Departmental investigation into the boiler fire aboard the livestock carrier MAWASHI AL GASSEEM in the port of Adelaide on 9 September 1995

Report No 85

DEPARTMENT OF TRANSPORT AND REGIONAL DEVELOPMENT

Contents

Navigation Act 1912
Navigation (Marine Casualty) Regulations
investigation into the boiler fire aboard the livestock carrier MAWASHI AL GASSEEM in the port of Adelaide on 9 September 1995

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Summary

The 46,265 deadweight tonne livestock carrier Mawashi Al Gasseem arrived in the port of Adelaide on 7 September 1995 to load fodder and water. The vessel was on a ballast voyage from Jeddah, in Saudi Arabia, to Napier, New Zealand, where it was to load a cargo of sheep for the Middle East.

Mawashi Al Gasseem was built as a tanker in 1973 and converted to a livestock carrier in 1983. At sea, steam for fuel heating, deck machinery and hotel services is provided by an exhaust gas economiser unit, while in port it was provided by a single Hitachi Zosen two-drum, water-tube, oil-fired auxiliary boiler.

On the morning of 9 September 1995, Mawashi Al Gasseem was at No.1 berth, Outer Harbour, Adelaide, with the auxiliary boiler in use supplying steam for the auxiliary services. The oiler on watch had joined the ship, for the first time, the previous evening. Shortly after coming on watch, he began to encounter problems maintaining steam pressure and water level in the boiler. At about 0920, when he was asked to supply steam to the deck machinery, he called for the assistance of the Fourth Engineer, who, when he saw the low water level in the boiler, immediately shut off the fuel to the burner.

Five or ten minutes later, the Fourth Engineer saw what he believed was still a fire in the furnace, but was, most probably, the boiler internals glowing white hot. He shut off all the valves in the fuel system, but the fire appeared to continue burning and the boiler casing around the aft end of the side water-wall began to glow red hot and give off smoke.

The ship's staff used a number of foam and CO_2 extinguishers in an attempt to cool the casing. Hoses were then rigged and used to cool the casing more effectively. At 0950, the fire brigade was called and arrived at 0957, by which time the apparent fire in the furnace seemed to burn itself out and the furnace was cooling down. The fire brigade took over from the ship's staff and continued for the next hour to cool down the boiler casing.

After some inspection doors in the casing had been removed, a cursory inspection of the boiler gave the impression that, apart from some distorted tubes, it had suffered no damage. However, when the Chief Engineer went into the furnace that

evening, he found that the boiler had been severely and extensively damaged. The side water-wall and refractory had collapsed, the rear water-wall was burned out and most of the screen tubes were burned out. Most of the furnace tubes in way of the radiant heat from the burner showed signs of having reached white heat and had begun to melt.

The evidence indicates that the damage to the boiler was caused primarily by the burner being fired without water in the tubes. Accumulations of soot, oil and scale on the boiler tube surfaces, caused by poor operating and maintenance procedures, may have contributed to the apparent fire.

The incident was investigated by the Marine Incident Investigation Unit under the provisions of the Navigation (Marine Casualty) Regulations.

Sources of information

The Master, officers and crew, Mawashi Al Gasseem

Australian Maritime Safety Authority

South Australian Metropolitan Fire Service

Ports Corp, South Australia

Ministry of Surface Transport, Government of India

Phillipine Coastguard

Narrative

Mawashi Al Gasseem

Mawashi Al Gasseem is a Saudi Arabian flag livestock carrier of 46,265 tonnes deadweight (30,435 gross tonnes) capable of carrying 96,740 head of sheep or 556 head of cattle. It has capacity for 6070 m^3 of fodder, 20,000 m^3 of fresh water and can also carry 88 TEU[(1)] containers. It has a length of 195.29 m, a beam of 33.74 m and a moulded depth of 17.6 m. The main engine is an Hitachi-Sulzer 6RND90 of 12,799 kW driving a single screw. Auxiliary steam for fuel heating, deck machinery and for hotel services, is supplied at sea by an Hitachi Zosen, bare tube type, exhaust gas economiser unit and, in port, by an oil fired auxiliary boiler. It is classed with Lloyd's Register of Shipping.

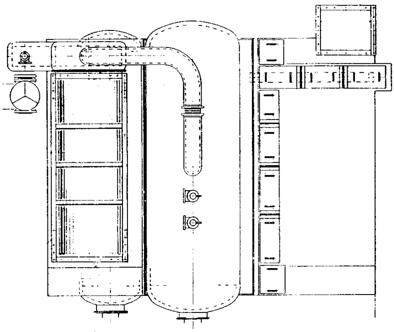
The ship was built in 1973 in Japan by Hitachi Zosen Maizuri as a tanker and originally named Lynda. In 1983 the tanker was converted to a livestock carrier by Hyundai Mipo Dockyard at Ulsan, Korea, and came under the Saudi Arabian flag, renamed as Mawashi Al Gasseem. The vessel was managed, on behalf of the owners, by Wallem Shipmanagement Ltd. until 17 April 1995 when the owners themselves took over the management.

