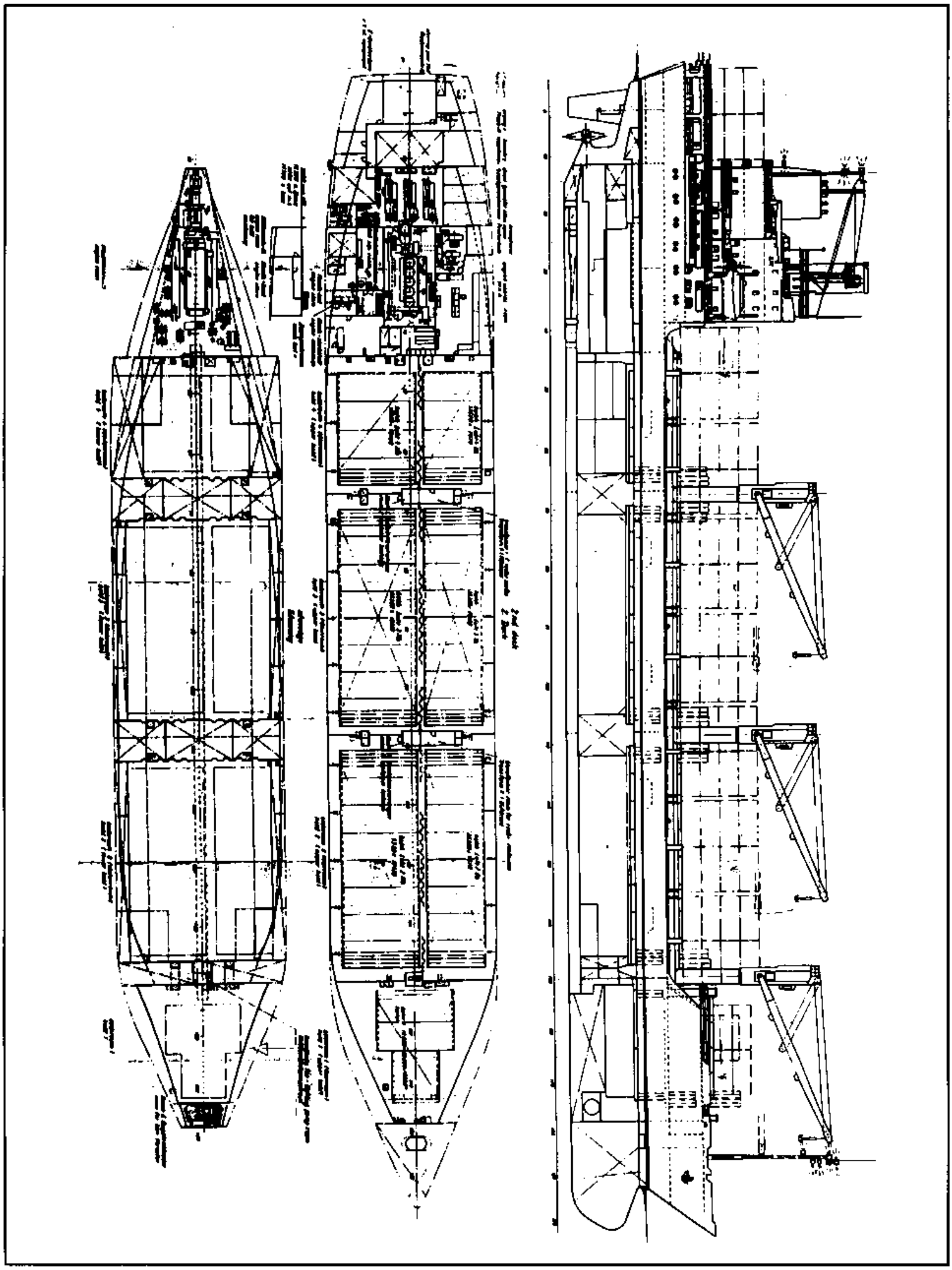
Contents



Iron Flinders general arrangement

Summary

Shortly after berthing at West Swanson dock, Melbourne, on 24 September 1993 the 13280 g.r.t. container and general cargo vessel "Iron Flinders", on charter to BHP Ltd., suffered a fire in the waste-heat unit (economiser) which is situated in the main engine exhaust trunking at the base of the funnel.

The fire gained sufficient hold for an hydrogen-iron fire to become established, and the internal tube banks of the unit were completely destroyed before the fire was extinguished some eight hours later by the Melbourne Metropolitan Fire Brigade, assisted by the ship's staff and the use of over 8 tonnes of liquid carbon dioxide.

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

The investigation revealed a combination of several factors which played an important role in causing the fire. The main ones were :-

Poor design.

Poor maintenance and operating procedures, due in part to the inadequate provision of on-board instructions and information and, in part, to a lack of instrumentation on the waste-heat unit.

The initial response to the fire revealed considerable uncertainty about, and a lack of specific training for, this kind of fire on the part of the ship's staff. It also revealed some inadequacies in the type of fire-fighting equipment fitted in the vessel.

Information source

The Master and Officers of Iron Flinders.

The Melbourne Metropolitan Fire Brigade.

Occupational Health & Safety Authority, Victorian Department of Labour and Industry.

BHP Transport.

In-Mar-Tech Pty Ltd.

Lloyd's Register of Shipping.

Commonwealth Fire Board.

MAN-B&W, Copenhagen.

Acknowledgments

Photographs page 11 Courtesy of Audio Visual Unit, Training College, Melbourne Metropolitan Fire Brigade

Photographs page 13 Courtesy of BHP Transport

Terminology

The fire occurred in the ship's waste-heat boiler, which is built into the main engine exhaust trunking. Waste-heat boilers are known by a variety of names including economisers, exhaust gas economisers and waste heat units.

For the purposes of this report, the waste-heat boiler will be referred to as the waste-heat unit to prevent confusion with the oil-fired auxiliary boiler or the seconomisers fitted to many other types of boiler.

Iron Flinders

Iron Flinders was built in 1986 in the "Neptun" yard of VEB Schiffwerft at Rostock, East Germany, as the "Atinuke Abiola" for Nigerian owners. In 1988 it was renamed "Multitrader" and registered under the Liberian flag. In 1989 it was renamed again, this time "Marlinda" and registered under the Panamanian flag before being chartered by BHP Transport in 1991 and named "Iron Flinders" under the Australian flag.

Since its launch it has been variously crewed by Nigerians, Yugoslavs, Greeks, Filipinos and Argentinians and now (since its charter by BHP) by Australians.

Iron Flinders is employed on a regular monthly service from Australia to New Zealand, calling at Brisbane, Sydney, Melbourne, Auckland, Tauranga, Napier and Port Lyttleton, the crew working on a basis of two round voyages on, followed by two off.

