Report of the Investigation

into fire on board

Ro-Ro Passenger Vessel

SALLY STAR

on 25 August 1994

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1. SUMMARY

On 25 August 1994, mv SALLY STAR, a Bahamian registered Ro-Ro passenger ferry was en route to Ramsgate from Dunkirk and in a position about 6.5 miles east of Ramsgate when fire broke out in the main engine-room. The fire was caused by the failure of a bolted flange joint on the low pressure fuel system of No 4 main engine, allowing flammable fuel oil vapour to come into contact with part of the engine exhaust system. Initial attempts to extinguish the fire were unsuccessful, mainly due to failure of the auxiliary generators and the emergency fire pump and despite the injection of halon gas into the space. However, closure of the engine-room ventilation and fuel oil systems effectively starved the fire of fuel and oxygen. The fire was finally reported as extinguished about three hours from the onset of the emergency.

The incident required the co-ordinating role of HM Coastguard, Dover, offshore fire fighting teams from Kent Fire Brigade, RAF and HM Coastguard helicopters. A total of 85 non-essential crew and 17 passengers were transferred ashore by RNLI lifeboats based at Ramsgate and Margate. Tugs and other vessels stood by SALLY STAR which was finally towed to Dunkirk for repairs. One crew member suffered an injury during fire fighting operations and was evacuated ashore by helicopter. There were no other injuries and no loss of life.

The fire and heat damage was limited to the main engine-room and the spaces above, within the central casing leading to the funnel space. Although the heating of some boundaries surrounding the main engine-room space caused some concern, the fire was extinguished and effectively prevented from spreading by the actions taken by both the Kent Fire Brigade and ship's staff.

As a result of findings of the investigation a number of recommendations have been made which include matters concerning the early warning of oil fuel vapour leakage in machinery spaces and more stringent requirements for low pressure fuel systems of medium speed diesel engines.

PART I FACTUAL ACCOUNT

2. PARTICULARS OF SHIP AND CREW

2.1	Type	:	Ro-Ro passenger ferry
	Name	:	SALLY STAR
	Built	:	1981, at Helsinki, Finland
	Port of Registry	:	Nassau, Bahamas
	Overall Length	:	137.42 metres
	Extreme Breadth	:	22.62 metres
	Maximum Draught	:	5.75 metres
	Gross Tonnage	:	16829
	Main Engine	:	Four Wartsila, Type 12V32, 4 stroke turbo charged 12 cylinder diesel engines, with cylinders arranged in Vee formation, reduction gear to 2 controllable pitch propellers
	Propulsion Power	:	14712 kW
	Maximum Speed	:	18.5 knots
	Manager	:	Sally Line Ltd, Argyle Centre, York Street, Ramsgate, Kent
	Classed	:	Det Norske Veritas (DNV)

2.2 There was a total crew of 100, comprising the Master, Deputy Master, Chief Engineer, Chief Purser, three deck officers, one radio officer, five engineer officers, one electrical engineer officer, and 86 ratings. The Master, officers and ratings within the deck and engine departments and some staff engaged in retail, casino and security activities were British. All catering and hotel staff were French. All deck and engineer officers held United Kingdom Certificates of Competency and corresponding Licences issued by the Bahamian Authorities.

In addition to the vessel's crew, four shore based sub-contractors were carried on the vessel at the time of the incident.

2.3 Although SALLY STAR's Safe Manning Certificate, issued by the Bahamian Administration, allowed for operation on bridge control with an unmanned engine-room whilst the vessel was engaged in trade between England and France, she was not operated in the unmanned machinery space mode when sailing on the Ramsgate/Dunkirk service. The manning on that service was in excess of the requirements of the Safe Manning Certificate. All deck and engine-room watchkeeping duties were normally shared by the two Second Officers and two Fourth Engineers respectively, plus ratings.

It was normal practice for the Deputy Master to take over command from the Master between 2230 and 0630 hours.

2.4 The vessel operated on the English Channel route between Ramsgate and Dunkirk, a crossing of approximately three hours duration. SALLY STAR held a valid Passenger Safety Certificate for Short International Voyages issued by DNV Classification Society on behalf of the Bahamian Administration under the provisions of the International Convention for the Safety of Life at Sea, (SOLAS 1974). Expiry date for this Certificate was 30 January 1995. This Certificate permitted the ship to carry 1754 passengers and 105 crew. In addition, the United Kingdom Marine Safety Agency (MSA) issued to the vessel a Passenger Numbers Certificate endorsing the permitted number of passengers allowed to be carried. Expiry date for this Certificate was 17 November 1994. The ferry carries a mix of freight vehicles, cars and other vehicles. Some voyages are designated to carry only freight vehicles. The incident reported here occurred on one of these voyages.

2.5 The ship is of all welded construction with raked stem and transom stern. Passengers have access to the upper five decks of the vessel while at sea. These are designated as follows from the uppermost deck: wheelhouse top, pilot deck, bridge deck, cabin deck and saloon deck, or alternatively, as decks A, B, C, D, and E respectively. The latter system has been used in this report. Below the passenger decks is the vehicle space which is divided into a lower or main vehicle deck (G deck) and an upper vehicle deck (F deck). The space below G deck is sub-divided into watertight spaces devoted to the steering gear, main and auxiliary machinery, compressor machinery, fuel and freshwater storage, sewage and fuel treatment plants, ballast and trim tanks, storage rooms and voids.

The machinery control room (MCR) is on the starboard side of the auxiliary generator room. Watertight doors are fitted between machinery spaces and, except when being used for access, are kept closed at sea. Normal operating procedure prior to an emergency is that the Master Switch on the bridge for the watertight doors is left in the OPEN position and all doors are closed locally. This allows for local control of these doors, and in this mode does not require continuous operation of the door control lever to maintain an open or part-open condition. On the day of the fire the Master Switch was in the CLOSED position. In this mode, opening of the watertight door requires its control lever to be held against a spring, to prevent the door closing, while personnel pass through.

G deck is a through vehicle deck, enclosed by the full superstructure with watertight doors at the bow and stern. F deck is a second vehicle deck, enclosed by the superstructure but open at the after end, served through side and stern access ramps. On each side of F deck there are three hanging mezzanine decks. G deck has three sections of hanging mezzanine decks on the starboard side only. The mezzanine decks are used for light vehicles.

The central casing housing stairway access, machinery exhaust pipes and ventilation trunking etc is situated between frames 60 and 156, along the centre line of G deck and extending up to E deck. On the port side of this casing, fitted at G deck, is a service hatch with a watertight closure leading to the main machinery space. This gives direct access to the main engine-room for large engine components etc from the main lower vehicle deck, G deck.

Decks E and D extend the full breadth of the ship and house the passenger and galley areas. Crew and officer accommodation is situated on C deck which is used for embarkation of crew and passengers into the lifeboats and liferafts. The wheelhouse, the emergency generator and battery space, air-conditioning and exhaust gas economizer boiler spaces are situated on B deck.

Access from G and F decks to the upper five A, B, C, D and E decks is by way of internal and external staircases. Crew have access from the watertight compartments to G deck and the decks above. All these accesses provide means of escape to the lifeboat and liferaft embarkation areas.

2.6 Fire protection and extinguishing systems for the main engine-room and vehicle deck spaces

The fire fighting system consists of a fire main and hoses and portable fire extinguishers throughout the vessel, halon 1301 gas extinguishing in the machinery spaces and a drencher installation in the vehicle deck spaces. The machinery compartments and vehicle spaces are equipped with an automatic fire detection and alarm system. The emergency quick closing fuel oil valves to the main and auxiliary diesel engines are remotely operated from a position adjacent to a halon control station on G deck.

The halon gas fire extinguishing system is used in the boiler/fuel treatment space, auxiliary and main engine-rooms. Halon storage bottles are positioned within each space. Remote manual release of halon into selected spaces is controlled from stations on G deck in the form of two lockers positioned in the central casing. One locker serves the main engine-room alone and the other serves the auxiliary engine-room and boiler/separator room, albeit with two separate sets of controls.

The fire main is supplied by any of three fire pumps, one of which is designated as the emergency fire pump. This pump is situated in the compressor room, adjacent to the drencher pump, and is designed to start automatically should the fire main pressure drop. Residual water pressure within the fire main is maintained by an air/water charged reservoir. The correct proportion of air and water in the reservoir is maintained by an air supply from the ship's compressed air system and by a small independent water pump. The emergency switchboard supplies electrical power to the emergency fire pump.

Forced draught air is supplied to the main engine-room by electrically powered fans situated on A and B decks. These fans draw from induction chambers which are in turn supplied from the open air by way of grills, the aft sets of which are fitted with external dampers. The forward dampers close automatically when the fans are shut off. The fans discharge to trunks contained within the central casing which lead to the main engine-room.

When operating in the normal seagoing mode, with watertight doors closed, any air supplied to the engine-room and which is not used by the main engines is exhausted upwards by way of the central exhaust casing and to atmosphere via the exhaust grills in the aft part of the funnel.

To exclude air from the engine-room for fire fighting purposes, and to retain halon gas discharged into it, remotely operated flaps are installed in the ventilation air routes leading to and from the space. The flaps in the air route leading from the space are referred to as halon flaps. The halon flaps are operated remotely from G deck, and the air inlet ventilator flaps are closed by hand operation locally on B deck and by shutting off ventilation fans. Ventilation fans can be stopped from the MCR, drencher room and bridge.

The main pump supplying water to the drencher system is situated in the compressor machinery compartment room and electrical power is supplied from the main and auxiliary generators via the main switchboard. Drencher control valves are on a distribution manifold, situated in a space at the aft end of the central casing on G deck. Connected to this manifold is a cross connecting valve allowing water to be supplied to the drencher system from the fire main. Drainage scuppers are installed on G deck in order to avoid accumulation of large quantities of water on the deck as a consequence of operating the drencher system.

The hull, superstructure, structural bulkheads, decks and deck houses are constructed of steel to meet the fire division and insulation standards required by the 1974 SOLAS Convention. Decks G and E enclosing the vehicle spaces, and the central casing housing the stairway access, machinery exhaust pipes and ventilation trunking etc are insulated to A60 standard. The fire integrity of the central casing above E deck, dependent on the type of space adjacent to it, is to the required standard. The main engine-room access hatch on the port side of the central casing at G deck is insulated to A60 standard. The space below G deck is divided by four vertical A60 fire divisions, which include two divisions enclosing the main and auxiliary engine-rooms and the fuel oil separator room.

2.7 **Emergency Generator**

The emergency generator and emergency switchboard are housed on the port side of B deck, with access from the open deck. The generator is a 240kVA, 50Hz, 3 phase machine driven by a Detroit diesel which is equipped with an air motor starter and a battery powered electric starter. The emergency switchboard is divided into two sections, namely 440V and 220V.