Mawashi Al Gasseem is both owned and managed by the Almawashi Almukairish United Saudi Joint Stock Company of Jeddah, Saudi Arabia and is employed in the livestock trade, mainly shipping sheep from Australia and New Zealand to the Middle East. It has a crew of 61 consisting of the Master, four deck officers, a radio officer, six engineer officers, an electrician, three fitters, Bosun, three able seamen, 28 ordinary seamen, three oilers, three wipers, three cooks and four messmen. The ordinary seamen tend the cargo of sheep, when carried, but when a cargo of cattle is carried, there may also be a number of stockmen on board to tend the cattle, and a veterinary surgeon.

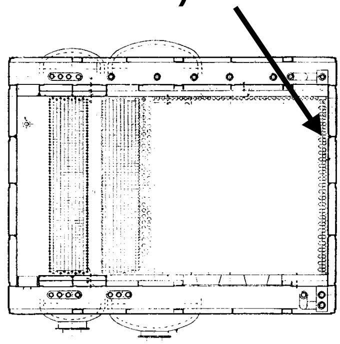
The Master, Chief Engineer and Chief Officer are Indian nationals and have Indian certificates of competency, the remaining officers and crew are Filipino nationals and, where appropriate, hold Filipino qualifications.

[(1)] Twenty-foot equivalent unit.

Area of most extensive damage
(Port aft corner)



View B - B



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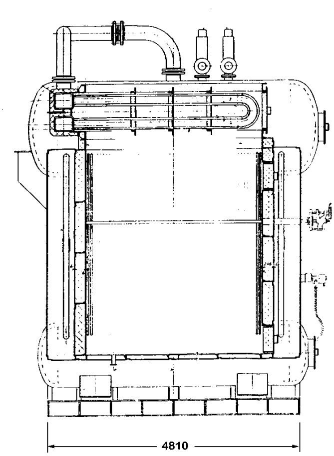

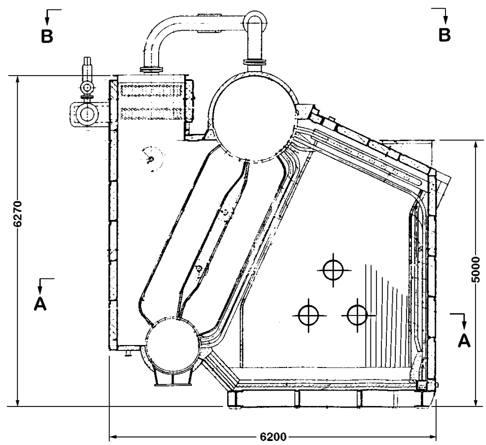

Hitachi Zosen HZA-4SR

Two drum, water-tube oil-fired auxiliary boiler

Working pressure 18kg/cm²

Evaporative capacity 45,000 kg/hour

Auxiliary boiler

The auxiliary boiler, used in port to supply steam to auxiliary machinery and services, is an Hitachi-Zosen HZA-4SR, oil-fired, two drum, water-tube type with a designed working pressure of 18 kg/cm^2. When the vessel was a tanker, this boiler, with its evaporative capacity of 45,000 kg per hour, was capable of supplying steam for cargo tank heating and for running the cargo and ballast pumps as well as for the deck machinery, fuel heating and hotel services. It was supplied with feed water by two turbo-driven feed pumps and two electric auxiliary feed pumps. After the vessel had been converted to a livestock carrier, the capacity of the auxiliary boiler was greatly in excess of the steam demand, and as a consequence, only one of the three oil burning registers remained in use.

The boiler was fitted with fully automatic combustion control equipment, including automatic control of the boiler water level, however, none of the automatic equipment was in working order and, as a result, the single burner was manually ignited and used on a 'stop-start' basis as the steam pressure required. A similar routine was followed with the supply of feed water to the boiler, the watchkeeper stopping or starting the electric feed pump as required to maintain the water level between high and low limits.

Fire-fighting arrangements

Mawashi Al Gasseem has three muster stations, one on the main deck aft, one on the starboard side of the boat deck and one in the ship's hospital. It has three electrically driven fire pumps, a dedicated fire pump, a larger fire, bilge and ballast pump and an emergency fire pump. In addition, there are a number of foam, CO_2 and dry powder extinguishers stowed around the engine room and the accommodation spaces.

The fire

Mawashi Al Gasseem arrived in the port of Adelaide on 7 September 1995 after a voyage in ballast from its home port of Jeddah in Saudi Arabia and was berthed at No.1 berth, Outer Harbour. It was en route for Napier and Timaru, in New Zealand, where it was to load a cargo of sheep for the Middle East. The ship called into Adelaide to load fodder and water for its next livestock cargo. During the afternoon of 7 September and on 8 September, the Australian Maritime Safety Authority (AMSA) conducted a Port State Control Inspection on the vessel and a list of defects, requiring attention, was given to the Master.