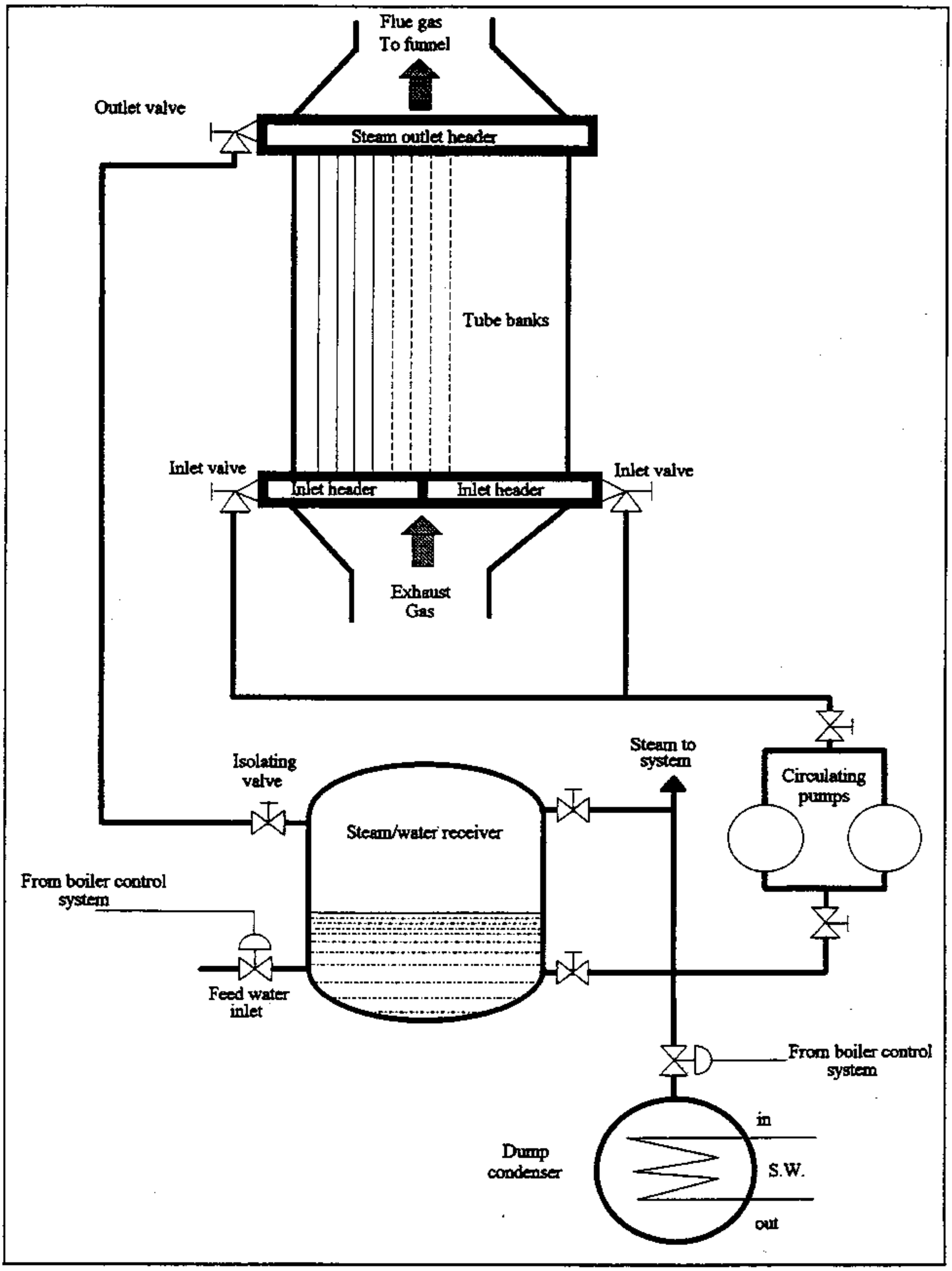
The vessel's Senior Officers are appointed to the ship on a permanent basis. The Chief Engineer had been with Iron Flinders since the ship was acquired by BHP in 1991.

The ship is classed with Lloyd's Register as a 100 A1 General Cargo vessel equipped to operate with unmanned machinery spaces and is strengthened both for heavy cargoes and to Ice Class 3 (for general service ice navigation). It is 158.07m in length, with a beam of 23.09m and a depth of 13.42m. The ship is of 13280 gross tonnage and has a container capacity of 928 TEUs (Twenty foot Equivalent Units).

Propulsion is provided by a 5 cylinder MAN two-stroke diesel engine generating 7,600 kW driving a single shaft and controllable-pitch propeller. This machinery is capable of giving the ship a sea service speed of 15 knots when loaded.

In order to maximise the overall thermal efficiency of the machinery at sea, the exhaust gas from the main engine is passed through a waste-heat unit where the heat remaining in the exhaust gas is used to generate steam, which in turn is used for such purposes as the heating of oil in bunker tanks, domestic hot water and the pre-heating of main engine fuel.

When in port and the main engine is shut down, steam is generated by a separate, small, oil-fired auxiliary boiler.



Schematic diagram of waste–heat unit

Waste–heat unit

The waste-heat unit, a VEB type AKSR 2,0-16/16+16 built by Rostock Repair Service, is approximately 4.5m in height, with sides of 3m and 2.4m. It is situated three decks above the main deck level, above and aft of the main engine, on the vessel's centre-line.

Contained within the waste-heat unit were banks of horizontal finned tubes through which water was circulated. As the exhaust gas passed over these tubes the heat in the gas was transferred to the water, generating saturated steam at a pressure of 7.0 bar which was collected in a steam receiver. The amount of steam generated in this fashion was a function of the power output of the engine at any particular time.

At the bottom of the waste–heat unit was an inlet header, or manifold, into which feed water was fed by a circulating pump, and at the top was an outlet header from which a mixture of saturated steam and water returned to the steam receiver. The inlet header was divided into two halves, port and starboard, each half being fitted with a separate inlet valve to allow either one or both halves of the unit to be put into service, depending on the demand for steam and the engine operating condition at the time. The outlet header, however, was common to both sections and was fitted with only one outlet valve. The finned steam generating tubes were designed such that either one, or both, of the sections could be run in the "dry" condition.

Isolating one half of the bank of tubes provided the means of coarse adjustment of the mass of steam being generated. Fine adjustment of steam pressure was achieved by means of a control valve sensing the steam pressure in the receiver and, at an overpressure of 7.2 bar, opening to dump excess steam to a sea-water cooled "overproduction" condenser.

Engine exhaust gases contain carbon particles in the form of soot which, in any waste-heat unit, are deposited on the finned tube surfaces during the passage of the exhaust gas through the tube banks, reducing the efficiency of the heat transfer. Under some operating conditions, if there are accumulated deposits of soot in the tube banks, there is a likelihood of the soot reaching ignition temperature resulting in a fire within the unit. It is thus recommended by manufacturers that waste-heat units be cleaned of soot on a regular basis.