The 440V supply serves the steering gear, emergency air compressor, emergency bilge pump, emergency fire pump, diesel oil booster pump, radar, car deck hydraulics, battery charger for emergency lighting, radio station, personnel lifts, and vent fan for the radio room. The emergency switchboard supplies all No 4 main engine pumps for the first start sequence.

The 220V supply serves the gyro compass and auto-pilot, machinery alarm system, battery charger for emergency generator, emergency lighting, watertight door indicators and general alarm.

The emergency generator is routinely tested.

2.8 **Emergency Plan and Procedures**

Four lockers (referred to as fire stations), are distributed around the vessel. Each locker contains two firemen's outfits which include breathing apparatus (BA) equipment. Fire station No 1 is on B deck starboard side. Fire Stations No 2 and No 3 are within the enclosed stairway leading up from the forward starboard corner of G deck and the aft starboard corner of G deck respectively. Fire Station No 4 is approximately at midships within a space in the centre casing on G deck.

Coded public address announcements by the Master, in the form of 'Mr Skylight', followed by fire station numbers to be attended by fire parties, indicate to members of the crew that they should make their way to their emergency stations. Once at emergency stations, crew members form emergency groups which have pre-determined functions as follows:

- Fire Group 1 and Fire Group 2 to assemble at the Fire Stations stated in the 'Mr Skylight' announcement. These groups are in the charge of the Third Engineer and Chief Officer respectively. The task of these groups is fire fighting and dealing with spillages of hazardous substances. These two groups are under the direct control of, and report to, the Fire Chief, who is normally the Chief Engineer and who is stationed on the bridge.

- Engine Control Group to assemble in the MCR. The group is led by the Second Engineer. The primary task of this group is to secure the electrical distribution system and the function of pumps and main engines. This group is also under the direct control of the Fire Chief.

- Boat Control Group Port and Boat Control Group Starboard to assemble at the respective side of C deck, each in the charge of a Second Officer. The primary task of these groups is to lead all work such as the closing of manual fire flaps, preparation of lifeboats, assistance with helicopter operations etc. These two groups are under the direct control of the Master who is stationed on the bridge.

- First Aid Group to assemble at the hospital with the task of treating and transporting injured persons. This group is under the direct control of, and reports to, the Evacuation Leader, who is normally the Chief Purser and who is stationed on the bridge.

- Control Group to assemble at the Information Desk with the task of evacuating and watchkeeping in the area of an accommodation fire. This group is under the direct control of the Evacuation Leader.

- Evacuation Groups: the members of the Control Group transfer to the Evacuation Groups when accommodation needs to be cleared of persons. There are two Evacuation Groups, one to serve the forward part of the accommodation and one to serve the after part. These two groups are also under the direct control of the Evacuation Leader.

The three persons stationed on the bridge, namely the Master, Fire Chief and Evacuation Leader, are normally supplemented by the Deputy Master, the Radio Officer and two ratings.

2.9 Life Saving Apparatus

Lifeboats and liferafts are embarked from C deck. The lifeboats have a total capacity of 955 persons. The lifeboats are numbered 8 to 16 which refer to the Muster Station number at which the respective lifeboat is positioned. There are 18 Muster Stations, Station Nos 1-7, 17 and 18 are equipped with a total of 40 x 25 person davit launched inflatable liferafts. Life-jackets for the use of passengers are stowed in overhead baskets and deck lockers on C deck.

2.10 Cargo Carried on Board

Two vehicles loaded in Dunkirk on 25 August carried Dangerous Goods for which Declarations were submitted. Stowage of the two vehicles was in accordance with the International Maritime Dangerous Goods Code. One vehicle was stowed on G deck starboard side, adjacent to the centre casing and forward of the main engine-room. The other vehicle was stowed at the extreme aft end of F deck, the only vehicle on this deck. This area is open at the aft end. In addition to these two vehicles a further 22 vehicles were stowed on G deck.

2.11 Main Engines

The main engines operate on ISO180 fuel, blended (by suppliers) to ISO150. Each pair of engines drives, via clutches, a gearbox coupled to a propeller shaft. The main generators are coupled to the main engines via a power take off from each of the main gearboxes. These generators are positioned in the compressor room, with the necessary drive shafts passing through the separating bulkhead. In the centre of each engine's 'Vee' are cylinder exhaust pipes, encased in lagged boxes leading to the turbochargers mounted at the forward end of each engine. Along the outer part of each cylinder bank is a 'hot box' within which are the high pressure fuel pumps, high pressure fuel pipes and low pressure fuel rail. To maintain the temperature of these components, and thus sustain the operating temperature of the fuel oil within them whilst engines are stationary in port, insulated covers are secured in place so that these components are totally enclosed. The cover securing arrangements consist of studs trapped in the sheet metal of the cover with attached thumbwheels. The studs screw into the cylinder heads. Leakage of fuel from any components within the hot boxes should be contained within the space by the covers and engine structure and collect in the lower part of the space before draining, via tundishes situated at the forward and aft ends of the engine, to a drain tank. A single high level alarm is fitted to this tank.

2.12 Auxiliary Engines

Installed in the auxiliary engine-room are two auxiliary generators each driven by a 4 cylinder in-line Wartsila diesel, Type 4R32. These generators are normally used in port and during periods of manoeuvring. However, with a main engine out of service, as was the case during the voyage considered here, it is normal to use an auxiliary generator instead.

2.13 Fuel System

The low pressure fuel rails on each main engine are supplied by booster pumps, each having a capacity of 3.6m^3/h at 6bar, situated in the separator room. Two discreet low pressure fuel systems are supplied by these pumps and each system is connected to two main engines. The two inner engines share one system and the two outer engines the other system. The normal operating pressure within these low pressure systems is 5bar to 7bar, at a temperature of 110°C to 120°C to maintain the desired fuel viscosity. Fuel supplied to the engines' fuel rails, which is in excess of the requirements of each pair of engines, is returned to an oil receiver or column to mix with fuel entering the system. The total quantity of oil within each low pressure system, including the return receiver, is maintained approximately constant by one of two supply pumps from the heavy fuel day tank discharging into the corresponding oil receiver. The capacity of each supply pump is 6.2m^3/h at 1.5bar and each pump can supply both oil receivers.

On the discharge side of the supply pumps is a cross connection that supplies the return oil receiver serving the auxiliary engines. A quick closing valve on this cross connection, designated as V79, can be closed remotely from a position at G deck level adjacent to the halon control cabinet which serves the auxiliary engine-room and separator room. The auxiliary engine return oil receiver can be gravity fed directly from the heavy fuel oil day tank. The two suctions on the heavy oil day tank serving the main and auxiliary engine fuel systems are fitted with remotely operated quick closing valves. A separate pair of booster pumps, drawing from the diesel oil day tank, allows the auxiliary engines to operate on diesel oil. In port, with the main engines stopped, the fuel oil booster pumps are normally kept running continuously in order to circulate fuel through the heater and low pressure fuel system to maintain the operating temperature of the fuel oil and components of the low pressure fuel system. As there is no circulation of fuel oil through the high pressure parts of the fuel system under these conditions, some reliance is placed on the efficacy of the hot box covers as thermal barriers.

Fuel oil viscosity is maintained by a Viscotherm unit, giving a corresponding temperature of 110°C to 120°C. Although not precisely recorded, the flash point of the fuel is noted as being 70°C, or greater.

3. NARRATIVE

Note: All times are UTC on 25 August 1994

3.1 Between 0120 hrs and 0205 hrs SALLY STAR was alongside her berth at the Loon Plage Terminal, Dunkirk West, France. At 0200 hrs a change of watchkeeping Fourth Engineers and motormen took place. Also on duty, on a non-watchkeeping basis, was the Second Engineer. 'Standby' was rung on the telegraphs at 0202 hrs. The Fourth Engineer started Nos 2, 3 and 4 main engines at which time the Second Engineer arrived in the MCR. The motorman commenced his routine machinery inspection procedure. First starting the economizer pump in the boiler room, he then worked through the machinery spaces beginning from aft. After clutching-in the main engines, and receiving the report of the motorman's inspection, the Fourth Engineer indicated to the bridge that the main engines were ready for use: the bridge acknowledged. SALLY STAR sailed shortly afterwards, clearing Dunkirk Pierhead at 0223 hrs.

During manoeuvring operations the fuel pump spaces on the main engines were checked by the motorman. No fuel oil leaks were reported. 'Full Away' was signalled from the bridge at 0230 hrs and answered from the engine-room. The Fourth Engineer made load adjustments on the main engines. The port shaft generator was put on the port galley load, No 1 auxiliary generator was on the main bus-bar and No 2 auxiliary generator was shut down.

3.2 The Fourth and Second Engineers and the motorman made their way to the main engine-room to work on No 1 main engine that was out of service. After assisting with the removal of one cylinder liner from No 1 main engine, at 0245 hrs the duty Fourth Engineer inspected exhaust and jacket water temperatures on the running main engines. He returned to assist the Second Engineer and motorman with their work on No 1 main engine.

The work on the main engine was completed at 0400 hrs. The Fourth Engineer made his way to the MCR visually inspecting the running main engines from the walkway across the forward end of the engines. He performed an instrumentation check on his arrival in the MCR. Before returning to the MCR, the Second Engineer and motorman returned their tools and equipment to the stores and then inspected the running main engines. No abnormalities were observed.

3.3 At 0418 hrs, shortly after the Fourth Engineer, Second Engineer and motorman returned to the MCR, the fire detection panel on the bridge indicated a fire in the main engine-room. Simultaneously the fire alarm failure alarm sounded in the MCR. While the Fourth Engineer was answering the Second Officer's telephone call of enquiry from the bridge, the TV monitor, which coincidentally was scanning No 4 main engine, was seen to go blank immediately after flashing white. The Fourth Engineer indicated to the bridge that he would investigate. From the auxiliary machinery room side, the Fourth and Second Engineers opened slightly the forward engine-room watertight door. Seeing black smoke in the space the watertight door was shut immediately.

The Deputy Master was called to the bridge. The bridge was informed of the engine-room fire and permission was given for the main engines to be stopped. The Fourth Engineer proceeded to shut down the engines starting with No 2, at which time Nos 3 and 4 main engines commenced to shut down automatically. No 2 auxiliary generator was started and put on load so that both auxiliary generators were then on load.

The bridge fire detection panel indicated fire or smoke on the port side of the main vehicle deck and in parts of the main engine-room. Steering control was changed over from auto-pilot to manual and main propeller pitch placed on zero. The Master was called to the bridge at 0420 hrs and informed that there was a fire in the engine-room. At about this time the steering gear failure alarm sounded, and he assumed command, shortly after which the navigation light failure alarm operated. The seaman on safety and security rounds was instructed, by radio, to clear the anchors. The accommodation fire doors were closed and ventilation to car decks, machinery spaces and accommodation shut off.