On 8 September, the day after the vessel arrived, a number of crew changes were made. Among these, three new engine room staff arrived on board to replace the Third Engineer, the Electrical Engineer and one of the oilers, all of whom had been dismissed on the grounds of incompetence. The three who had been dismissed left the ship at 0500 on the morning of 9 September. Their reliefs had arrived on board the vessel at about 1800 the previous evening and the new oiler stood the 8-12 watch that same evening, with a brief (30 to 40 minute) handover from the oiler on the 4-8 watch. It was the first time he had joined this ship.

On the morning of 9 September 1995, the auxiliary boiler was in use supplying steam for the auxiliary services. The 8-12 oiler had come on watch at 0800 and had been told by the 4-8 oiler that the steam pressure was dropping and that they would need to fire the boiler. Some time after 0800, they started the forced draught fan and ignited the burner using an oily rag on the end of a rod. When the burner had been successfully ignited, the 4-8 oiler went off watch. After a lengthy period of firing, however, the steam pressure did not rise. The 8-12 oiler checked the water level in the gauge glass and noticed the water level was low, so he started the feed pump. He noticed, also, that the flame was very yellow and not burning as brightly as it had been on the previous evening during his first watch on the boiler.

At about 0920, the watchkeeping oiler received a phone call from the Bosun telling him that steam was required on deck for the operation of the winches. The oiler, having joined the ship for the first time only the night before, was not aware of how to supply steam to the deck, so he called the Fourth Engineer and asked to be shown what to do.

The Fourth Engineer, who had been working down in the pumproom, arrived and looked at the steam pressure on the boiler. The steam pressure was still low. He waited some five minutes before just slightly cracking open the valve to the deck steam line. The oiler, seeing that the water level was still low, went to check that the feed pump was running and that the cascade tank, from which the feed pump takes its suction, still contained some water, which it did.

The Fourth Engineer, meanwhile, had also seen that the level in the gauge glass was very low and, at about 0930, had shut off the fuel to the burner. With the boiler not now firing, the oiler went down to the compressor flat to start one of the air compressors and to attend to his other watchkeeping duties before returning to the boiler front.

About five minutes later, the Fourth Engineer noticed through the sight glass on the front of the register[2] that, although he had opened the bypass valve and shut off the fuel to the burner, there still appeared to be a fire in the furnace. He sent the oiler to fetch the Chief Engineer, who was in the steering flat checking through the stock of spare gear. In the meantime, the forth Engineer set about shutting off the fuel pump, its suction and delivery valves and the quick-closing emergency shut-off valve on the heavy oil settling tank. The fire in the boiler furnace, however, seemed to continue.

The Chief Engineer arrived from the steering flat and he and the Fourth Engineer looked into the furnace through the sight glass in the register. Everything on the fuel oil system had been shut off, yet looking into the furnace, it appeared that there was still a fire inside.

By about 0940, smoke was coming off the port side of the boiler casing, along the junction of the top of the boiler with the water-wall, and the casing was beginning to glow red hot. The 8-12 oiler sounded the engineers' call from the engine control room. One of those who responded to the alarm was the 4-8 oiler who had stood the previous watch. When he arrived in the engine room, he saw the smoke and heat emanating from the port side of the boiler. Checking the boiler water level sight glasses on his way down, he could see no level in either glass. As he passed the boiler front, the 8-12 oiler told him that there had been a request for steam on deck and that was when the trouble had started.

The 4-8 oiler continued down to the next deck to check the feed pumps and started the larger feed pump. He checked the cascade tank and found it empty, so he put the feed pump suction on direct, cold feed from the feed water tank. After a few minutes, he returned to the level of the boiler front on the next deck, but could still see no water level in the gauge glasses. By this time, the heat was too intense to pass the port side of the boiler to more closely check the gauge glasses at the top level of the boiler. He briefly looked into the boiler furnace through the register sight glass, and although he could see what seemed to him to be a fire inside, he did not see what it was that was actually burning.

The Chief Engineer had ordered the engine room personnel to apply both foam and CO_2 extinguishers to the outside of the boiler casing and, by this time, a number had been collected from all around the engine room and were being discharged in an attempt to cool the casing, but with little effect.

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[2] Removable circular covers on the front of the furnace through each of which is mounted a burner carriage, or holder, and the damper for controlling air flow. Registers are usually fitted with a sight glass for viewing the flame and sometimes also with an electrical igniter.

The Chief Officer, meanwhile, had been on deck attending to some of the defects which had been notified to the Master as a result of AMSA's Port State Control Inspection. As he entered the accommodation, an oiler ran up to him telling him that there was a fire in the engine room. He told the oiler to sound the general alarm before himself heading for the engine room, where, on his arrival, he saw the hot casing and smoke coming off the port side of the auxiliary boiler. He rushed back up to No.1 deck to find the Master and inform him of the situation. The Master told him to find the agent and to get the agent to use his mobile phone to call the fire brigade.

The Master had been walking around the deck with the company's lawyers and was just leaving the sheep pens when the Chief Officer found him. He left them and went down to the engine room. When he saw the boiler, there was an area about one metre square on the port side of the boiler glowing red hot. The crew were already using extinguishers on the casing.