Sequence of events

Iron Flinders arrived at the Port Phillip pilot station at 2322 on 23 September, after a voyage from Sydney carrying containers and mixed general cargo. After embarking the pilot, the vessel resumed full sea speed for the passage through Port Phillip Bay before reducing to manoeuvring speed at 0249 on the 24th, prior to berthing at No.4 West Swanson Dock . "Finished With Engines" was rung on the engine-room telegraph at 0436 and cargo operations commenced almost immediately.

After berthing, the shut down of machinery was carried out by the Chief and Fourth Engineers. This routine, in accordance with the ship's engineering procedures, included stopping the water circulating pump for the waste-heat unit. The Chief Engineer went for breakfast at approximately 0630. At 0725 he was informed by an Integrated Rating that there was a smell of burning in the accommodation, particularly around the ship's office. As there was no obvious source of the smell of burning the ship's staff started removing panelling on the bulkhead adjacent to the engine-room. It was then noticed that smoke was issuing from the vents in the office. At 0735, the IR, having looked into the engine-room, reported a fire in the waste-heat unit. It was found that the base of the unit, particularly at the for'd end of the starboard side, was glowing at orange heat. There was no visible flame but the radiant heat was causing paint to blister on the adjacent (Ship's Office) bulkhead approximately one metre away. The Master was informed and, at approximately 0740, the general alarm was sounded for the crew to muster at stations.

No smoke or heat sensors had, at this time, been activated and no automatic alarm had sounded.

The main engine is fitted with electrically driven auxiliary blowers for supplying air during manoeuvring. To prevent air being drawn up the exhaust trunking to the fire, these air inlets to the auxiliary blowers were blanked off soon after the fire was discovered, the main turbo-charger air intake having being automatically blanked by a sliding sleeve mechanism when the vessel had commenced manoeuvring upon arrival in port.

A fixed CO_2 system, serving the main engine, diesel generator and boiler uptakes and separate from the main engine-room system, includes a discharge to the base of the waste-heat unit and another to the uptake immediately above the unit. This system is served by four 70 kg CO_2 bottles, two full bottles and two half bottles of which were discharged by the Chief Engineer. However, because of a split in the pipework, possibly caused by the pipe having been struck by the engine-room crane and apparently undetected by the ship's staff, this attempt to extinguish the fire was ineffective.

Following this failure of the uptake CO_2 system, the Chief Engineer and an Integrated Rating entered the waste-heat unit space wearing breathing apparatus and played a 12mm fresh-water hose onto the bulkhead between the engine-room and the ship's office in an attempt to cool it. The Chief Engineer then advised the Master that the vessel needed assistance and at 0817 the Master telephoned the emergency number provided by the Melbourne Port Authority. The call went directly through to the Metropolitan Fire Brigade, by-passing Harbour Control who were intially unaware of the emergency. Pending the arrival of the Fire Brigade, the ship's crew started boundary cooling the outside of the bulkheads surrounding the engine room, a task that was taken over by the Fire Brigade upon their arrival 5-10 minutes later.

After the Fire Brigade had been summoned, a call was made to the Melbourne office of BHP, 30 minutes after which the Ship Manager and BHP Project Officer arrived at the scene.

The Fire Brigade called for the fire-fighting tug "Gabo", with foam capability, to stand by aft. With the exception of the Chief Engineer, all ship's personnel were directed by the Master to leave the vessel. The BHP Ship Superintendent and BHP Project Officer, both present at the time, also remained on board. The Second Engineer, however, was called back shortly afterwards to assist the Fire Brigade. Other ship's staff were later called back as required.

At approximately 0900, an Occupational Health and Safety Officer from the Department of Labour and Industry, who is routinely called by the Fire Brigade in the case of industrial fires, arrived and advised the Brigade not to spray water directly onto the economiser (waste-heat unit). This advice apparently confirmed that which they had already received from the ship's Master, who was concerned about both the possibility of causing an explosion and also about the possibility of burning debris being carried down the exhaust trunking thus spreading the fire to the lower areas of the engine-room.

Between 0900 and 0930, the Master sought advice from the Melbourne office of BHP on the best method to employ in fighting the fire, reference being made to the report into the recent, similar, fire aboard the Australian Achiever and at 0930 a Senior Personnel conference was held on the bridge. At 1000, the control centre was moved from the bridge to C Deck for safety considerations, the bridge being in close proximity to the funnel. It was decided at this time that bulk CO_2, which had been called for by the Fire Brigade at 0840, was likely to be the best method with which to fight the fire which was not yet under control. At 1035, an Engine-Room Party, led by the Chief Engineer, advised the Master by VHF radio that they had found a suitable point through which to admit the liquid CO_2 into the main engine exhaust trunking. This was at a thermometer pocket immediately above the main engine turbo-charger. Actions within the area of the waste-heat unit were, by this time, being hampered to some considerable extent by the absence of lighting, both the main and emergency lighting circuits in this area having been isolated on account of water and heat damage which had occurred to several fittings and cable runs.

As the fire continued to burn and the situation seemed to be deteriorating, causing major concern to the fire officer in charge of the response, he directed Fire Brigade personnel to cool the casing of the unit with water mist from high pressure hose reels.

At 1045, the ship's fire-detection system was activated by the affected zone. This was the first time during the incident that any automatic alarm sounded.