3.4 On opening the aft main engine-room watertight door in the compressor room the Second Engineer observed a small amount of black smoke issuing from the opening. The watertight door was again closed. On his return to the MCR the Second Engineer shut down the main engine fuel oil supply and booster pumps and instructed the Fourth Engineer and motorman to collect the firemen's outfits from Fire Station No 4 on G deck.

3.5 The general alarm was operated at 0422 hrs for about 15 seconds, followed by a 'Mr Skylight 4 and 3' announcement over the public address system. The alarm was operated again for about 10 seconds. On reaching the bridge, the Chief Engineer was informed of the situation and assumed the role of Fire Chief. On receiving a report from the Second Engineer, the Chief Engineer instructed that all relevant quick closing valves, fuel pumps and halon flaps were to be shut down. The Second Engineer closed all quick closing valves except those supplying the auxiliary generators, boiler and emergency generator and the cross connection V79.

The Fourth Engineer and motorman donned the firemen's outfits at Fire Station No 4 and proceeded to the MCR. Members of Fire Party 1 arrived at Fire Station No 4 to collect fire fighting equipment as required and, finding most of it missing, made their way to the MCR. Once the Second Engineer had checked their BA sets, the Fourth Engineer and motorman assisted in the setting up of a fire hose within the auxiliary engine-room. The Fourth Engineer opened the forward watertight door leading into the main engine-room and, after instructing the motorman to hold the door's lever in the open position, entered the space. Because of intense heat and smoke he retreated into the generator room allowing the watertight door to close behind him. The Fourth

Engineer had observed no flames during his brief time in the main engine-room. Leaving the charged fire hose at the watertight door, both he and the motorman returned to the MCR to report to the leader of Fire Party No 1.

3.6 Meanwhile, using a mobile telephone, the Master contacted Dover Coastguard at 0425 hrs to report an engine-room fire. The vessel's position was 51°19'N 001°35'E, approximately 6.5 miles east of Ramsgate. The total number of persons reported on board was 104 crew and 17 passengers. The Master asked for emergency services to be alerted.

Ramsgate Port Control was also contacted by SALLY STAR by mobile telephone to request tug assistance.

3.7 The BA Team, consisting of the Fourth Engineer and motorman returned to the forward main engine-room watertight door and entered with the charged fire hose while an assistant held the door open. The hose was used to extinguish several small fires over and around No 3 main engine. During these efforts the sound of escaping high pressure gas or air was heard from the area adjacent to No 4 main engine.

3.8 Between 0428 hrs and 0432 hrs Dover Coastguard requested via RCC Plymouth, that RAF Wattisham Rescue helicopter R125, be called and tasked, and that Kent Fire Brigade despatch a fire fighting team to RAF Manston. In response, three Kent Fire Brigade appliances were instructed by Kent Fire Brigade Control, Maidstone, to proceed to RAF Manston. Other appliances were instructed to proceed to Ramsgate in preparation for a waterborne approach to SALLY STAR.

3.9 The 'Mr Skylight 4 and 3' announcement was repeated by the Master at 0430 hrs and the general alarm rung again.

At 0432 hrs the Second Engineer informed the Fire Chief by UHF Radio that all halon flaps were in position. Because of shortage of BA air, the BA team withdrew from the main engine-room closing the watertight door after them and returned to the MCR to report to the Leader of Fire Group No 1. A second BA team consisting of the Junior Engineer and a motorman donned equipment brought from Fire Station No 2 and entered the main engine-room with a fire hose.

By 0437 hrs all passengers were assembled at the Information Desk and on outer decks of C deck. An announcement was made, over the public address system, advising passengers and crew of the fire in the engine-room. All passengers and those crew not required for the emergency proceeded to the outer decks. Accommodation spaces were checked and reported clear of personnel.

3.10 Both auxiliary generators automatically stopped at 0440 hrs due to high cooling water temperature, so that the main electrical power supply for the vessel was lost. In response, the emergency generator started automatically. However the emergency fire pump, which had stopped because of loss of electrical supply, failed to restart and the fire main pressure inevitably dropped. Because of this loss of water pressure, the second BA team was forced to abandon fire fighting and withdrew from the main engine-room closing the watertight door on departure.

The vessel's Radio Officer established contact with Dover Coastguard on Channel 67 VHF, and this link was maintained throughout the remainder of the incident. The Boat Control Group reported that all the engine-room fire flaps on B deck were closed. Initially they had experienced some difficulty in closing them because the flaps were hot and because there was smoke on the port side of the deck. Oxygen and acetylene bottles adjacent to the funnel space on B deck were disconnected and removed from their lockers and placed on the open deck.

3.11 Leader of Fire Party No 1 reported the aborted efforts of the first fire fighting team to the Fire Chief.

In preparation for the release of halon gas into the engine-room at 0448 hrs, a head count was made. Fully charged BA bottles were obtained and fitted to the BA sets as required. At 0449 hrs the main engine-room was reported clear of personnel and halon gas was released into this space two minutes later. The alarm which indicates that the gas release is about to be released was not heard.

Inspections for hot spots in the accommodation spaces commenced at 0452 hrs. The visibility in some of these spaces was poor.

The emergency situation was upgraded from Securitė to Pan Pan (Urgency).

At 0453 hrs reports on the status of the emergency fire pump indicated that the emergency generator's main breaker had tripped open and could not be reset closed. However, the emergency generator remained running.

3.12 At 0500 hrs Rescue helicopter R125 was reported to be airborne at RAF Wattisham. The First Strike Team of Kent Fire Brigade was recorded as being ready for departure from RAF Manston at 0503 hrs. Two minutes later the Liaison Officer of the Kent Fire Brigade arrived at Dover Coastguard Control Room. At 0507 hrs the Rescue helicopter R92 was airborne and tasked to proceed to SALLY STAR from its base in Koksidje, Belgium.

3.13 The forward bulkhead of the main engine-room showed signs of overheating. Boundary cooling of both this, and the aft bulkhead, was performed as water availability allowed. The watertight door into the separator/boiler room was opened in order to dissipate the smoke. Fire Party No 2 also found that the main vehicle deck above the main engine-room was overheating, but reported as abating at 0509 hrs. Because of the lack of fire main water pressure, cooling of this deck was performed using a fresh water hose connected to the domestic fresh-water system still under pressure from the static head in its water pipes.

Lifeboat Nos 8, 9, 10, and 11 were lowered to embarkation level, and the passengers and crew were instructed by crew members in charge of the muster to assemble on C deck, the embarkation deck.

3.14 The Ramsgate lifeboat arrived on scene at 0513 hrs followed by the tug ANGLIAN RIEVER at 0515 hrs. Rescue helicopter R125 landed at Manston at 0521 hrs departing for SALLY STAR with the First Strike Fire Team at 0529 hrs. At 0527 hrs the rescue helicopter R92 was requested to proceed from SALLY STAR to Manston to transport the second fire brigade team.

Surface vessels on the scene were requested to cool the vessel's outer hull in way of the main engine-room. At 0530 hrs preparations were made to disembark passengers and non-essential crew, at which time the Margate lifeboat was just arriving on scene. Because of continuing problems with the electrical supply to the emergency fire pump there was still a shortage of fire fighting water. It was reported that smoke had reached the accommodation spaces.

At 0537 hrs passengers and those of the crew who were not assisting in the emergency, started to transfer from the starboard side pilot door on G deck into the Margate and Ramsgate lifeboats using the tug ANGLIAN RIEVER as a platform. The crew transferred were noted against a crew list and passengers' names were recorded. A total of 102 persons were transferred. The wind was south west force 3 and the sea was calm.

Meanwhile, at 0539 hrs Rescue helicopter R125 arrived on scene with Kent Fire Brigade personnel and requested to stand off until transfer of personnel was complete. The rescue helicopter R92 left RAF Manston at 0544 hrs with the second fire brigade team and a portable fire pump. All members of the First Strike Fire Team were on board SALLY STAR by 0550 hrs. At 0558 hrs, after consultation with the Master, the Senior Fire Officer of the team requested further portable fire pumps. From 0605 hrs the emergency fire pump on SALLY STAR was operational so boundary cooling was recommenced. Rescue helicopter R92 arrived on the scene at 0618 hrs and the second fire team and fire pump were landed on board.

The starboard anchor of SALLY STAR was reported as down at 0621 hrs with the vessel's position as 51°20'N 001°38'E. The Master requested that Dover Coastguard monitor the position of the vessel and issue a warning should it drift into danger. At this stage 39 persons were recorded to be on board SALLY STAR; 20 Kent Fire Brigade personnel and 19 crew.

By 0630 hrs it was becoming clear that boundary cooling operations were proving effective and that the cooling water, at this time being supplied to the drencher system from the fire main cross connection, was draining from the main vehicle deck.

A crewman, injured whilst manhandling fire fighting equipment, was evacuated by helicopter R92 at 0647 hrs and transported to RAF Manston.

3.15 At 0713 hrs Kent Fire Brigade recorded that 22 of their staff had boarded SALLY STAR. This figure was amended at 0736 hrs to 26 staff. The tug ANGLIAN RUNNER arrived at the scene and transferred, via the starboard pilot door, eight Kent Fire Brigade staff, three Ambulance personnel and equipment to SALLY STAR at 0725 hrs. Helicopter R92 was released by Dover Coastguard at 0733 hrs. A team of firemen entered the main engine-room from the compressor room at 0809 hrs. Two BA teams from Kent Fire Brigade again entered the main engine-room at 0821 hrs and the fire was reported as under control at 0825 hrs.

A small fire was discovered in the funnel spaces and was put out at 0834 hrs. At 0836 hrs the fire in the main engine-room was reported as having been extinguished. The halon flaps and dampers were opened to ventilate the main engine-room at 0844 hrs and boundary cooling operations continued until 0937 hrs. The Dover Coastguard was informed that the fire was out at 1112 hrs.

4. EXTENT OF DAMAGE

4.1 Fire damage was confined mainly to the main engine-room, the uptake casing and funnel interior. The most significant damage in the main engine-room was in the port area of the space. Many rubber and non-ferrous components had suffered serious damage, particularly electrical cables and control air lines above Nos 3 and 4 main engines. The starboard side of the space appeared to have suffered only minor damage, mainly due to smoke. The upper parts of the forward and aft main engine-room bulkheads showed paint damage on the compressor and auxiliary engine rooms sides. There was no distortion of bulkheads. A notable area of heat damage, confined mainly to electrical equipment, occurred within the base of the funnel at economizer level on B deck, adjacent to and slightly above the halon flaps.