The Chief Officer spent some minutes searching for the agent around the accommodation but was unable to find him. He then decided to go ashore to use the public telephone kiosk along the wharf. He reached the phone kiosk and called the fire brigade at 0950. As he returned on board, he met the agent who, after being appraised of the situation, also called the fire brigade to give confirmation of the situation.

Returning to the engine room, the Chief Officer found a degree of panic existed as the crew excitedly used the foam and CO_2 extinguishers to try to cool the boiler casing.

The Master, the outgoing Chief Engineer and the new Chief Engineer (the former Second Engineer) were all in the engine room directing the fire-fighting operations. About 18 to 20 fire extinguishers had been used when the Master told them to stop using the extinguishers and cool the boiler casing with fire hoses. Four hoses were rigged and cooling of the casing was carried out using the large fire, bilge and ballast pump. Cooling of the casing was still under way and the fire inside the furnace appeared to have almost burned itself out when the fire brigade arrived at 0957. A number of members of the fire brigade assisted the ship's staff with the ship's hoses, while others rigged their own hoses from the brigade's appliance to the engine room.

By 1030 the fire inside the furnace appeared to be out but the fire brigade kept cooling the boiler down for another half hour until, at 1100, it was decided that nothing more was required. By this time, the boiler casing was cool to the touch.

After the fire, the ship's staff removed some of the inspection doors in the boiler casing, those where the side water-wall tubes join the steam drum and one above the rear water-wall header. An inspection was carried out and it was determined, from the very limited view these openings provided, that, although some of the side water-wall tubes could be seen to be distorted, the boiler appeared to be in sufficiently good condition to apply a hydrostatic pressure test to the boiler the next day, after it had cooled down. The three burner registers were removed to assist in cooling down the inside of the boiler.

Shortly after the fire, an AMSA Surveyor found that the steam cocks on both the water drum gauge glasses were closed.

That evening, at about 2000, the Chief Engineer decided to enter the, now cooled, boiler to take some photographs of the distorted tubes. Once he had entered through the lower register opening, he found that the interior of the boiler had sustained very extensive, and severe, damage.

Collapsed side water-wall and refractory

The full length of the side water-wall had collapsed. The tubes had folded into an S-shape, and the refractory had collapsed into the space which had formed behind the sagging tubes. It was through this area of collapsed refractory that the heat had reached the outside of the casing. The damage was worst at the aft end of the side water-wall. The tubes

Rear water-wall burnt out tubes

of the rear water-wall were also severely distorted and many had burned away completely in the area in which the worst of the flame impingement appeared to have occurred.

The screen tubes were also badly burned with many of the front few rows having had holes burned through them. Most of the screen and rear water-wall tubes showed signs of having begun to melt, being covered with a skin of melted and oxidised steel in those areas most exposed to the radiant heat from the burner. The molten slag had been flowing in a trickle down many of the screen tubes.

The damage to the boiler was so severe that the decision was made to defer repairs to the boiler, or not repair it at all, and to obtain another boiler either as a temporary, or possibly permanent, measure. A second-hand package boiler was purchased from a winery in the Barossa Valley and fitted in the ship's swimming pool on the boat deck. Although the designed output of the package boiler was considerably less than that of the original, it was considered sufficient to meet the ship's reduced steam requirements and it was with this arrangement for its steam supply that Mawashi Al Gasseem sailed from Adelaide.

Front of boiler (with registers removed)

Port side of boiler casing after fire

Comment and Analysis

Hitachi-Zosen auxiliary oil-fired boiler

The boiler was installed to supply the steam needs of the vessel when it was constructed as a tanker. Since it was converted to a livestock carrier, the steam demand has been only a fraction of the original and, at sea, the demand is met entirely by the exhaust gas economiser unit suppling steam generated by the exhaust gas from the main engine. The reduced steam demand required that the auxiliary boiler was fired in port using only one of the three oil burners. The boiler was fitted with an automatic combustion control system for control of water level, combustion air RDL[(3)] and fuel oil pressure. It was evident to the investigation, however, that none of the automatic control systems were in a serviceable condition and the boiler was being fired in a totally manual mode. This mode of firing would have been regarded as the 'emergency' operating mode when the boiler was originally commissioned, as all the safety interlocks are effectively bypassed. In addition to the control systems being inoperable, all the remote instrumentation in the engine control room was also defective. The one and only means of monitoring the water level in the steam drum of the boiler was by visual inspection of the two gauge glasses on the drum.

An essential item of safety equipment on the boiler was the emergency fuel shut off, or trip, valve which was actuated by a 'low-low' water level alarm which was sensed by the feed water control system. As this control system was not operational, the trip valve was wired in the 'open' position. The lack of an operational feed control system meant also that there was no alarm, either audible or visual, for low boiler water level.

As a consequence of there being no functioning control systems on the boiler, it was necessary for the boiler to be attended almost constantly, in port, by a watchkeeping oiler. The oiler's duty included flashing up the boiler at regular intervals to maintain steam pressure and to start and stop the electric feed pump(s) as required to maintain a level of boiler water in the steam drum. In addition to tending the boiler, however, the oiler also had other duties to attend to around the engine room, such as starting or stopping air compressors and pumps and lubricating various items of machinery.