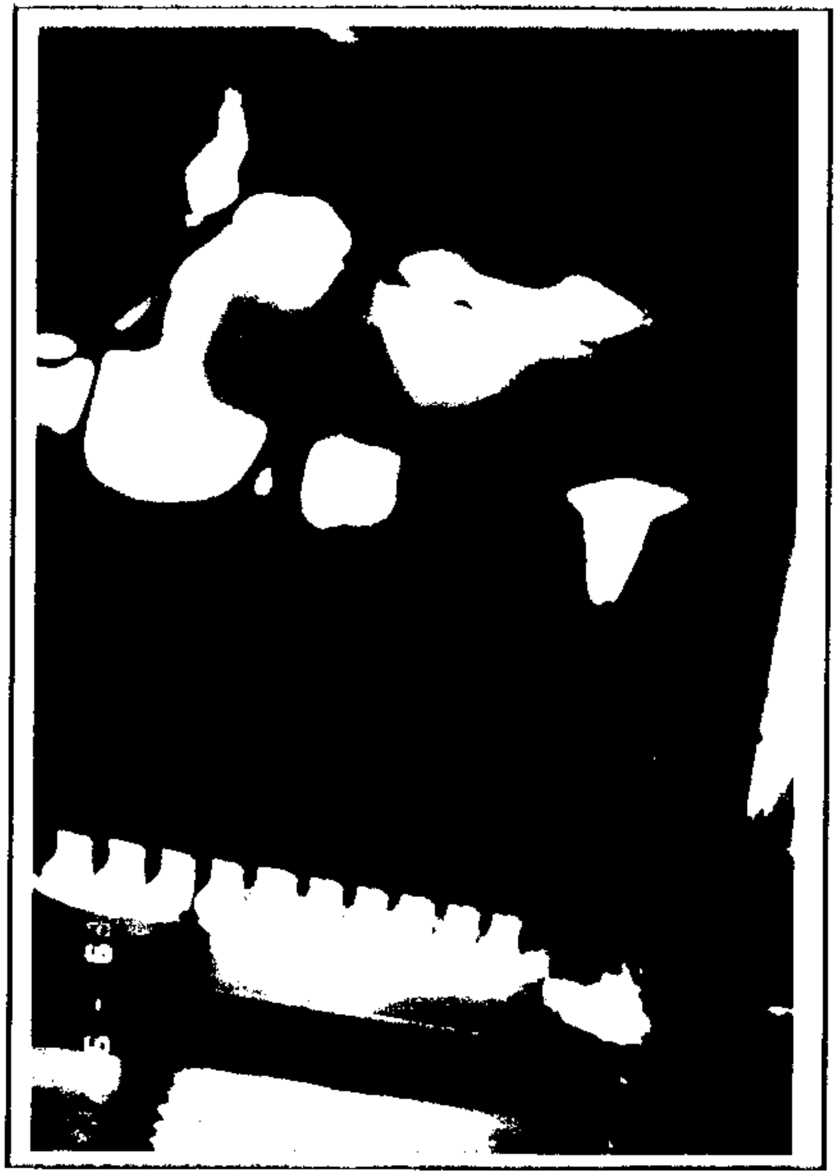
Hoses were run from the CO_2 tanker on the wharf to the engine-room and all personnel were evacuated from the engine room with the exception of the Third Engineer and three firemen who remained in the Machinery Control Room. At 1115, injection of liquid CO_2 was slowly started into the base of the waste-heat unit. Soon afterwards flames were observed coming from the top of the funnel, but after about a further 25 minutes they had died down. In order to contain the CO_2 within the uptake, a cover for the top of the funnel was made up from the galley fire blanket and two stores pallets. This was then lowered onto the top of the funnel, using the vessel's stores crane, where it remained for approximately the next 70 minutes. This technique proved effective in further subduing the fire.

At 1230, the fire having died down, the Melbourne Fire Brigade dismissed the tug "Gabo" and at 1325 the decision was taken to turn off the CO_2 and to cool the unit by admitting a water spray down through the funnel. This first required the removal of the funnel rain baffle and the removal of the drain at the bottom of the unit to check that it was clear thus preventing the possibility of water reaching the main engine. The bottom inspection door of the unit was removed and it was observed that, although some hot-spots remained, the fire had been extinguished. The water spray down the funnel was maintained until 1515, when the District Fire Officer was satisfied that the fire was extinguished and no further danger existed. The Brigade then stood down.

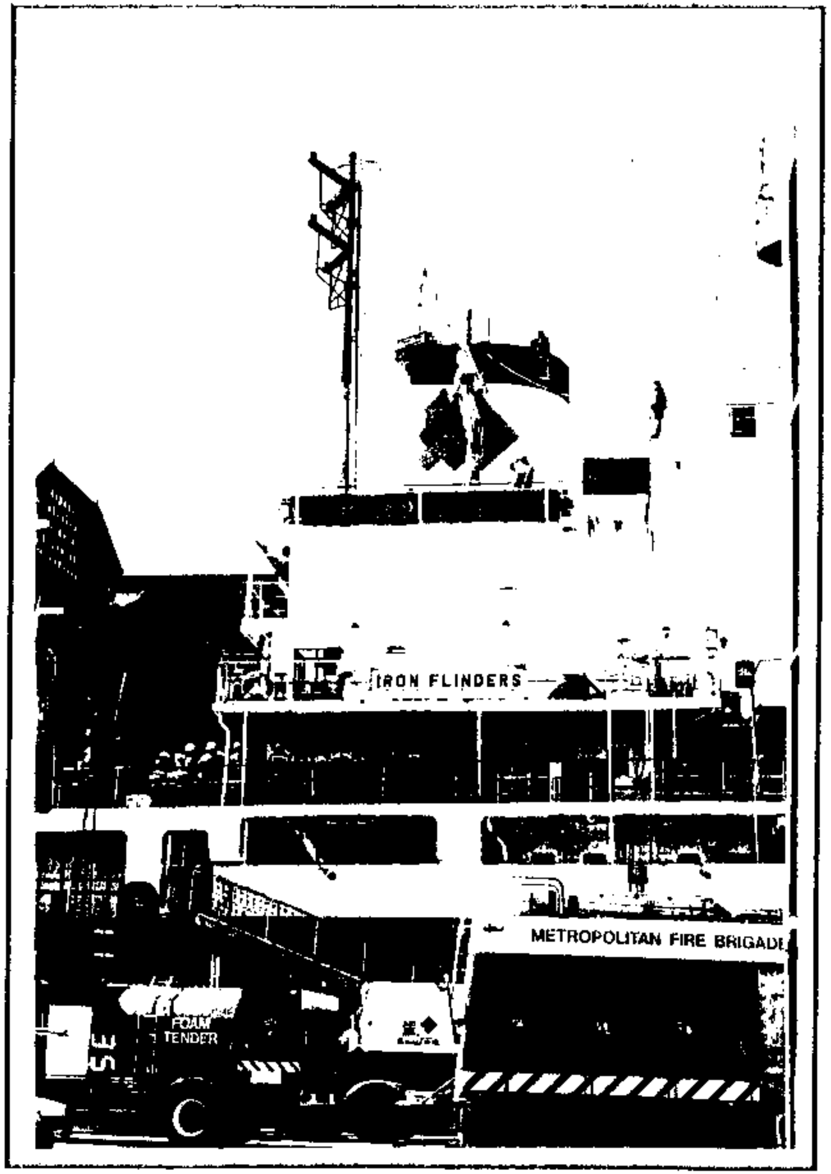
The vessel's crew members were billeted ashore that night. Shore labour was employed from 1800 to midnight to remove the cladding and insulation around the unit and on the following morning a visual inspection was carried out.

The inspection revealed that, at the bottom of the unit where the fire had started and the heat had been most intense, the lower rows of tubes had burned away completely, the rows of tubes above being badly sagged indicating that an intense hydrogen-iron fire had occurred. For the next four days, shore labour cut away and removed the remains of the interior of the unit and renewed much of the casing in order to enable the vessel to proceed without a waste-heat unit.

