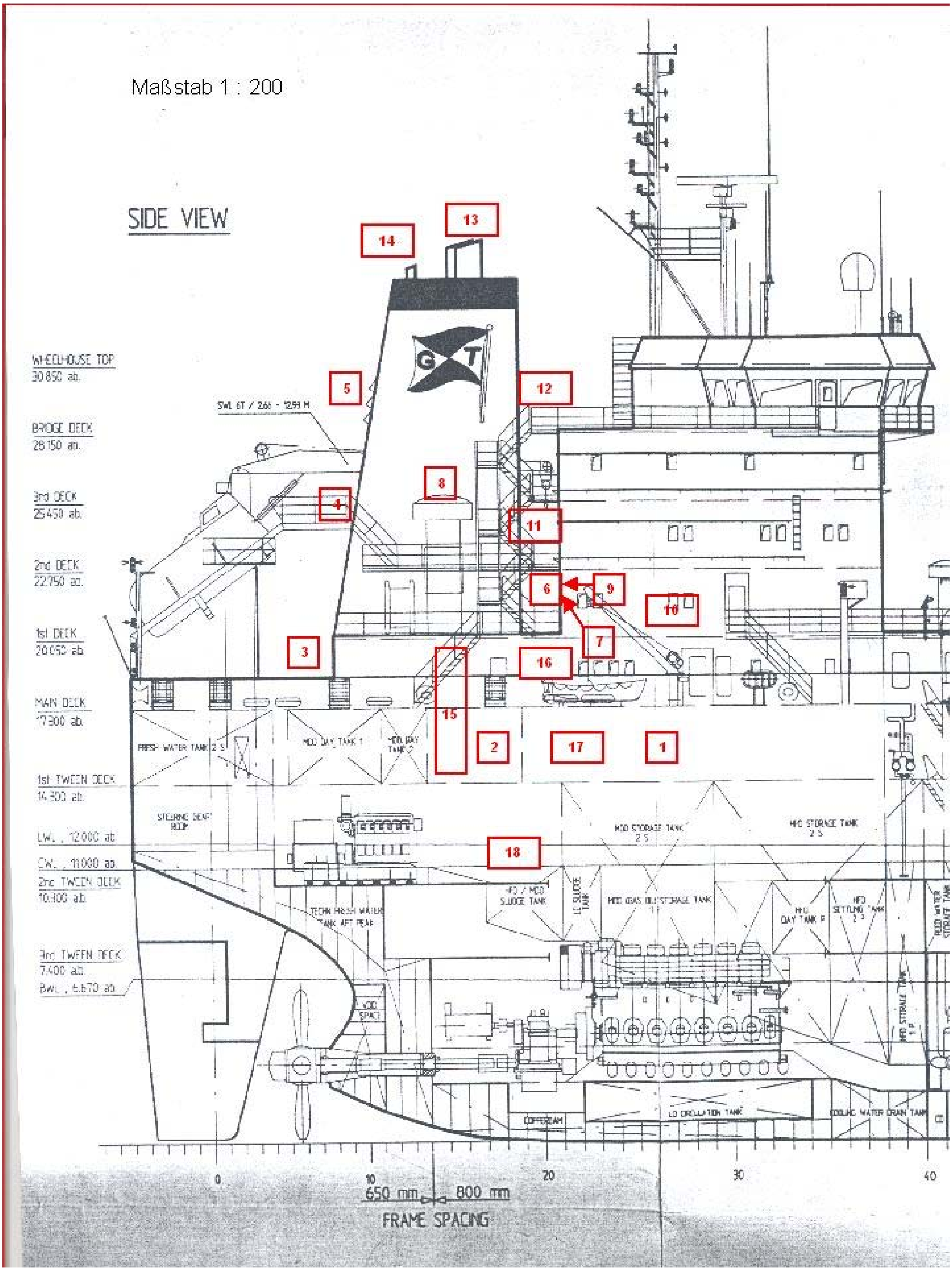

Figure 19: Side section superstructure

Legend General Arrangement Drawing SEATURBOT

1) Engine control room (ECR)
2) Switch cabinet ECR-ventilator
3) Fire damper
4) Inert gas outlet
5) Louvers
6) Air inlet portside air conditioner
7) Inert gas line
8) Engine room ventilator starboard
9) Supply air galley, supply air laundry
10) Aft edge midships air conditioner room
11) Exhaust air wet cells, exhaust air mess, exhaust air hospital
12) Exhaust air galley
13) Main engine
14) Auxiliary engines
15) Inert gas system
16) Galley
17) Provisions and store rooms
18) Separator room