4.2 An inspection by ship's staff shortly after the fire was extinguished, established that the hot box covers to the inboard bank of No 4 main engine were displaced and sitting on the walkway between Nos 3 and 4 main engines, at cylinder head level. Found within the hot box of No 4 main engine was a fractured socket-head screw on a flange of the low pressure fuel rail serving the high pressure fuel pump of No 5 cylinder of the inboard bank. This screw was one of two intended to secure this flange; the other screw was in place but only finger tight.

PART II CONSIDERATION OF POSSIBLE FACTORS

5. SEQUENCE AND CAUSE OF FAILURE

5.1 There can be little doubt that the primary source of combustible material for this fire was fuel oil and vapour leaking from the flange on No 4 main engine on which the screw had fractured. It is probable that the leaked oil vapour ignited once it was in contact with a hot surface. The hot box covers serve as baffles to contain liquid fuel leaks within the space before draining to the fuel drain tank. The covers were found on the platform between the Nos 3 and 4 main engines. These covers may have been displaced during fire fighting or more likely were blown off as a result of ignition of vapour within the hot box space. With the covers displaced, oil would have been free to spray from the defective flange onto both Nos 3 and 4 main engines, leading to the damage described. The extent and intensity of the fire would probably have been much less had the hot box covers remained in place.

Comparison of the two socket screws in this flange showed that the hexagonal socket of the failed screw was slightly deformed, indicating that there had been several tightening operations with a hexagon key. The head of the intact screw showed no similar deformation. It is possible that there may have been repeated attempts at tightening the flange to endeavour to reduce leakage from the joint. The vessel's records indicated that the ship's staff were concerned about the effectiveness of the flange joint "O" rings and that frequent inspections of the joints had been made. This suggests that small leakage from these flanges had been a long term problem. The possibility therefore exists that the failed screw had been re-tightened or re-used more frequently than the intact screw. The appearance of the fracture surfaces on the failed socket-head screw indicated that the failure mechanism was one of fatigue.

Expert metallurgical examination of the failed flange screw concluded that it failed as a result of a slow progression of a fatigue crack over many loading cycles. Evidence from spring washer markings on the bolt head suggests that it had been tightly secured in its early history, unlike its counterpart which might possibly never have been tightened properly. In terms of microstructure and hardness both screws were identical. The leakage of fuel was probably a result of the combined effects of one loose screw and final breakage of the other due to possible robust use and progressive fatigue cracking.

5.2 The fatigue loading was probably induced by high frequency cyclic loadings induced by pressure transients within the low pressure fuel rail. Typical of many similar systems fitted to ships the dynamic nature of the fuel flow in parts of the low pressure side of the engine fuel system adjacent to the high pressure fuel pumps is characterised by high frequency peak pressure pulses of short duration. These pressure pulses cannot be measured on a conventional Bourdon Tube pressure gauge that is normally fitted to such systems. This type of gauge is not designed to register frequency response due to mechanical inertia. Because of the usual remote position of pressure gauges from the site of pulse generation, viscous friction dampens the pressure transient so that a steady reading on the gauge is ensured. The magnitude of these pressures is difficult to predict due to dependence on many factors such as engine speed, load, fuel line geometry, fuel properties etc. The pressures can only be measured using equipment having a high frequency response; equipment not normally fitted to such fuel systems in service. However, it is quite possible for these induced peak pressures to be many times the nominal working pressure on which test and design pressures are based.

Wartsila Diesel Company report that transient pressure measurements were carried out on the Vasa 32, the type of main engine installed in SALLY STAR, in 1977-78 before the engine was released for production. These pressure measurements have been repeated in response to development changes since this time. The transient pressure measured in connection pipes of the type used in the SALLY STAR's engines was approximately 45bar. Rarely are these peak pressures considered when testing low pressure fuel systems for statutory or classification purposes. Test requirements are based on normal working pressure which, in this case, is assumed to be 5bar to 6bar. The type Vasa 32 engine has been in service for more than 15 years and today there are more than 1500 engines in service. During this period continuous product development has taken place; one such modification during this process has been the introduction of 4 bolt flanges on the fuel pipes. Like most manufacturers of marine engines, Wartsila do not, as a matter of routine, advise shipowners of the need to ensure that the low pressure fuel supply pipes can withstand the expected peak pressures in service.

Failure of low pressure pipes and connections are a common cause of fuel leakage which, on many occasions, has resulted in engine-room fires and loss of life. In response to the high incidence of low pressure fuel system failure on marine engines Marine Safety Agency (MSA) Merchant Shipping Notice No M.1456 warns of the dangers and advises measures to be taken to reduce the risk of leakage and fire outbreak in engine rooms. There is no official MSA advice to shipowners and officers highlighting the high fluctuating peak pressures generated during operation which are well in excess of the working pressure of the system. Greater consideration needs to be given to the measurement of pressure transients and the specification of low pressure fuel systems. Consideration should be given to establishing the peak pressures within the low pressure fuel systems of a variety of engines to establish whether there is a need to introduce enhanced requirements for these fuel systems.

5.3 The fuel oil viscosity within this system is automatically controlled, maintaining an associated temperature of about 50°C above flash point. Any loss of integrity of the system would produce a corresponding release of flammable vapour. Once released, this vapour would have had an unpredictable route towards a hot surface or other point of ignition. Surfaces of sufficiently high temperature to cause ignition would have been present in the vicinity of the engine's top; the most notable being the exhaust pipes within the engine's 'Vee', with an exhaust gas temperature of 500°C. Some of these pipes had imperfect lagging, and they must be considered as the most likely cause of ignition of the fuel vapour.

5.4 The period which elapsed between the commencement of the fuel leakage and ignition of the vapour is unlikely to have been greater than the 5 to 10 minute interval between the engine inspection by the motorman and the Second Engineer and the automatic activation of the fire alarm. This conclusion is based on the assumption that any spillage of fuel oil from the hot box onto the external surfaces of the engine crankcase would have been noticed during this inspection. It is recognised that leakage may have occurred for a greater period than this and been contained within the hot box and its drain system. However, this scenario would not necessarily have given any external symptoms, such as spillage down the side of the crankcase, nor would it have contributed significantly to the quantity of liquid fuel available to feed the subsequent fire.

5.5 The prompt shutting down of the main engines within about 2 minutes after the fire alarm was activated, probably assisted in restricting the quantity of fuel oil available to the fire. Based on the extreme delay of 10 minutes, mentioned in the previous paragraph, the total period during which oil discharged into the main engine-room would have been in the order of 12 minutes. Given that the capacity of each booster pump is $3.6m^3/h$, at 6bar, then the maximum likely fuel oil release would have been 720 litres, less the amount of fuel consumed by No 4 main engine during the period and the amount which would be in recirculation around the fuel system. The amount of vapour associated with this quantity of escaped fuel is unknown. However, even a tiny proportion of the liquid fuel would, as a vapour, have a comparatively large volume and the ability to travel rapidly, in forced draught air streams, to most parts of the main engine-room and associated upper casing.

5.6 When the main engines were stopped, and the quick closing valves actuated, there still existed a possible route by which fuel oil may have continued to enter the area of the fire from the leaking flange. The auxiliary engine's booster pump remained running until power failed. The pressure in this fuel system may have caused fuel to pass between the main and auxiliary engine fuel systems via the cross connection valve V79. The presence of a head in the heavy fuel daily service tank, sufficient to supply this system, is indicated by the continued operation of the auxiliary engines after the booster pumps were stopped. An instruction label adjacent to the quick closing remote control for valve V79 on G deck, indicates that this valve is 'Normally to be open and to be Shut in an Emergency'. The closing of valve V79 would prevent fuel passing to the main engines via a return oil receiver. This valve was given a quick closing facility to prevent the possibility of fuel back flow suggested here. Valve V79 was not closed in this incident, and it is suggested that the shipboard instructions for the closing of the valve V79 in an emergency should be amplified.

5.7 During normal main engine operation, possible indication of a leak from the low pressure fuel system would be a low fuel pressure alarm. An alarm condition was not reported in this case. Nos 1 and 4 main engines share the same low pressure fuel supply system in which the pipe connection failed. No 1 main engine was out of service so that the normal running pressure within the system was slightly higher (6.8bar) than that pressure with both main engines running (5.2bar). Any reduction in pressure due to fuel leakage from the system would need to have been greater with one engine running than with two, in order to initiate the alarm. It is probable therefore that due to the absence of an alarm, fuel leakage from the pipe connection was more in a form of a jet or spray rather than full or near full bore leakage.

5.8 A standard operational procedure had been developed by the ship's staff to monitor, and rectify, any oil leakages within the hot box spaces of the main engines. At every port departure, from either Ramsgate or Dunkirk, an inspection of the hot boxes was performed shortly after the main engines were started. This inspection required hot box covers to be removed and, after completion of the inspection, refitted and secured. Any leakages found on the low pressure fuel system were frequently rectified without the respective engine being stopped; the problem was often cured by re-tightening the joint screw using an Allan key. However, leakages from the high pressure fuel systems were not normally cured until the relevant engine had been stopped.

Each complete inspection of this type required a total of 16 hot box covers to be removed and then replaced. This was a considerable task. Each cover is designed to be secured with four thumbscrews. However, some of these screws were missing from some covers and the screw threads on some of those remaining were badly worn. The effectiveness and reliability of these covers as screens must therefore be considered to have been affected. The vessel's managers should restore the cover securing arrangements and, should the same inspection procedures be maintained, investigate the possibility of performing modifications which will enable these covers to be quickly and reliably removed and refitted.

PART III FURTHER COMMENT AND DISCUSSION

6. EFFECTIVENESS OF FIRE FIGHTING AND CONTAINMENT SYSTEMS

6.1 Fire Detection and Alarms

The vessel's automatic fire detection and alarm system effectively and correctly brought the presence of fire in the main engine-room to the attention of the bridge and watchkeeper. SALLY STAR is fitted with sensors suitably positioned so as to detect the presence of smoke or flame generation within a matter of seconds. As in this case, in any machinery space, smoke and flame generation is generally caused by oil leaking onto a hot surface. Automatic fire detection systems are an "after event installation". Thus, once an alarm is indicated, the potential for a flash-over and explosion is high, endangering all who may be present in the space affected.

Alarm systems are presently under development which, as well as detecting smoke and flame, activate on the release of explosive hydrocarbon vapour. These detectors are able to provide an early warning so that the potential for pre-empting a fire and explosion and reducing the risk to personnel is more likely. The unknown factor in the employment of such a system is the time delay between the generation of a flammable vapour and its ignition; this delay period would be that during which a watchkeeper would be investigating the alarm and in some cases may well ensure his presence in the danger area at the instant of vapour ignition. However, serious consideration should be given to investigating the feasibility and desirability of developing systems of this type for use in machinery spaces where there is a risk of a hydrocarbon fire.