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[3] Register Draught Loss - measured pressure drop across the register, from which the mass flow rate of air is deduced by the control system.

Igniting the boiler, instead of being carried out by using an electrical igniter as originally intended, was accomplished by lighting an oil-soaked rag on the end of a steel rod and inserting it into the furnace through a hole in the register, then opening the fuel oil cock on the burner. This is the means by which boilers were ignited before the advent of automation and safety interlocks, such as purge timers(4). It required a good knowledge of the associated hazards and the safety routines to be followed during the lighting-up process.

The lack of a functioning combustion control system also meant that when the watchkeeping oiler was away from the boiler front, carrying out his other engine room duties, there was no means by which the existence of a flame in the furnace could be monitored. A failure of the boiler flame, for whatever reason, would allow unburned fuel oil to be sprayed into the furnace where it would vaporise on the hot surfaces and fill the boiler with an explosive mixture of air and fuel vapour, a particularly hazardous situation.

The boiler had been surveyed by Lloyd's Register in Singapore during October 1994, and the record of this survey, when the vessel was under the management of the previous ship managers, is the only record relating to the history of the boiler which was available to the investigation. At that time the safety valves were floated at 16 kg/cm^2, however the investigator was informed that the boiler, at some time in the past, had been de-rated to 9 kg/cm^2, the working pressure being used at the time of the incident. The classification society, however, had no record or knowledge of this de-rating and it appears that this was a procedure adopted on board some time after the vessel's conversion to a livestock carrier in 1983.

The report on the boiler survey carried out by the class surveyor in October 1994 states:

"ABS2 Water-wall side tubes evenly distorted inwards over full length of vertical drop. Distortion minimal at front to a max. of 2 inches at the rear. No other defects noted."

This indicates that the boiler had suffered some slight, similar, damage to the same area of water-wall at some time in the past.

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[4] A timer which ensures that the boiler furnace is purged with air by the forced draught fan for a specified time before the fuel oil to the burner can be turned on. This ensures that there will be no explosive oil fumes in the furnace when the burner is ignited.

The constant use of the boiler at low pressure and reduced forcing[5] rate, together with the on/off firing method employed to control the steam pressure, would have provided the worst possible conditions for fouling of the boiler tubes. This was further exacerbated by there being no automatic control of fuel temperature. The temperature of the fuel was not recorded in the engine room log book, but it was stated to have been kept at around 90°C (irrespective of the viscosity of the fuel used.) A fuel temperature too high in relation to the viscosity of the fuel being used would lead to rapid carbonising of the burner tip, while a temperature which was too low would cause poor atomisation, an erratic flame, carbon build up on the boiler tubes and water-walls and increased chances of afterburning.

Lighting up from cold was carried out on heavy fuel oil and not on diesel fuel as instructed in the boiler manual, another factor which would have contributed to fouling of the tubes.

Oil burner

The oil burner which had been in use at the time was examined after the fire. The burner tip was removed during the investigation and it was found that one side of the annular ring of holes which impart a swirling motion to the fuel oil as it sprays from the tip, were solidly blocked with heavy deposits of carbon. It is conceivable, and indeed quite possible, that the oil remaining in the burner, after it was shut down at the beginning of the fire, was baked and carbonised by the heat within the furnace, however it is also possible that the blockage was responsible for directing the flame towards the port after corner of the furnace where the worst effects of heat damage were observed.

The manufacturer's manual states that the correct type/size of tip to be used in the burner is an AS-24. The tips used on board had no markings on them to indicate the type or size. The absence of any records made it impossible to ascertain whether or not these were the tips originally supplied with the boiler or whether they had been replacements supplied at a later date.

It is also stated in the manufacturer's manual that, although the pressure range for fuel oil at the burner is 1-21 kg/cm², it should not normally be above 18 kg/cm² to reduce the likelihood of fuel impingement on the rear water-wall. Those interviewed during the investigation seemed unaware of this instruction.

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[5] Rate of steam generation

The investigation was unable to ascertain when the oil burner had been last stripped and the tip examined or cleaned. It appeared that there was no routine for this maintenance, nor was it the duty of any specific person on board.

Combustion

The main factors which will affect the quality of combustion are the fuel/air ratio, the fuel viscosity, the pressure of the atomising steam, the alignment of the register and the position of the burner tip in relation to the front of the air swirler.

During the investigation it became apparent that it was the custom to leave the air slide on the register in the 'full open' position. With no functioning automatic control of the air flow, there would be no control of the fuel/air ratio and it is likely the boiler was fired regularly with excessive air flow.

The correct fuel viscosity for good atomisation, and hence combustion, was 80 seconds Redwood no.1. The actual viscosity is dependent on the fuel being used and the fuel temperature at the burner. It was stated that the fuel temperature was maintained at around 90°C, however this did not take into account the characteristics of the fuel being used. The fuel temperature was not entered in the engine room log book.