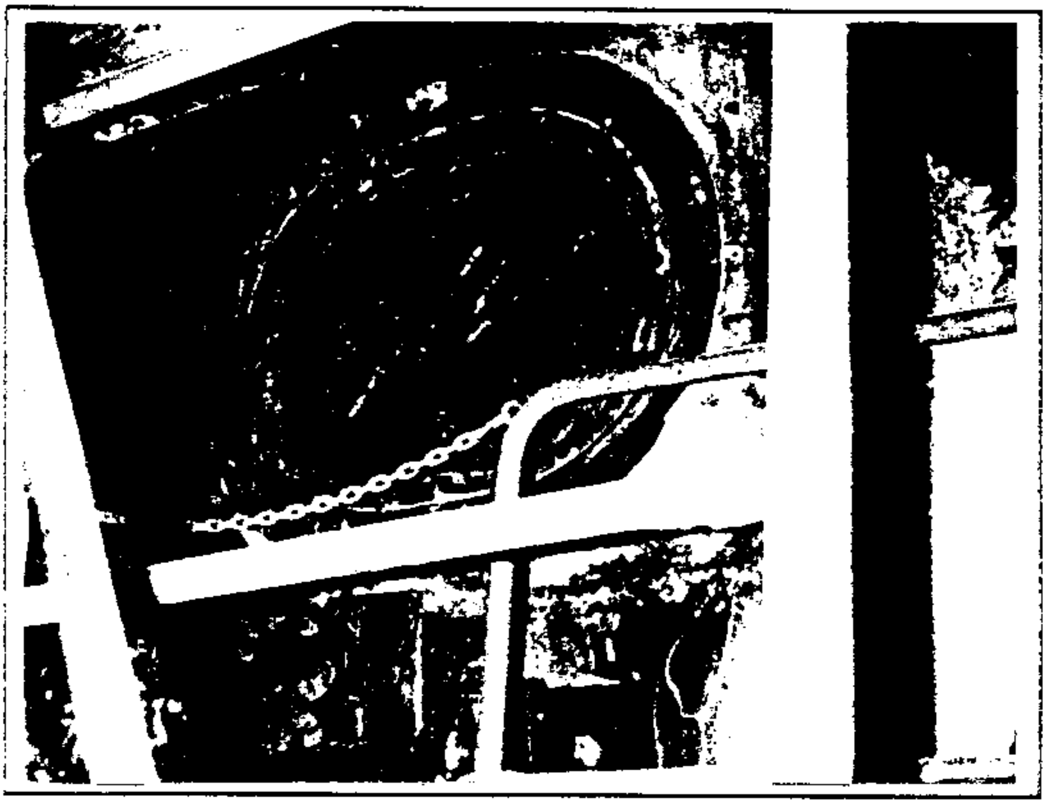
The Melbourne Fire Brigade expended 8.62 tonnes of liquid carbon dioxide during the fire-fighting operations. For three days following the fire the main engine turbo-charger remained full of ice and covered in frost.



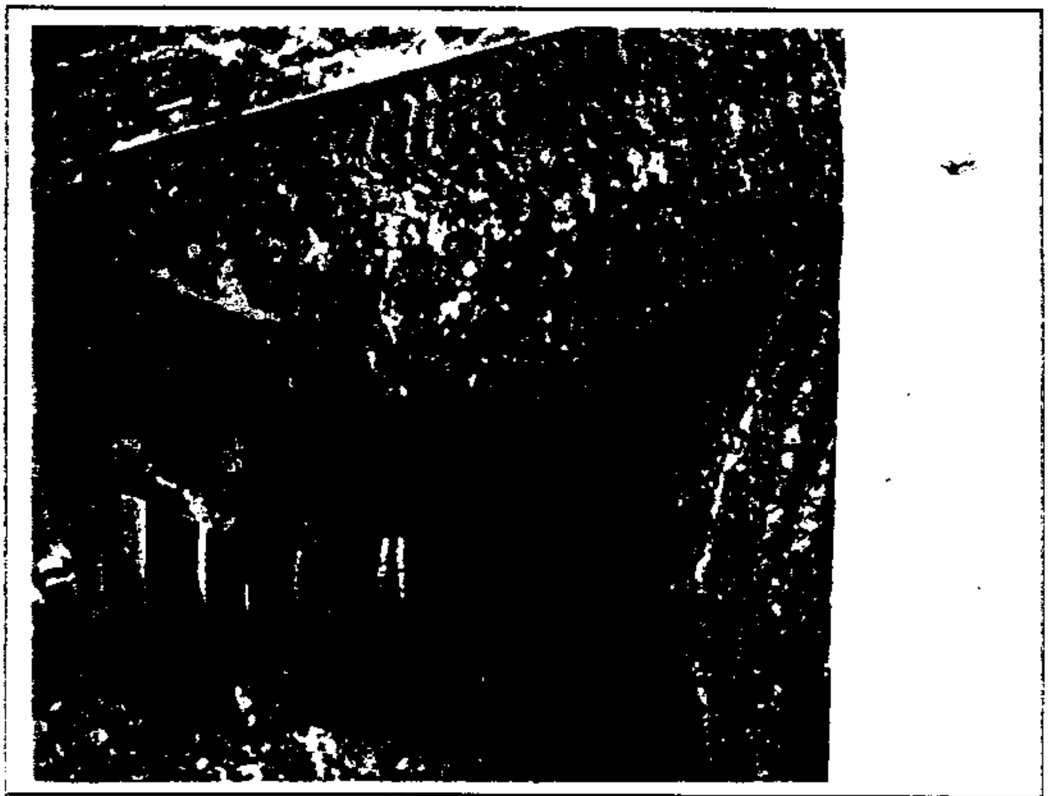
Waste heat unit on fire at 0959, 24 September 1993



Fire blanket and pallet "plug" being positioned over the funnel, approx. noon 24 September 1993



Waste heat unit lower inspection access (door removed)



Interior of waste heat unit after fire, showing melted and sagging water tubes

Comment

Over the last few years, concern has been growing over the number of incidents of soot fires in exhaust gas boilers and economisers. This is the second incident within 12 months in which an Australian registered ship has had a waste-heat unit fire which reached fusion temperatures and resulted in a melt-down of the boiler steel work. It was also the second such incident in this particular vessel, the original waste-heat unit having been burned out in similar fashion in August of 1986, when the ship had been in service for only a few months. The original unit was replaced with one of the same design.

Several manufacturers and technical organisations have issued reports drawing the attention of ship operators to an increase in these incidents of boiler damage resulting from soot fires.

No single cause has been pinpointed for the increase in the outbreak of these fires, however the risk appears to stem from a number of individual factors which, in combination, increase the likelihood of a soot fire starting. These include :

1. A major shift, throughout the industry, to cheaper, lower grade fuel oils, with greater carbon emissions.

2. Long stroke diesel engines, making more economic use of fuel, emit exhaust at lower temperatures, leaving heavier soot deposits.

3. The presence of lubricating oil carry over or mist in the exhaust gases.

4. Waste-heat units constructed to extract the maximum heat energy from the exhaust gases, with narrowly spaced finned tubes designed to offer the maximum surface area for heat transfer.