6.2 Muster of Passengers and Crew

Those of the crew who were not required in the emergency operation together with all the passengers, 104 persons in total, were successfully assembled at the designated muster stations on C deck. Personnel nominated to assist passengers during an emergency ensured that all cabins and spaces were empty.

When SALLY STAR sailed from Dunkirk, a safety announcement was made over the public address (PA) system, explaining the emergency instructions to passengers and the locations around the ship where these instructions were displayed. The instructions included the kind of signal expected when the general alarm was sounded, which was seven or more short sounds followed by one continuous sound of the alarm. On hearing the signal, passengers were expected to proceed to a muster station where a life-jacket would be issued.

However, alerting of crew and the few passengers on board during this incident was not quite so effective or comprehensive due to the intermittent sounding of the general alarm. The mandatory signal, as described to passengers, was not sounded. The general alarm was functional, but because continuous sounding of the alarm required constant finger pressure to its operating button, this took up valuable time of a crew member who could otherwise have been better occupied. The alarm which sounded during this emergency could not be related to that described in the emergency announcement and passengers may have been tempted to ignore the signal once the sound ceased. In this type of situation, had a full complement of 1754 passengers been on board, confusion and possibly panic may have resulted. There is no requirement for the general alarm to be capable of continuous and unattended operation, although, many vessels are installed with this practical capability. Sound signals made in passenger accommodation should relate directly to those described in the passenger safety announcement.

During muster operations, difficulties were experienced in distinguishing between passengers and crew, mainly because of lack of crew identifying features such as uniforms. The factor was not particularly significant during this incident, but is one to which the owners should give consideration so as to ensure that crew can be clearly identified in future.

The Master, at this time, was concerned that, due to the apparent failure of the PA system, passengers were not fully informed of the situation. From a passenger's perspective this concern was largely ill-founded because the crew passed on information which they received on their UHF radios. The passengers were therefore confident that they knew what was happening and this feeling was enhanced because they could see the Master on the bridge from the muster stations on C deck.

Subsequent investigation established that the call-tone of the PA system, which indicates that an announcement is about to be made, did not operate when the system was on emergency power supply. The Master interpreted the loss of the call-tone as indicating the PA system itself to be faulty and thus abandoned its use.

An indication that power was on the PA system would have informed the Master that it was working, irrespective of whether the electrical power was from main or emergency supply systems.

On those occasions when the public address system was employed, the need to broadcast to both the English and French speaking crew and passengers was executed quite simply by making bi-lingual announcements. The vessel's emergency plan required the Chief Purser, a French National, to be part of the bridge team and available to make all the necessary French language announcements on behalf of the Master. At no time during this incident did the dual language staffing of the vessel cause any difficulty or confusion.

6.3 **Communications**

The main route for routine communications on board the vessel was through personal UHF radios. These radios were of great value during this incident. Indeed their efficacy is recognised by the Kent Fire Brigade who, during this incident and on previous exercises with the vessel, requested that some of these radios be made available to their staff when on board. However, even when using the vessel's own UHF sets, communication between some machinery spaces and the bridge was sometimes unreliable. To overcome the problem, several important conversations between the MCR and the bridge were made by telephone. The use of the telephone ensured that reliable communications were maintained between the two control centres, but the other staff, such as those in the fire fighting teams, were prevented from following fully the developments in the emergency operations because they were using UHF communications.

6.4 **Loss of Electrical Power**

With the emergency stopping of the fuel oil supply and booster pumps, and the closing down of the main engine fuel tank quick closing valves complete, the fuel supply to the auxiliary generator diesels was totally and effectively dependent on gravity feed from the heavy fuel day tank. However, shortly after the outbreak of the fire, the fuse boxes serving the cooling water pumps for the auxiliary generators, situated within the main engine-room, were affected by the heat of the fire, and the power supply to these pumps was cut off. Consequently, the generators stopped automatically because of high cooling water temperature in the diesel engines.

SALLY STAR was built in accordance with the SOLAS 1974 Convention. Chapter II-1 Regulation 23 of the Convention, states that installations in passengers ships shall be such that:

> "services essential for safety will be maintained under various emergency conditions."

Regulation 24 in the same Chapter states that:

> "in a passenger ship where there is only one main generating station, the main switchboard shall be located in the same main fire zone. Where there is more than one main generating station, it is permissible to have only one main switchboard."

The main engine-room and the auxiliary generator room are separated by a watertight bulkhead although both spaces are within the same fire zone. However, the fire was contained in the main engine-room and the installation in the adjoining auxiliary generator room remained undamaged. It is probable that main electrical power supply would not have been lost had the installation of the auxiliary electrical power units been self contained, totally within the auxiliary generator space away from the effect of the fire. The installation in the main engine-room of electrical power feeder cables serving essential services for the auxiliary generators proved, on this occasion, to be ill conceived. However the Convention requirement for the main electrical installation appears to have been satisfied.

Amendments incorporated into the SOLAS 1974 Convention and which apply to passenger ships which are newer than SALLY STAR provide more extensive regulation of electrical installations. In particular Chapter II-1 Regulation 41 states that for main source of electrical power:

> "the main switchboard shall be so placed relative to one main generating station that, as far as is practicable, the integrity of the normal electrical supply may be affected only by a fire or other casualty in one space. An environmental enclosure for the main switchboard, such as may be provided by a MCR situated within the main boundaries of the space, is not to be considered as separating the switchboards from the generators."

The Regulation is open to interpretation, and the important safety consideration that a fire in one compartment will not affect the main power supply from another, as was the case with SALLY STAR, may be overlooked. Ideally designs should be such to ensure that mains power is guaranteed during an emergency.

Once the auxiliary generators had stopped the emergency diesel generator started correctly. It ran continuously until the vessel arrived at its repair berth in Dunkirk some 36 hours later. Unfortunately, shortly after it started, its electrical power output was interrupted by the opening of the circuit breaker on the emergency switchboard. The ship's staff attempted to restore emergency electrical power and, in particular, electrical power to the emergency fire pump. Their attempts were only successful once a main circuit breaker control relay had been removed. Power to the emergency fire pump was finally restored. After some 30 minutes of operation in this mode, power supplies to other systems were gradually restored.

Some difficulty was experienced in establishing the cause of the emergency power failure. An instrument transformer serving the tripping relay circuit breaker on the emergency switchboard was proved to have had an intermittent open circuit.

The emergency generator was routinely tested by the ship's staff, the most recent occasion being on 22 August shortly before this incident. However, the vessel's records did not show the nature of the test or the load that was placed on the generator as part of the test. The vessel's managers should introduce a formal testing procedure which includes periodic full load tests; these tests and loads should be recorded.

Failure of emergency electrical power during an emergency on board is not uncommon. Investigation into previous accidents has raised concern over the reliability of emergency power supplies. Because of this, Department of Transport's Marine Safety Agency recently issued Merchant Shipping Notice No 1626 "Testing of Emergency Sources of Electrical Power" which advises the need for a regular and formal testing procedure of emergency generators under load.

6.5 Role of Ship's Fire Fighting Teams

The decision taken by the Second Engineer Officer to use an ad-hoc fire party rather than wait for the official Fire Party No 1, gave some advantage in assessing and tackling the fire at the earliest possible opportunity. This course of action resulted in the equipment from Fire Station No 4, which Fire Party No 1 had expected to use, not being immediately available for them. However there was no significant confusion, since Fire Party No 1, on realising that equipment was missing from the locker, proceeded to the MCR where their services were required.

Fire fighting by the BA parties was a partial success. Entry into the machinery space was prompt, within a few minutes of the fire alarm sounding, and although they had to retreat for the reasons discussed in the next paragraph, the ad-hoc fire party managed to extinguish three separate fires on their second entry into the space. The third entry, executed by members of Fire Party No 1, was wasted because of the failure of the emergency fire pump and loss of fire water. This failure prolonged the emergency thus further endangering the lives of personnel, extending the material damage to the ship, and demanding further the resources of the emergency services.

During their initial entry into the main engine-room the first BA team was unable to perform any effective fire fighting function. This was due to the need for the second man of the team to remain at the controls of the watertight door to prevent the door closing automatically, and consequently cutting the fire hose and isolating the first man of the team. At this stage of the incident, no other crew were available in the MCR to perform the watertight door control function. It is unfortunate that the need for a third man in the team was not anticipated; had it been so, then effective fire extinguishing operations could have started sooner than they did.

During the second entry of this team into the main engine-room useful fire fighting efforts were made until their air supply was exhausted.

Once the first BA team had retreated from the main engine-room another team from Fire Party No 1, consisting of the Junior Engineer Officer and a motorman, entered with a fire hose. These two men had been briefed by the returning BA team. However, the leader of Fire Party No 1, stationed in the MCR, was unaware of the entry of the second BA team into the main engine-room. His understanding was that both BA parties were being employed in boundary cooling operations. Because there is no line of sight between the

MCR and the watertight door leading to the main engine-room, the Fire Party Leader had to rely entirely on verbal communication between himself and BA party members in order to be aware of and to control their actions. Although the Fire Party Leader was in contact with the Fire Chief on the bridge, communication with his fire fighters was unreliable.

This breakdown of communication indicates the need for further training aimed at the efficient deployment of BA teams. All ship's staff involved in tackling the fire on SALLY STAR attended approved Merchant Navy fire fighting courses. However, these mandatory courses do not cover the optimum procedures suitable for ships of all types and sizes because of differences in manning and the quantity of equipment available. On-board exercises undertaken by the ship's staff should include procedures which will enhance the efficacy and control of BA teams.

Once halon had been injected into the main engine-room regular checks were performed by ship's staff, and latterly Kent Fire Brigade personnel, for signs of heat transfer into spaces adjacent to the uptake casing. Some signs of heating were observed behind linings in corridors and sanitary spaces within the accommodation areas, but none was of any significance. The smells generated by these heated surfaces probably produced symptoms which were perceived to be more serious than was the case. However, the prudence of performing these precautionary inspections was correct.

6.6 Use of the Halon System

Some unexpected difficulties were experienced by the Boat Groups in closing the main engine-room ventilation dampers on B deck. These problems were caused by smoke issuing from the dampers, and by the damper flaps being too hot to touch with the unprotected hand. The presence of intense heat and smoke at B deck within minutes of fire breaking out is indicative of the rapid speed with which the fire spread through the affected areas. The difficulties encountered by the Boat Groups were quickly overcome by donning smoke hoods stored on the bridge, and by wearing gloves.