The atomising steam supply was a constant 2.5 kg/cm^2. It is essential that steam traps[(6)] in the atomising steam supply to the burner are working effectively so that only steam, and no water, reaches the burner. Water passing through the atomising steam passages in the burner will produce poor atomisation, unstable combustion and can lead to flame failure. With the boiler out of commission after the fire, the investigation was unable to ascertain the effectiveness of the steam traps.

After the fire, the register was removed from the boiler front and the burner was removed from the register, making it impossible to assess the alignment of the register and the position of the burner tip in relation to the swirler at the time of the fire. However, the engine room staff did not appear to be aware of the significance of these factors.

Poor combustion results in increased deposits of soot on the surfaces of the tubes. Impingement will result in deposits on some areas of tubes, notably the rear water-wall and will contribute to the rate of tube wastage.

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[6] Devices in the steam line which allow water in the line to drain away but prevent the escape of steam.

Accumulations of soot within tube banks and superheaters are normally removed, to a significant degree, by the routine use of soot-blowers (usually once or twice a day). In the case of Mawashi Al Gasseem, however, an examination of the sootblowers indicated that they had not been used for a very long time. The operating mechanisms were covered with an accumulation of paint and were too stiff to turn by hand. Neither the hand wheels of sootblowers in easy reach nor the chains used to rotate those sootblowers which are out of reach, showed any signs of the usual polish imparted to them by regular use. None of those interviewed on board after the fire had ever used the sootblowers.

Water level

The water level in the boiler was maintained by the manual starting and stopping of the feed pumps as required, while the level was observed in the two gauge glasses on the steam drum. There were no functioning remote indicators or alarms for the boiler water level. The feed control valve, part of the automatic system for control of water level, appeared to be quite new and in good condition. There was no knowledge, among those interviewed on board, as to what was wrong with the automatic control system or why it was not in use.

The survey report from the drydocking in October 1994 stated:

"Automation system serviced and put in order".

No other records relating to the automatic control systems on the boiler were available for inspection during the investigation.

During the Port State Control Inspection conducted during the two days before the incident, the AMSA Surveyor noticed a leak at the steam cock of the upper of the two gauge glasses. This was one of the defects noted on the list of items requiring rectification which was passed to the Master after the inspection.

After the fire, the AMSA Surveyor found that, although the water cocks were open, the steam cocks on both of the gauge glasses were shut. There was no apparent reason for these to have been shut during the fire or after it, and, although it cannot be stated with certainty, and it was not acknowledged by any of those interviewed, the strong possibility exists that they were shut before the fire by one of the ships staff after the leak had been noted during the Port State Control Inspection.

If the gauge glass steam cocks had been shut before the fire, there would have been no reliable indication of water level and, even if there was some level of water showing in the glass, the likelihood is greatly increased that the boiler could be steamed for some considerable time without sufficient water in the tubes. The water level in the gauge glasses would only have moved at a rate dependent on the leakage past the shut steam cocks.

With no other type of water-level indicator in working order, the ship's staff should have been carrying out regular gauge glass drills—the routine shutting and opening of the water, steam and drain cocks on the gauge glasses to prove them clear and to show that the level in the glass was actually representing the water level in the steam drum. This routine was not followed on Mawashi Al Gasseem. A gauge glass drill would, in addition, normally be carried out if there was any doubt, in the mind of the person operating a boiler, about the reliability of the level shown in the gauge glass. It is possible that, had this been done early in the 0800-1200 watch on the morning of 9 September, the damage to the boiler may have been limited and the incident averted.

Had the emergency fuel oil shut-off valve not been wired open, and had the automatic system for control of the boiler water level been in working order, the system would have tripped the fuel valve, shutting down the boiler as soon as the water level started to fall below a preset point, usually at a level just above the bottom of the lower gauge glass.

Boiler tubes

Examination of the damage to the boiler tubes from within the furnace, after the fire, revealed that tubes in many areas of the water walls, the screen tubes and the generator bank were wasted and thinned. Inspection of the risers from within the steam drum revealed a significant degree of wastage through scab pitting.[7] These problems are prevented by regular inspections, boiler cleaning and maintaining the correct conditions of the boiler water to minimise corrosion. This latter, the most important of the three, is achieved by regular, (weekly at a minimum) tests of the boiler water for such things as acidity (pH value), chloride levels, hardness and dissolved solids. Regular dosing of the water in the boiler with chemicals is usually required to maintain the levels of these parameters within specific limits.

[7] Where deep pits of corrosion occur in the tube wall, underneath a "scab" of scale.

Boiler water tests were carried out on a regular basis and the results were satisfactory (in those records sighted on the vessel) until August 1994. The quality of the boiler water deteriorated between then and March 1995. In mid-April 1995, the management of the vessel changed and there were only two monthly records available after that time. These were for the months of July and August 1995. During this period, the concentration of chlorides was observed to be getting progressively higher, exceeding the limit of 300 parts per million at the end of July and throughout August. The pH was consistently too low (high acidity) through July and for most of August. Conditions such as these would be conducive to increased corrosion and tube wastage.