5. Manoeuvring operations after time in harbour, when the tubes within the waste-heat unit are cool or cold.

For a fire to start in any waste-heat unit, there must be an accumulation of soot to ignite and provide the initial fuel for combustion. If the fire then gains hold, the temperature of the steelwork can rise sufficiently for the structure of the unit itself to burn. Steam generated by fire-fighting water or from water from fractured tubes (contained in the boiler's water tubes or drums), can then lead to an "hydrogen-iron" fire in which the temperature can rise sufficiently for the hydrogen and oxygen in the water to dissociate and in this situation, iron, (or the steel from which the tubes are made) will itself burn with increased intensity in the absence of free air. Hydrogen is released in this exothermic reaction, thereby promoting further combustion or explosion. Hence the difficulty encountered when fighting this type of fire, where the use of water as an extinguishing agent directly onto the burning tubes can actually increase its severity or lead to an explosion.

In the absence of any extinguishing agent such as a chemical powder designed specifically for this type of application, the only recourse is to cool the boundaries of the fire, that is the casing of the unit, to remove heat from the casing and allow the fire inside to burn itself out - without adding water to the interior where the fire is most intense. The danger is that the fire, by breaking through the casing, could spread to the engine-room. In this respect, quick reaction to a waste-heat unit fire is very important, particularly where a ship must rely on its own resources. In this case the vessel was in port and was able to draw on the resources of the Melbourne Metropolitan Fire Brigade.

Main engine operation

Iron Flinder's engine is a M.A.N. KS2 70/125 BL/B with a bore of 700 mm and piston stroke of 1250 mm. The fuel burned by the engine is heavy oil with a viscosity of 180 seconds cSt, although the engine is designed to burn fuel of maximum viscosity 380 seconds cSt.

Due to problems which had been experienced over a considerable period with piston ring and cylinder liner wear, the engine-builders had recommended that the consumption of cylinder oil should be substantially increased above the 1.0 to 1.1 gms/shp/hr. recommended in the engine operating manual. Prior to the fire, the engine was consuming 345 litres of cylinder oil per day, or approximately 1.7 gms/shp/hr. [1]

There is a requirement by the engine-builders that, for the first 500 hours after a piston overhaul, the lubrication to the cylinder concerned should be increased to its maximum setting. With an average period between piston overhauls for this particular engine of only 3,000 hours, this would indicate that there would at any time, on average, be at least one unit which was running on maximum, or at least increased, cylinder lubrication. Before the vessel's arrival at Melbourne, unit No.1 was running with increased (although not at maximum) cylinder lubrication, following a piston overhaul.

The main engine fuel valves of East German origin, fitted at the time when BHP acquired the vessel, had caused considerable problems with the nozzles

1 Grams per Shaft Horse Power per Hour.

frequently cracking, possibly allowing the carry-over of unburned fuel with the exhaust gases. This problem ceased when the nozzles were changed for those from a different manufacturer, approximately 5 months before the fire.

Examination of the engine-room log book showed that the temperature of the exhaust gas leaving the main-engine turbo-charger, while the vessel was at sea, had remained at a consistent 280-300° C for at least the last six months before the fire. This temperature may increase, however, when the main engine power is reduced at, for example, "End of Passage" prior to the vessel manoeuvring into port. The reason for this apparent anomaly is that the turbo-charger is designed and matched to the engine such that it runs at maximum efficiency when the engine is running at its maximum continuous rating. As the engine load decreases, so does the efficiency of the turbo-charger, this efficiency being a measure of the effectiveness with which it converts the heat energy in the engine's exhaust gas into mechanical energy to drive the compressor. Hence at lower engine loads, less heat is converted and higher turbo-charger outlet temperatures can result.

Waste–heat unit

The makers operating instructions allow for the operation of the unit with one side, or bank of tubes, being run in the isolated or dry, condition. With the excess of steam usually being produced by the waste-heat unit, this became the normal condition when running at sea and was the condition in which the unit had been operating immediately prior to the fire. The feedwater to the starboard side was isolated and it was in this side of the unit that the fire appeared to have been most intense.

Although the design of the waste-heat unit allowed either one or both halves of the unit to be run in the "dry" condition, running a waste-heat unit dry is normally recommended only when it has been cleaned and it is known to be free of carbon deposits. The manufacturer's operating manual fails to address the question of the increased risk of soot fires when the unit has accumulated soot on the tubes and the water circulation is stopped. Maintaining water circulation plays an important role in reducing the temperature of the tube surfaces and of the soot deposits which may be present on them.

The routine for cleaning and maintenance of the waste-heat unit, drawn up by the vessel's staff, consisted of operating the steam soot blowers twice daily, once in the morning and once in the evening, this being based on the manufacturer's recommendation that the tubes be soot blown "at least once per day". Soot blowing was carried out by the Duty Integrated Rating while on his engine-room rounds and was recorded on a check-sheet. In addition to this, every third day the Fourth Engineer would inject a dose of Drew Ameroid "LT Soot Release", a low temperature soot-release powder, into the base of the unit using the fitted compressed-air injection equipment. On a planned maintenance basis, the unit was inspected every three months. The schedule for this item required the removal of the lower of the two inspection doors, there being one at the top of the unit and one at the bottom. The drain at the bottom of the unit was also to be checked clear as part of the routine. With the door removed, the condition of the finned steam generating tubes was assessed by visual inspection, as was the degree of fouling by soot build-up. The practicality of effectively following this instruction seems to the Inspector to be doubtful, given the tube spacing and the inability to see into the corners and the absolute blackness of the interior of the waste-heat unit which absorbs the beam from any light source.

Apart from the manufacturer's recommendation on the frequency of soot blowing, the maintenance instructions also include a section referring to mechanical cleaning using brushes and scrapers. This method was to be employed when soot blowing failed to reduce the differential gas pressure across the unit to its normal level. Pressure gauges for measuring this pressure drop were originally fitted to the inlet and outlet of the unit, but were not in existance at the time of the fire. This mechanical cleaning routine, however, had not been carried out since BHP acquired the ship, although the unit was water-washed at the time the ship was taken on charter. According to the vessel's records, the last internal inspection was carried out on 24 July 1993, two months before the fire. In the opinion of the ship's staff, however, the limited access to the unit, together with the fact that it was hard to see into the centre of the tube stack on account of the close proximity of the finned tubes to one another, had always made a thorough inspection of the condition of the interior of the unit a most difficult and somewhat inconclusive operation.

No other instructions from the makers, in company standing orders, or ship's departmental standing orders, make further reference to the cleaning of the gas pass of the waste-heat unit.