Failure of the auxiliary generators was followed almost immediately by the loss of the emergency fire pump. The Master therefore had no choice but to employ the halon gas system to extinguish the fire. Fire flaps and fuel quick closing valves were closed within minutes of the onset of the emergency. Once the decision was taken to use the halon system, little time was lost in ensuring that the main engine-room was clear of personnel and the halon system activated. The halon gas was released 33 minutes after the fire alarm was activated, during which time attempts were made to tackle the fire locally. This is a substantial period during which the fire may have had the opportunity to become well established. Halon extinguishing systems are best used as rapidly as possible before the fire has time to take hold. To achieve the optimum performance, fire fighting control systems need to be designed accordingly.

It is probable that the fire was not extinguished as a direct result of the discharge of the halon gas into the main engine-room. Witnesses report that smoke was issuing from the funnel vents, and the presence of smoke and heat damage within the funnel casing indicates that the ventilation covers and halon flaps were ineffective in containing the halon gas once injected. The halon flaps were found to be distorted due to heat, which seriously affected their gas retaining ability. Any substantial gas leakage past these flaps would have diluted the halon concentration within the main engine-room, so reducing its effectiveness. The dimensions of these flaps are substantial, each of the larger pair being 2m x 1m and the smaller ones 1.6m x 1m. None was equipped with any stiffening arrangements other than that provided by a small lip around its perimeter. This lack of stiffness to resist heat distortion is considered to have been the primary cause of the flaps allowing gas to pass into the funnel space. The guaranteed gas tightness of the machinery spaces when maximum percentages of fire extinguishing gas are utilised is of utmost importance.

Testing the efficiency of fire dampers and other closure mechanisms is extremely difficult to achieve without major disruptive procedures. The measurement of gas tightness of the machinery space can be measured by computing the air pressure loss against a fixed and precision measured fan. The air loss from the space can be equated against a percentage of gas tightness of the space. The vessel's owners need to assure themselves that the gas tightness of the machinery spaces is satisfactory.

Halon gas in the machinery space may have been further diluted for a number of reasons. While the first BA team was still tackling the fire with a hose, they heard a rush of gas into the space. It is a matter of speculation whether or not it was a halon bottle releasing gas prematurely. However, as a consequence of the heat build up in the space, it is possible that one of the port side halon bottles, outboard of No 4 main engine, may have discharged prematurely, due to a heat induced pressure increase. During replenishment of the halon gas system after this incident, it was established that the bursting disc on the aft port halon bottle had ruptured. The bursting disc is designed to rupture at a specified gas pressure induced by a heat build up in the surrounding space.

It is also possible that the fire-fighters heard a leakage of compressed air. The failure of compressed air lines in the main engine-room would have discharged the air bottle contents into the main engine-room thus reducing the halon gas concentration. The main compressed air bottles are situated in the compressor room, and it is probable that because of this configuration the diluting effect on halon concentration by the contents of the air bottles was not considered when the required halon volume was calculated.

The 1974 SOLAS Convention makes provision for extra halon capacity to compensate for the possible release of air from air receivers contained within a space. However, there is no direct provision to compensate for leakage of air from air receivers which are contained within a space which is other than the protected space.

When the effect of discharge of the contents of the compressed air system on SALLY STAR was considered, the free air volume of these air receivers was recorded as $101m^3$. If this volume of free air was released into the main-engine room, together with the discharge of all six halon bottles, a halon concentration of 4.98% would be achieved. Although this concentration is in excess of Convention requirements (4.25%), it would be prudent for the halon system's operating instructions to be modified in order to indicate that air bottles should be isolated before the halon system is activated. If the premature discharge of one halon bottle plus the discharge of both air receivers occurred, then the potential halon concentration would be 4.15%. This is below the required value.

The activation of the smoke detector head on the port side of G deck, almost immediately after the main engine-room fire alarm operated, indicated that some smoke or hot gases had escaped from the main engine-room during the very early stages of the fire. The most probable route of such an escape was through the access hatch to the main engine-room on the port side on the central casing at G deck level. This suggestion is supported by the indications of smoke scars past this hatch. The access hatch was another possible leakage route for the halon gas.

The total halon dilution, which may have been caused by the sum of the effects mentioned above, or a combination of the same, is considered to have diminished the fire extinguishing capability of the system. The fire is thus most likely to have been extinguished by being starved of oxygen and fuel.

When the halon was released, there was no corresponding activation of the associated alarm. The alarm should have functioned automatically. In view of the damage on the auxiliary generator and steering system electrical cables, which occurred before the gas was injected, there can be little doubt that the failure of this alarm system was due also to fire damage.

6.7 Fire Protection

The fixed fire divisions' boundaries surrounding the main engine-room, the central casing in the vehicle space, and the machinery uptake casing leading up to the funnel space were generally effective in containing the fire to within that space. The indication of smoke scars on paint work around the central casing port engine-room hatch implied some flame and smoke passage. The vehicle space is a hazardous area designed to contain vehicles carrying petrol and diesel fuels as well as hazardous loads. Apart from the need to contain the halon extinguishing gas within the engine-room, any leakage of smoke or flame into the vehicle space, whatever the intensity, must be considered unacceptable. The vessel's owners should consider improving the securing and sealing arrangements of this hatch.

A few items of flammable material which were stowed in the funnel space and which caught fire, were extinguished in the latter stages of the incident. There was no great risk that these items would cause the fire to spread or intensify, but the potential dangers of using spaces for storage which are not designated as storage spaces is obvious.

The space in the funnel casing, into which exhaust air from the engine-room is discharged before passing to atmosphere, has two lockers set into its sides, one port, one starboard. Each of these lockers, which has access only from the outer deck, held a cylinder containing either compressed oxygen or acetylene. Despite the heat in the funnel space there was no evidence of internal damage to these gas cylinder storage lockers.

Heat damage to fire protection insulation was limited. The crew were concerned that the vehicle space was overheating as three vehicles, stowed on the port side of this deck adjacent to the centre island, were observed to have had heat damage. However, this damage was limited to suspected overheating of the rubber tyres on their road wheels. One measure of the effectiveness of the insulation on this deck was that heat transfer through the deck from the engine-room was limited, even though no fire fighting water was available to perform boundary cooling for a substantial period during the incident. The paint on the central casing, with the exception of smoke scars around the main engine-room access hatch, remained largely unmarked.

Various levels of smoke in the main vehicle spaces were recorded at several stages later in the incident, only some of which can be considered as having come via the main engine-room access hatch mentioned above. A significant quantity of smoke was produced by the petrol engine powered portable fire pumps brought on board by the Kent Fire Brigade. None of the smoke caused any great difficulty or concern at any stage, but it is notable that once the emergency fire pump had been returned to service, and a supply of water made available by connecting to the drencher system, the employment of just three sections of drencher sprays brought about a noticeable reduction in smoke concentration.

During the emergency there were several reports of significant quantities of smoke in the accommodation. The smoke was probably of very low density, albeit rather irritating to the eyes, and played no significant role in hindering the search or evacuation of people from the accommodation. The source of the smoke is considered to have been smouldering dust and debris that had been in contact with the outer surfaces of the upper central casing. The structure of this casing in areas of passenger toilets is built to fire division A0 standard, an uninsulated steel structure, because combustible material would not normally be found in these areas. It was those areas particularly which were identified as generating such smoke. Although the quantity of this smoke was not significant, the need to ensure that fire divisions are kept clean and free of inflammable materials was demonstrated.

6.8 Emergency Lighting

When the auxiliary generators failed, only the emergency lights were available. However, because this incident commenced at dawn, daylight made it possible to see quite clearly within SALLY STAR's accommodation areas where there were windows. At this stage of the incident all passengers, and most of the crew not required for fire fighting duties, were mustered on C deck. The loss of main lighting was thus not of significance to the evacuation of the accommodation. However, during tours of the accommodation spaces undertaken by crew and Kent Fire Brigade staff to locate hot areas, regions of very poor visibility were reported, due largely to defective bulbs within the light fittings. It was noted that the fittings which contained the emergency lights could not clearly or easily be identified or separated from the non-emergency light fittings. It is speculated that not being able to easily identify the emergency lights contributed to their incomplete maintenance. The owners should introduce a clear marking and maintenance system for the emergency lights.

The supplementary emergency lighting did, as far as can be established, function correctly.

6.9 Role of Kent Fire Brigade

On receiving a request to assist at an offshore incident, Kent Fire Brigade appliances from designated stations, and a senior officer, proceeded independently to RAF Manston. On arrival at Manston, equipment stored at the Offshore Operations Unit was prepared by Kent Fire Brigade crews for transfer to a helicopter. This equipment included life-jackets, immersion suits etc. Standard operational procedures of Kent Fire Brigade prevented the deployment of the First Strike Team, and their equipment, to an offshore incident until the senior officer, who is an officer of Divisional Officer rank, or above, was in attendance. Because an officer of this rank is not normally part of a designated station's complement, he needed to travel to Manston independently and arrived there shortly after the appliances.

Waiting for this officer caused no delay, and the team were fully assembled, complete with senior officer, and ready for the helicopter transport at 0503 hrs. However, their readiness at Manston was not reported to Dover Coastguard, nor to the Kent Fire Brigade liaison officer on his arrival at Dover Coastguard station shortly afterwards. The fact that they did not report their arrival and readiness to Dover Coastguard did not result in any delays. R125 could not have arrived from RAF Wattisham any sooner than it did and there were no other helicopters which could have been diverted to Manston to pick up this first team. However, had the situation on SALLY STAR seriously deteriorated and had Dover Coastguard the option to divert another helicopter to Manston which could have arrived before R125, the Coastguard would need to have been made aware immediately that the first team were ready and waiting at Manston. In future, in order that the Coastguard have the maximum possible flexibility to deal with unexpected developments during an incident, Kent Fire Brigade should be requested to report the readiness of their teams to the Coastguard, even though the anticipated transport may not yet be available.

At the time helicopter R125 left Manston with the first Kent Fire Brigade team, the auxiliary generators of SALLY STAR had failed and the emergency fire pump was not working effectively. In accordance with standard practice, a portable fire pump was not included in the equipment carried with the First Strike Team. Because of weight restrictions on the helicopter, carriage of a fire pump with the First Strike Team meant that other equipment or personnel would have to be left behind when a transfer by air was undertaken. Earlier despatch of a portable fire pump may have been an advantage in this case. Kent Fire Brigade should consider the possibility of including a pump as part of the First Strike Team's standard equipment.

The Kent Fire Brigade shipboard team made a number of requests for additional equipment to their Fire Brigade Headquarters in Maidstone. Various methods and routes of communication were used; directly, using a cellnet telephone, and indirectly, by VHF radio via the Liaison Fire Brigade Officer stationed at Dover Coastguard. This Officer passed on shipboard requests to Fire Brigade Headquarters by telephone. At the same time he ensured that Dover Coastguard were updated on any messages that were passed through him, either from the shipboard team or from Brigade Headquarters. Whichever communication route was taken, the role of the Liaison Officer was crucial. HM Coastguard have a coordinating role in an emergency and thus it is important that any information which may help them fulfil this role is timely and relevant.