When the watchkeeping oiler came on watch at 0800 on the morning of the fire and the boiler had been fired, he noticed the flame was very yellow and not burning as clearly and brightly as it had been the evening before. It is likely that the boiler was, by that time, already suffering from a tube failure and a large volume of steam blowing into the furnace was significantly affecting the combustion process, although the oiler was unaware of it. He was advised by the 4-8 oiler that the steam pressure was dropping and that they would need to fire the boiler again. After the two oilers fired the burner, the steam pressure did not rise and the 8-12 oiler noticed that the water level appeared very low. These are both indications of a tube failure, although they were not recognised as such by the oilers.

Although the indications are that a tube, or tubes, had failed at some time during the morning of 9 September, possibly even before 0800, causing the water level in the boiler to fall, the rate at which the water level fell would not have been accurately reflected by the apparent level in the gauge glasses if the steam cocks on the gauge glasses had previously been closed.

The fire

Steaming a boiler without sufficient water will inevitably, and quickly, lead to local overheating of one or more of the water tubes and further tube failures will ensue.

As the water level in the boiler falls, circulation of the boiler water ceases and the upper ends of the water tubes become ‘dry’. So long as water is circulating within all the boiler tubes it will exercise a cooling effect on the tubes. However, once that circulation ceases the temperature will rise rapidly and tubes will soften and deform before melting and burning away. The indications are that the boiler was fired without water for a sufficient length of time, possibly 1½ hours or more, for the furnace to have been raised to a very high temperature and for extensive damage to have occurred to the boiler tubes and refractory. The temperature of the steel tubes exposed directly to the radiant heat of the burner was raised to white heat, as evidenced by the runs of molten, oxidised steel down the tube surfaces. Movement of the side water-wall tubes, as they began to soften, together with the intense heat, caused the refractory behind the side water wall to collapse, thus exposing the boiler casing to the radiant heat within the furnace. The casing became overheated and, in turn, caused all the symptoms of fire observed from outside the boiler during the incident. The heat radiating from the furnace would have given the impression of an intense fire and would have lasted for a considerable time before it eventually cooled down.

The fact that the screen tubes were burned away at a level of only 0.5 to 1 metre above the furnace floor gives further indication that the damage to the boiler was caused by radiant heat from the burner rather than by any other type of fire on the opposite side of the furnace.

During the incident, any unburned oil, soot and scale on the tubes, or between the water-wall tubes and the refractory surfaces behind the water-walls, would have burned also. As discussed above, there were factors (poor combustion, no sootblowing, oil impingement) which would have led to an accumulation of soot and oil in the furnace. It seems that, although the combustion of this accumulation may have contributed to the incident, it was mainly the white heat of the tubes within the furnace which gave the Fourth Engineer the impression of a continuing fire after he had shut off the oil to the burner.

It is considered unlikely that the quantities of soot and oil which may have been present on the tubes could have caused sufficient intensity of heat, or burned for sufficiently long, to have resulted in the damage which was observed and there was no other combustible material in the furnace which would have provided fuel for such a fire.

Fire-fighting

Fire musters were held aboard Mawashi Al Gasseem once a week. On most occasions this took the form of a muster only, followed by some instruction in fire fighting. On only one occasion each month, however, was the fire-fighting equipment actually taken from the lockers and practical instruction given, this being the minimum required by the regulations.

Upon the vessel's arrival in Adelaide, the port authority's 'Notices to Masters of Ships' was placed on board. Under 'Fire Prevention and Control' is a requirement, in case of fire, for the Port Manager or his representative, to be notified immediately, and a requirement for the Master and deck officers to acquaint

Descriptions of events, received by the investigation during interviews, indicated that some confusion, and a certain degree of panic, existed while the fire-fighting operations were under way. There was concern on the part of many of the crew about being close to the boiler and it appears that, mainly for this reason, nobody made a concerted effort to observe, through the sight glasses, exactly what was occurring within the furnace.

The fire brigade was eventually called by the Chief Officer from the public telephone at 9.49.45, according to the fire brigade's log. This would seem to put the ship's time, on the evidence of those interviewed, about ten minutes fast.

The fire brigade reacted very quickly, the first appliance arriving at 0957. A further six appliances arrived in the succeeding few minutes and a total of 36 fire brigade staff attended the incident. With the assistance of the ship's staff, they continued to spray water on to the casing until it had completely cooled down. The furnace, meanwhile, would also have been slowly cooling down since the oil to the burner had been shut off.

Sabotage

During the investigation, suggestions were made that one or more of the three dismissed crew members, who had left the vessel early that morning, may have intentionally flooded the boiler furnace floor with fuel oil as an act of revenge before leaving the vessel. A careful examination of the refractory on the furnace floor was made with this possibility in mind, but no evidence was found to support this theory. It would be expected that the refractory would have, even after the fire, shown signs of having been soaked in heavy fuel oil but this was not the case. In addition, the boiler had been fired many times between the time the three crew members left the vessel and the time of the fire. Any oil on the furnace floor would have ignited on the first of those occasions when the boiler was fired - probably at some time around 0500 that morning. This theory was, accordingly, discounted.