The ship's instructions for shutting down the waste-heat unit at "finished with engines" include a routine for closing the feedwater inlet valves and for shutting the main steam stop valve. The steam return line to the steam receiver, however, was usually left open and there are no non-return valves in this line. It is conceivable that, as the fire developed and the first boiler tube failed by melting, any remaining steam pressure within the receiver, would have been vented directly into the fire. If this occurred, then the intensity of the fire would have increased considerably due to the steam dissociating into hydrogen and oxygen and initiating an hydrogen-iron fire as described earlier.

It is possible that the fire had been smouldering for some considerable period of time before "finished with engines". Observations at the early stages of the fire indicated that it started in the starboard side of the unit, the side which had been running "dry". When the circulating pump was stopped as part of the shut down procedure, the fire may also have started to gain a hold in the port side of the unit. It is recommended by technical organisations and the manufacturers of most waste-heat units, that water circulation is maintained for some time (typically 6-12 hours) after shutting down the main engine.

Although the waste-heat unit had been inspected after the change to a new type of fuel valve nozzle, the facility for inspection of the tubes for fouling did not allow a thorough visual check of the whole unit. This inspection, in most instances, is carried out by removing the upper and lower inspection doors and then sighting up and down through the gas pass, between the rows of finned tubes, against a bright light held at the opposite end. In addition, the degree of fouling of any waste-heat unit is usually monitored during operation of the main engine by a manometer, or other differential pressure measuring device, which indicates the pressure drop of the gas as it passes through the unit. By recording the increase in this pressure drop, an indication can be obtained of the degree of soot build-up as it occurs. Some removal of this soot build-up is achieved by the use of regular (in this case twice daily) steam soot blowing. The vessel's records indicate, however, that soot blowing was carried out only once on each of the two days preceding the fire.

Instrumentation

Lloyd's Rules and Regulations for the Classification of Ships require an "Uptake Temperature High" alarm "where economisers and/or gas air heaters are integral with the boiler". A note with the appropriate regulation however, allows this requirement to be waived "for boilers not supplying steam for propulsion or for services essential to the safety or the operation of the ship at sea". It would appear therefore, that it is acceptable for such an alarm not to be fitted in this particular instance. There is no requirement in the Rules for differential pressure monitoring of the gas flow across waste-heat boilers, although such instrumentation is invariably fitted to facilitate correct operation of the unit.

The only instrumentation fitted to the gas pass through the waste-heat unit consisted of two dial thermometers at the top of the unit, one measuring the temperature at the for'd end of the casing and one at the aft end and, at the base of the unit, a single dial thermometer measuring the gas inlet temperature. None of these thermometers registered in the control room or at the boiler control panel, but had to be read locally.

The two upper thermometers are fitted with an adjustable second pointer for the presetting of the alarm set point and at the time of the fire were both set at 365° C. Cables from these thermometers run to a junction box and thence to a cable tray.

During the investigation it proved impossible to establish to where these cables ran and the conclusion reached was that they were not connected. No temperature alarms were received from these thermometers during the fire and "making" the contacts during the investigation also failed to initiate any form of alarm.

The manufacturer's instructions and drawings refer to installed facilities for measuring the differential pressure drop in the gas flow across the waste-heat unit, but no such facility existed at the time of the fire, nor could such facility be remembered by the ship's staff.

The absence of a manometer for measuring the pressure drop across the unit combined with the fact that the temperatures of the gas flow into and out of the unit were never recorded, would indicate that the degree of fouling of the tubes was not monitored. It is acknowledged, however, that instrumentation by itself, would be unlikely to indicate a localised area of soot build-up which is not cleared by regular soot blowing, (it being unlikely that steam from the soot blowers would impinge on all areas within the unit). Instrumentation will nevertheless give an indication as to the degree of general fouling of the unit.

In January 1993, a new control system, designed by In-Mar-Tech of Melbourne, was installed for both controlling the oil-fired auxiliary boiler and for monitoring the operation of the water/steam side of the waste-heat unit. This system, the specifications of which were agreed by BHP, monitors water level and steam pressure in the waste-heat unit, but does not incorporate any monitoring of the temperatures or pressures of the gas flow through it. While the subject of monitoring of pressure differential and temperature was raised, it was decided that, in view of budget restraints, this part of the system would be installed at a future date after the new system for the oil fired boiler had been completed.

Plans for the new system were submitted to Lloyd's in May 1993, four months after it had been installed and, at the time of the fire, eight months after the system was installed, the modifications were still awaiting type approval by Lloyd's Register.

Fire fighting

Upon discovering the fire, the ship's staff initially set about cooling the surrounding compartment bulkheads, which, although necessary to prevent the fire from spreading, did not remove heat from the source of the fire itself - a measure which needs to be adopted at the earliest possible moment.

From the time that the fire was discovered, a period of over forty minutes elapsed before the Melbourne Fire Brigade was summoned. In the opinion of both the Inspector and the Brigade, this was an excessive delay. In port, the Port Authority and Fire Brigade should be advised immediately of a fire aboard a vessel so that, with the appropriate information, a properly phased response can be initiated. It is likely that the fire would have been controlled earlier than was the case, had this been done.

Once the decision was taken to call the Fire Brigade, the Master followed the emergency procedures as laid down in the instructions received from the Port of Melbourne Authority. However, the system in place alerts the emergency service required (in this case the Fire Service) but the PMA itself was not included in the information loop. There was thus a delay of some twenty minutes before the Port Authority was informed of the fire by the Fire Brigade. The instructions on board the ship were dated August 1991 and were still current. The Inspector understood these instructions to be under review at the time of the investigation.

Nobody attempted to cool the casing of the waste-heat unit, which itself was not in a state of melt-down. At the time of the discovery of the fire, the casing was glowing at "orange - red" heat, but over a relatively confined area. It is acknowledged that it would have been dangerous to have played water directly onto areas where the temperature of the steelwork may have been approaching its melting point, ie. at yellow-white heat, however, cooling water could have been played, in the form of a spray, onto the casing in general, and if directed with care, should have drawn the heat away from the hot-spots.

According to the ship's staff, it appeared to them that the Fire Brigade did not immediately realise that the emergency involved an hydrogen-iron fire, and that they were unfamiliar with such fires. They were advised not to direct water hoses down the funnel directly into the unit. This advice was repeated by the officer from the Department of Labour and Industry who arrived later as an adviser to the Fire Brigade. The OH&S inspector stated that under no circumstances should water be allowed onto the overheated economiser, but also advised that the economiser casing should be cooled with a fine mist spray. The Fire Brigade were well aware of the dangers of playing water on to such fires. However, when the Fire Brigade first arrived, the assessment of the situation was that the fire did not appear to be particularly hazardous, and advice from the Master was that they should not play water on to the casing of the waste-heat unit. When the situation deteriorated, the fire officer in charge did direct that the casing should be cooled.