A second Kent Fire Brigade Liaison Officer was stationed at RAF Manston. Part of his role was to maintain a record of the total number of Kent Fire Brigade personnel despatched to SALLY STAR by air. A third Liaison Officer, designated as the Port Embarkation Liaison Officer, performed a similar role at Ramsgate for the Kent Fire Brigade personnel making a seaborne approach to SALLY STAR. However, some difficulties were experienced in maintaining and making available to Dover Coastguard an accurate total of Kent Fire Brigade staff on SALLY STAR. For this reason the communication system should be reviewed so as to enhance the already crucial role of the Fire Brigade Liaison Officer based at Dover Coastguard should a similar emergency occur in future.

Communication problems were experienced amongst Kent Fire Brigade personnel on board SALLY STAR, mainly because of a shortage of effective radio equipment. Although they used the vessel's own UHF sets as well as their own VHF sets, all of which functioned reasonably well in some areas of the vessel, some communications were necessarily performed by messengers. As a result, at times there was a delay in communication. However, although communicating through messages may well have been frustrating, it did not cause any serious difficulties during this incident.

Since the fire on SALLY STAR, a Memorandum of Understanding has been agreed between the Coastguard and the Chief and Assistant Chief Fire Officers Association. This Memorandum is largely based on the practices of those fire brigades, including Kent Fire Brigade, who have had the most experience of offshore operations with the Coastguard. These fire brigades and others are maintained by Fire Authorities having powers under The Fire Services Act, 1947 Chapter 41, Section 3(d). Signing and implementation of the Memorandum of Understanding has had no significant effect on Kent Fire Brigade's offshore operational practices. It effectively sets out the practices of the brigade in a formal manner. It is observed that they had not, at the time of this incident, formally declared any resources available for offshore operations. However, the regularity of the joint Coastguard/Kent Fire Brigade exercises, together with the demonstrable commitment of Kent Fire Authority, ensured that Dover Coastguard were well versed in the likely response of Kent Fire Brigade to a request for assistance offshore.

At the time of the fire on board SALLY STAR a British fire brigade was under no obligation to attend any ship at sea. The Memorandum of Understanding does not change this position. A ship's crew necessarily has to perform the role of fire brigade using the fire fighting equipment on board and supported by their own training, resources and initiative. This situation has remained unchanged since fire first occurred at sea. Any assistance received from shore based agencies must be seen as a bonus, the availability of which is dependent on the lottery of the ship's geographical position at the time of the incident. It is recognised that the fire on SALLY STAR occurred while the vessel was within range of assistance available from air and surface craft; assistance which proved to be prompt. Other vessels and their crews may not be so fortunate. It is thus essential that ships are equipped, and crews are trained sufficiently to handle safely such incidents without the benefit of prompt assistance from shore.

6.10 **Watchkeeping Practices**

During the passage of the vessel from Dunkirk, and across the two lanes of the Channel Navigation System, both of the engine-room watchkeepers were away from the MCR for a period of 1 hour 15 mins performing repair work to No 1 main engine. The MCR was thus unattended during this period. Paragraph 7 of Part 1 of Annex to Resolution 2 of the International Convention of Training, Certification and Watchkeeping, 1978, recommends that:

> "The Engineer Officer in charge of the watch should keep the main propulsion plant and auxiliary systems under constant supervision until properly relieved."

Moreover, Paragraph 22 in the Convention also recommends that:

> "The Engineer Officer in charge of the watch should ensure that all machinery involved with the manoeuvring of the ship can immediately be placed in manual modes of operation when notified that the ship is in congested waters."

The performance of duties, not directly associated with watchkeeping, in a space separated from the MCR by a watertight bulkhead in which the watertight door is quite properly maintained closed, may be viewed as not complying with the first of the two recommendations; particularly when the vessel's area of operation is considered.

Watchkeepers routinely man the MCR during 'Standby' periods when entering and leaving port, despite remote main engine control from the bridge. Manning of the MCR is considered necessary under these navigational circumstances so that immediate change-over to local manual mode is available should the need arise. This reflects the advice of the second recommendation. However, the area of the English Channel in which the SALLY STAR operates can reasonably be described as congested and thus it can be argued that constant manning of the MCR during the Channel crossing is necessary to ensure that rapid change-over to manual main engine control is always available.

Regulation 54, Chapter II-1 of the 1974 SOLAS Convention (as amended) requires that passenger ships shall be specially considered by the Administration concerned as to whether or not their machinery spaces may be periodically unattended. In this regard the Flag Administration issued a Safe Manning Certificate indicating that the SALLY STAR could operate in the unmanned machinery space mode whilst operating on the England to France routes. However, despite this provision, the vessel's managers had appointed an Engineer Officer as the designated Watchkeeping Engineer implying that his primary duties must be considered as those of a watchkeeper and thus his presence in the MCR, as far as is practicable, be constant.

Further assessment of the potential problems which may have been generated by having the Watchkeeping Engineer absent from the MCR for long periods is of value, if consideration is given to the possible sequence of events had the fire been ignited 30 minutes earlier, while all three men were in the main engine-room. There can be no certainty that any of these three men would have noticed the instant of ignition on the other side of the engine-room from where they were working. Heavy involvement with their tasks is likely to have prevented them from being alerted until the fire alarm operated. The sequence of events suggests that the time from the alarm to the flash flame was very short. There would probably have been insufficient time for these men to get out of the main engine-room, either by watertight door or central escape trunking. With all three men trapped, and possibly disabled in the main engine-room, the bridge watchkeeper would have been unable to obtain any information from the MCR. Also, any Emergency Group that made its way to the MCR would have had no means of knowing anything of the situation in the main engine-room, the number of people involved, or where they were. The time expended and the confusion generated by this shortage of information would undoubtedly have had the effect of prolonging, and possibly intensifying the incident.

The practice of allowing the Watchkeeping Engineer to perform maintenance tasks which require him to be absent for long periods from the MCR or immediately adjacent spaces, is one that has implications for safety. The prudence of allowing the practice to continue, while the vessel is at sea, should be carefully re-assessed by the vessel's managers. Managers of other vessels of this type, and particularly those operating on routes which are considered as busy sea lanes, may also consider the relevance of these comments to the operation of their own vessels.

7. SEARCH AND RESCUE

7.1 Sally Line vessels undertake regular exercises with HM Coastguard, Kent Fire Brigade, the RAF and other organisations. Sally Line's seagoing staff have also attended Coastguard Seminars aimed at enhancing the working relationship between the organisations.

The most significant and recent major exercise was Exercise Goodwin 93, which took place on 5 October 1993 using SALLY SUN. An engine-room explosion and fire was assumed and 160 persons were evacuated from the vessel. Coincidentally, the Exercise Goodwin took place in virtually the same position as did the incident on SALLY STAR. Although the Master of SALLY STAR was not involved in Exercise Goodwin, he had exercised on other occasions with the relevant emergency services and had attended the Coastguard's Seminars and a Command and Control course on emergency operations. The ultimate success of the total fire fighting and Search and Rescue operations on 25 August 1994 must be seen as being, at least in part, the beneficial result of the working relationship developed between Sally Line's seagoing staff and the emergency services.

7.2 **Coastguard**

It is recommended in the International Maritime Organization's Merchant Ship Search and Rescue Manual (MERSAR), that a ship in distress should transmit the distress call and message on any one or more of the following international maritime distress frequencies: 500 kHz (radiotelegraphy), 2182 kHz (radiotelephony) and 156.8 MHz (radiotelephony) (Channel 16 VHF).

Regulation 10 of Chapter V of the 1974 SOLAS Convention, places an obligation on the Master of a ship at sea, on receiving a signal from any source indicating that a ship is in distress, to proceed to the assistance of the persons in distress, informing them if possible that he is doing so.

In the early hours of 25 August, once the Master was aware of the emergency situation on board, his initial contact with Dover Coastguard was by use of a mobile telephone. This is contrary to the recommendation in MERSAR. The Master's reason for doing this was because, when he had attended a Coastguard Seminar in 1992, he had asked which was the preferred method for initial contact in the event of an emergency. He remembers being told that owing to the close working relationship between Sally Line and the Coastguard, although it was not official policy, the Cellnet (mobile telephone) would probably be preferred. Another sector of the Coastguard described this method as "somewhat unconventional" but that it did have benefits. However the Chief Coastguard has stated that the advice given at Coastguard Seminars is that the initial contact should be in accord with the MERSAR recommendation. After that call, a direct link between the ship's bridge and the Coastguard Operations Room needs to be established and this direct link could be a reliable mobile telephone link.

In view of the above conflict of views, the whole policy on communications during the course of an emergency should be made clear to all taking part in Coastguard exercises, seminars etc. However, although the initial contact was in this instance made by a mobile telephone, it did not result in any shortcoming in the search and rescue operation on the day.

Once SALLY STAR's emergency generator began to cause difficulties, it was decided to shut off all loads on the emergency switchboard. The radar set supplied by the emergency switchboard was therefore out of use, as were the other radar sets. With his knowledge of, and his confidence in the radar system with which Dover Coastguard can automatically and reliably locate and monitor the position of his vessel, SALLY STAR's Master requested that Dover Coastguard inform him in the event of his vessel running into danger. In so doing, he was able to concentrate on more immediate problems.

7.3 Role of Helicopters

The initial task of RAF helicopter R125 was to transport the First Strike Team of Kent Fire Brigade from Manston Airfield to the SALLY STAR; a type of operation frequently practised. This task required the helicopter to travel from its base at Wattisham, Suffolk, to Manston, Kent. From 0428 hrs, the time that R125 was called by Dover Coastguard via Plymouth RCC, to its landing at Manston, a period of 53 minutes elapsed. R125 reported to Dover Coastguard that it was airborne at 0500 hrs; however, RAF sources note that this aircraft had taken off at 0454 hrs.

HM Coastguard criteria for the deployment of Search and Rescue helicopters are that a helicopter should be able to reach 100 miles offshore within two hours of call out by night, and reach 40 miles offshore within one hour of call out by day. The criteria cover direct flights from the helicopter base to the offshore objective without diversion. The RAF defined night time hours as extending from the onset of darkness to 0800 hrs the following morning. In deciding whether the criteria can be met the availability of British helicopters only is considered. Standby times, the period between call out and take off, for daytime coverage, is 15 minutes, and for night-time coverage 45 minutes. RAF helicopter R125 took 1 hour 22 minutes from the time of call out at Wattisham, to the collection of the First Strike Team at Manston and delivery of the team on board SALLY STAR. This was considered to be a night-time flight. The stand-by time from call out to take-off from Wattisham was 32 minutes, thus all of the declared nighttime performance criteria were satisfied.