The possibility remains that the gauge glass steam cocks were closed by one of the dismissed crew members, as an act of revenge, shortly before leaving the vessel. It must, however, be stated categorically that it is only a possibility, there being no evidence to either support or to discount it, beyond the fact that it was reported to the investigation that there had been resentment and unrest among certain members of the crew before the ship arrived in Adelaide. It is equally likely they were closed to stop the leak after the Port State Control Inspection.

Manning

The Master, Chief Officer and Chief Engineer are Indian nationals, the remainder of the ship's complement being Filipinos. During the course of the investigation it became apparent that communication between the two national groups, particularly in the engine room department, was minimal.

The Master had been on the vessel for six months and had held his master's certificate for 20 years. The Chief Officer, who had held a master's certificate for 11 years, had joined the vessel the day before the fire. The Chief Engineer had held a first class motor certificate for 4½ years. It was his first appointment as Chief Engineer. He had been promoted to Chief Engineer on Mawashi Al Gasseem, having served as Second Engineer until the vessel arrived in Adelaide on 7 September. He had a two day handover before the outgoing Chief Engineer left the vessel after the fire.

The Fourth Engineer had been on the vessel for five months and was soon to go on leave.

The oiler on watch at the time of the fire had joined the ship the night before, having just arrived from the Philippines at about 1800. He had gone on watch at 2000 and received a 30 to 40 minute hand-over from the oiler on the 4-8 watch. This was all the instruction he had received before standing a watch, in charge of the boiler, on his own. In the opinion of the Inspector, this was insufficient time for a rating, comparatively unfamiliar with steam plant, to receive enough training to be left in charge of a boiler, particularly one with the number of defective controls and instrumentation such as was the case with that on Mawashi Al Gasseem. In addition, although fatigue was not considered to have been a factor in the case of this incident, the Inspector considers that it was inappropriate for a seafarer who had been travelling since the early hours of the morning on international flights and across time zones, to stand a watch almost immediately upon his arrival, on board a totally unfamiliar ship, that same evening. This is not in accordance with the International Convention on the Standard of Training, Certification and Watchkeeping for Seafarers, 1978, which states at Ch.3 Art.7:

"The watch system shall be such that the efficiency of the watch is not impaired by fatigue. Duties shall be so organised ..... that relieving watches are sufficiently rested and otherwise fit for duty".

Conclusions

These conclusions identify the different factors which contributed to the circumstances and causes of the incident and should not be read as apportioning blame or liability to any particular organisation or individual.

It is concluded that:

1. The extensive damage to the boiler water-walls, refractory and screen tubes in the auxiliary boiler of Mawashi Al Gasseem was caused by firing the oil burner after the water level had been lost, following a failure of one or more boiler tubes. Indications of a tube failure were present 1½ hours or more before the apparent fire.

2. The subsequent symptoms of fire were caused by overheating of the port side boiler casings by intense radiant heat from the furnace, after a collapse of the refractory behind the water-wall on the port side of the furnace. A build up of soot and oil on the tubes and water-walls may have contributed to the incident, these deposits occurring due to poor operating and maintenance procedures.

3. The boiler water level, observed by the watchkeeper, in the gauge glasses may have borne no relation to the actual level in the boiler on account of the steam cocks on the gauge glasses having been shut and no gauge glass drill was carried out to check the accuracy of the level shown in the glasses.

4. The main factor leading to the failure of the first tube, causing loss of water level, was progressive tube wastage, due in turn to the age of the boiler, lack of maintenance, poor combustion control and insufficient control of the chemical parameters of the boiler water.

5. The investigation revealed, among those of the crew who were interviewed, a considerable lack of knowledge and experience in the operation and maintenance of steam plant.

6. Had the automatic control systems on the boiler been in good working order, the incident would probably have been prevented, as the fuel trip valve would have shut off fuel to the burner as soon as the water level dropped.

7. The ship's crew successfully contained the heat from the furnace until the fire brigade arrived by which time the furnace had begun to cool down, however, there was an unnecessary delay before hoses were used to cool the boiler casing.

8. The initial reaction to the fire by the Master and crew was not in accordance with the prescribed and practised procedures in as much as the Master did not take control of the situation from the bridge and there seems to have been some confusion and a degree of panic in the response by the crew.

9. There was a delay in calling the fire brigade, exacerbated by the absence of a telephone on board the vessel and the Inspector considers that a more immediate and reliable means of contacting the emergency services should have been used. VHF radio was not used to contact the port authorities to advise them of the situation and they were eventually informed of the incident via a fourth-hand report.

Details of Vessel

Name	Mawashi Al Gasseem
IMO Number	7326893
Flag	Saudi Arabia
Classification Society	Lloyd’s Register
Ship Type	Livestock Carrier
Builder	Hitachi Zoosen, Maizuru
Year Built	1973
Owner	Almawashi Almukairish United Saudi Joint Stock Company
Gross Tonnage	30435
Net Tonnage	12237
Deadweight	46976 tonnes
Summer Draught	12.534 m
Length overall	195.29 m
Moulded Breadth	17.6 m
Engine	Hitachi Sulzer
Engine Power	12799 kW
Crew	61