The Inspector is satisfied that, in the intensity of the situation prevailing at that time, there was confusion between the meaning of directing water directly into the fire within the waste-heat unit (to try to extinguish it) and directing it directly onto the outside, or casing, of the unit (to contain it), which led to no direct action being taken. The consequence of this ambiguity was that nearly two full hours elapsed between the discovery of the fire and the time when the Fire Brigade's fog nozzles were first directed onto the casing of the waste-heat unit to cool and contain the fire itself, as opposed to the boundary cooling of surrounding bulkheads.

In the confined spaces of the engine-room, particularly in the area around the waste-heat unit, the ship's crew became exhausted attempting to manipulate the vessel's 65mm canvas fire hoses. By contrast, the preferred 25mm I.D. rubber fire hoses employed by the Melbourne Fire Brigade were considerably easier to handle, even up to the funnel. Their variable nozzles, using a low volume of water, gave a wide-angle fog more suitable for optimum cooling while restricting the run off of water into the engine-room bilges.

The variable nozzles carried by the vessel give a cone of approximately 60 degrees, providing insufficient break-up of water in a confined space.

It is evident that the ship's staff were aware of the hazards involved with using water to directly attempt to extinguish a waste-heat unit fire, but they failed to appreciate the need to cool the casing within which the fire was contained.

With the complete lack of any information carried on board the vessel from the manufacturers, or operational orders from the ship operators, concerning the best methods by which to tackle a fire in the waste-heat unit, it may be considered fortunate that the incident occurred in a situation where assistance from the Fire Brigade, using bulk CO_2, was available.

It should be noted that the major extinguishing agent was CO_2 and the ship was equipped with 280kg of CO_2. In the initial stages of the fire an attempt to use this fire-fighting medium was thwarted by a split in one of the delivery pipes. While it is not possible to make a judgement as to whether or not the defective pipe should have been seen and mended, it is apparent that these pipes are so placed as to be vulnerable to damage and are not protected. It cannot be determined whether the relatively small amount of CO_2 would have been effective, even at the early stages of the fire.

In spite of this, however, a good working liaison was quickly established between the ship's staff and the Fire Brigade and, during the course of the investigation, the ship's staff were commended by the Brigade on their efficiency, co-operation, and the standard of the assistance which they had rendered during the whole of the incident.

Training

Courses are run by various organisations to train seafarers in firefighting, as part of the syllabus necessary to obtain sea-going qualifications. It does appear, however, that the rather specialised aspect of fires in boilers and waste-heat units, or economisers, and in particular, hydrogen-iron fires, is either not covered in these courses at all, or touched upon only briefly.

The Inspector has been advised by BHP that the company's policy of running short refresher courses in fire-fighting and other safety courses for the Officers employed on its vessels lapsed a few years ago and, as a consequence, the Officers involved in this incident had not attended such courses. It is understood, however, that this situation is now being redressed by BHP.

Conclusions

1. The fire occurred as the result of a combination of factors:

Soot build-up

in order for the fire to have occurred, there must have been a build-up of soot within the unit. The production of soot in the exhaust gas was probably exacerbated by three factors, namely:

i) The poor performance of the East German fuel valve nozzles,

ii) The high consumption of cylinder oil, particularly following the frequent overhaul of pistons, and

iii) manoeuvring into port prior to the occurrence of the fire.

The first two of these may have caused fouling of the waste-heat unit over a prolonged period.

The measure employed to assist in the prevention of fouling was the use of Drew Ameroid "LT" soot release powder injected into the bottom of the unit every third day. The effectiveness of this treatment would be reduced if there had been significant oil vapour carry over.

Cleaning

With the inadequate arrangements for thorough inspection of the unit and no provision for water-washing, the quantity of deposits within the more inaccessible areas of the tube nest could have been considerable.

The only method employed for cleaning the unit was that of soot blowing, carried out twice daily. The check-off sheets, however, which were filled in by the Duty Integrated Rating for the two days at sea prior to arriving in Melbourne, that is the 22nd and 23rd September, indicate that the unit was soot blown only once on each of those days, instead of twice as was the routine.

Ignition

Ignition of the accumulated soot could have been caused by either high exhaust gas temperature or by sparks carried over from combustion into the exhaust gas stream. The engine manufacturers, MAN-B&W, have stated in one of their service letters that "oil-wetted soot" may ignite at temperatures as low as 150° celcius. If the fire, as is most likely, had been smouldering for some considerable period before "Finished with Engines", then the action of shutting down the feedwater circulation would have assisted the fire to gain a hold by stopping the only means by which the heat of combustion was being removed from the tube banks.

2. The lack of information provided by the manufacturers on keeping the tubes clean if part of the unit was to be run in the "dry" condition, is considered to be a contributory factor to the incident. Similarly, the absence of any instructions from the owners, following similar incidents in recent years, emphasising the importance of maintaining waste-heat units in clean condition to minimise the risk of soot fires, is also considered to have been a contributory factor.

3. No regular monitoring of the degree of fouling of the unit was carried out. The temperatures of gas flow into and out of the unit were not recorded and no instrumentation was fitted for measuring the pressure differential of the gas flow through the unit. Had the remote alarm for "Uptake Temperature High" been connected, an earlier warning of the fire would have been received.

4. No information was available on board, either in the equipment manuals, owners orders, or operating instructions concerning the means by which to fight this type of fire. This is considered to have contributed to delays in tackling the fire by the best means in the early stages.

5. No reports of similar incidents had been passed to their fleet by the vessel's owners, neither was this type of fire covered in the fire training courses undertaken by the ship's staff.

6. The ship's fire hoses carried in the engine-room, although complying with the requirements of the regulations, were not the most suitable size for use in this situation. Similarly, the nozzles, of East German design, gave a water flow rate and cone angle not well suited to the cooling of surfaces in confined spaces.

Submissions

Under the provisions of sub-regulations 16(3) and (4) of the Navigation (Marine Casualty) Regulations, if a report, or part of the report, refers to a person's affairs to a material extent, the Inspector must, if it is reasonable, give the person the report, or part of the report, to allow the person to provide written comments or information relating to the report.

Draft reports were sent to:
the Master and Chief Engineer of the Iron Flinders, BHP Transport, the Melbourne Metropolitan Fire Brigade and the Occupational Health & Safety Authority, Victoria.

Comments were received from the Deputy Chief Fire Officer of the Melbourne Metropolitan Fire Brigade. Where appropriate the text has been amended.

Attachment 1

Details of ship

Name:	Iron Flinders
IMO Number:	8407199
Ship Type:	General
Flag:	Australia
Owner:	AB 64 Actinor Conbulk AS
Charterer:	BHP Transport LTD
Year of Build:	1986
Yard:	VEB Schiffswerft "Neptun" - Rostock
Main Engine:	5 Cylinder MAN 7600kW
Speed:	15 Knots
Gross tonnage:	13280
Nett tonnage:	6802
Summer deadweight:	17373
Lenght overall:	158.07
Beam:	23.09
Moulded depth:	13.42
Summer Draught:	10.102
Classification Society:	Lloyd's Register