Assuming a ground speed of 100 knots could have been exceeded after leaving Manston, the performance of helicopter R125 was sufficient even to satisfy the nighttime criteria of reaching 100 miles offshore within two hours of call out. This takes into account that this aircraft landed at Manston for eight minutes whilst embarking the First Strike Team of Kent Fire Brigade before proceeding offshore to the SALLY STAR.

Notwithstanding the response of R125 and its crew, there is no evidence to suggest that arrival of this aircraft at SALLY STAR, with its payload of fire fighters and their equipment, at an earlier stage of the incident would have significantly influenced the eventual outcome. Helicopters which had previously been based at Manston would probably, had they been available, have been able to embark the fire fighters at an earlier stage. However, while still satisfying the nighttime performance requirements of being airborne within 45 minutes of call out, an aircraft based at Manston may still not have been airborne with the fire team on board until 0513 hrs, only 16 minutes earlier than was achieved by R125. Considering the large sea area within which ships may meet strife, and the time scale, typically measured in several hours, which offshore incidents usually cover, a saving of 16 minutes cannot be considered to be of great significance.

Other helicopters requested or alerted for this incident were R126 and R127 from RAF Wattisham, R92 from Koksidje Belgium and 'India Juliet' from Solent Coastguard. Once the fire had been extinguished and an entry made into the main engine-room, helicopter assistance was reduced to just R126 and 'India Juliet'. By this stage of the incident, surface vessels were transporting fire fighters and their equipment to the vessel, largely removing the need for further helicopter assistance.

In order to make air operations as safe as possible there is a maximum load limit imposed on a helicopter at take off, which establishes a restriction on the number of personnel and quantity of equipment which can be carried. The standard First Strike Teams of the Kent Fire Brigade consist of nine persons plus their basic equipment such as Self-Contained Breathing Apparatus, radios, thermal image camera, torches, resuscitator etc which is not fire fighting equipment. In the majority of ship fires the most significant stage is the very early part, probably rarely extending beyond the first hour after detection. The necessary steps taken during this period to contain or extinguish the fire can be taken only by the ship's own staff using the ship's systems and equipment. Any initial assistance from shore based personnel, rapidly deployed by helicopter, will be confined to an assessment of the situation, unless they use the ship's equipment to fight the fire.

In this incident, additional fire brigade equipment and personnel required as a result of an assessment made by the First Strike Team, was transported not only by helicopter but also by surface craft which had an important role during the emergency. Tugs from the ports of Ramsgate and Dover were engaged for this purpose, and stood by SALLY STAR in case rapid evacuation of fire brigade personnel was necessary. The tugs are not retained by formal agreement for use by Kent Fire Brigade, but the co-operation of the Port Authorities ensures that tugs are made available to the brigade during any maritime incident in which they could be involved.

7.4 Evacuation of Vessel

At the time the decision was made to transfer non-essential personnel to vessels standing by, difficulties were being experienced with the emergency fire pump, the Kent Fire Brigade First Strike Team had yet to arrive, and G deck, the vehicle deck, was judged to be overheating immediately above the main engine-room. Although there were no indications to suggest that the fire was likely to spread into the accommodation, the smell and traces of smoke within the accommodation, aggravated by lack of ventilation, ensured discomfort for anyone remaining in the space rather than in the fresh air of the open deck. In this respect, non-essential personnel were mustered at the forward end of C deck, outside and adjacent to those lifeboats which had been lowered in readiness for embarkation. They were in no immediate danger. However, the Master knew that the Brigade fire crews which he had asked for were likely to be transported to his ship by helicopter and that large numbers of non-essential persons on the outer decks of the vessel, over which the helicopters would be hovering and lowering equipment and personnel, was not desirable. It was decided to disembark non-essential personnel by sea.

The evacuation route taken from the muster stations on C deck to the pilot door on G deck, and thence to an attending tug and lifeboats, was down the external stairway on the bridge front into an enclosed stairway leading on the forward end of G deck, and 25 metres across that deck to the pilot door positioned at the forward starboard corner of G deck. The route taken from the internal stairway entrance on G deck necessarily passed the one vehicle on board which contained dangerous goods.

Due to the loss of lighting, visibility on G deck was poor, and crewmen equipped with torches and standing at strategic points were needed to guide the personnel around vehicles towards the pilot door. At the time of the evacuation, the amount of smoke in the area was not large. Any significant smoke was confined to the port side where the main engine-room access hatch may have been leaking slightly.

Having commenced the transfer, all persons who were to leave the ship were supervised and controlled, so that their passage across G deck took place in small groups. A check on a crew list and a record of passenger names was also made at this stage. This level of supervision, and the limitation on numbers of persons on G deck at any time, was also intended to allow a rapid evacuation of the area in the event of any unexpected and sudden deterioration in conditions. To be able to transfer a large number of the persons on board safely into suitable vessels must have been a very tempting proposition: suitable craft were readily available, weather conditions were favourable, and any risk from helicopters flying over a large number of persons congregated on the open deck would be eliminated. However, these considerations had to be measured against the wisdom of routeing people through the vehicle deck containing hazardous chemical cargo and petrol and diesel fuel oil, with a fire below deck and the drencher and emergency fire pump inoperable.

The decision whether or not to evacuate personnel using the ship's lifeboats could not be taken lightly since the risk of mishap is always present. However, it remains debatable whether these risks are in any way comparable to those taken by evacuating personnel on a route which takes them across the main vehicle deck.

The regularity with which Sally Line staff, Kent Fire Brigade, Dover Coastguard and the RAF exercised has already been highlighted. The value of these preparations was demonstrated by the ability of the ship's staff to co-operate smoothly with shore based agencies whose assistance had been offered and accepted. Not all shipping companies operating similar vessels participate in this type of exercise.

PART IV CONCLUSIONS

8. FINDINGS

8.1 The immediate cause of the fire was ignition of fuel oil and vapour leaking from a failed flange on the low pressure fuel system of No 4 main engine, coming into contact with a hot surface which was most probably that of an exhaust pipe.

8.2 Contributing factors which influenced the severity and extent of the fire were:

1. the failure of covers serving the engine mounted components of the low pressure fuel system to contain the discharge of fuel oil from the failed flange,

2. the failure of the auxiliary generators, leading to the loss of two of the vessel's fire pumps,

3. the failure of the emergency fire pump, due to the loss of power from the Emergency Switchboard,

4. the loss of halon extinguishing gas due to leakage past main engine-room ventilation flaps and access hatch.

Other findings were:

8.3 Halon was discharged into the main engine-room 33 minutes after the alarm was raised, and after one halon bottle had discharged prematurely due to overheating.

8.4 The general alarm could not be rung continuously without attendance.

8.5 The public address system was not used fully due to the loss of the call tone falsely indicating a defect.

8.6 The quantity of halon gas specified to be injected into the main engine-room did not take account of the possible discharge of air into the space from the air receivers positioned in the compressor room. Discharge of air from this system may have diluted the halon concentration, but not necessarily below the concentration required by regulation.

8.7 Lifeboats were deployed for embarkation, however they were not used, and non-essential personnel and passengers were evacuated, using an escape route across the vehicle deck, onto other surface vessels.

8.8 An accurate figure for the number of Kent Fire Brigade personnel on board SALLY STAR was not known to HM Coastguard at all stages during the incident.

8.9 The fire protection insulation on the divisions surrounding the main engine-room proved to be effective in preventing fire spreading to other spaces.

8.10 The emergency lighting in the accommodation was not fully effective due to defective bulbs, probably as a consequence of lack of identification on emergency light fittings.

8.11 A cross-connection valve between the fuel systems for the main engines and auxiliary engines was not closed when the quick closing valves serving the main engines were closed. Instructions on the vessel indicated that this valve should have been closed in an emergency.

8.12 Communications with, and control of, the ship's BA teams fighting the fire were not sufficiently disciplined and contributed to the delay in discharging the halon gas into the main engine-room.

8.13 The joint training exercises between Sally Line staff, HM Coastguard, Kent Fire Brigade, the RAF and others, contributed to the ultimate success of this operation.

9. SUBSEQUENT ACTION TAKEN BY SALLY LINE LTD

Following the incident Sally Line initiated a number of remedial actions. These subsequent actions are listed below:

- The flanges on the low pressure fuel rails and associated pipes on the main engines have been modified from two bolt to four bolt flanges.

- The main engine hot box covers securing arrangements have been restored. Inspection procedures have been changed to a daily rather than an "at every start up" procedure.

- Emergency quick closing fuel valves operated remotely from the MCR have been fitted to the fuel rail on each main engine and auxiliary diesel generator.

- Fuel Leakage alarms have been fitted to the forward and aft ends of each hot box of each main engine.

- The power supply for the call tone of the public address system has been connected to the emergency battery system.

- Changes have been made to the electrical supply arrangements and piping systems of the auxiliary generator cooling system.

- Additional halon and air supply flaps have been incorporated in the engine-room ventilation system.

- Halon flaps in the main engine-room have been fitted with stiffeners.

- "Red Dot" markers have been placed on emergency light fittings.

- The steering gear control cables have been re-routed away from the main engine-room.

- The general alarm has been made capable of continuous unattended operation.

- A formal testing and recording procedure for the emergency generator has been put in place.

10. RECOMMENDATIONS

10.1 **The Marine Safety Agency is recommended to:**

1. Give consideration to undertaking a research programme to establish whether there is a need to introduce clearer or more stringent requirements for the low pressure fuel systems of medium speed diesel engines to assure that the fuel supply pipes can withstand expected peak pressures in service.

2. Give consideration to investigating the advisability and feasibility of incorporating vapour detectors as part of Fire Detection Systems for use in Category A machinery spaces.

10.2 **Sally Line is recommended to:**

1. Amplify the shipboard instructions for the closing of the quick closing valve V79 in an emergency.

2. Address the problem of personnel not being able to distinguish between passengers and crew in the event of an emergency.

3. Introduce further on-board exercises undertaken by the ship's staff which include procedures designed to enhance the efficacy and control of BA teams.

4. Reconsider the practice of allowing the Watchkeeping Engineer to perform maintenance tasks which require him to be absent from the MCR, or immediately adjacent spaces, for long periods.

5. Consider pressure testing the main engine-room space to assess its gas retaining ability.

10.3 **Kent Fire Brigade is recommended to:**

1. Establish a procedure for reporting the readiness of their First Strike Team at Manston to Dover Coastguard.

2. Consider the possibility of including a light portable pump as part of the First Strike Team's equipment for offshore operations.

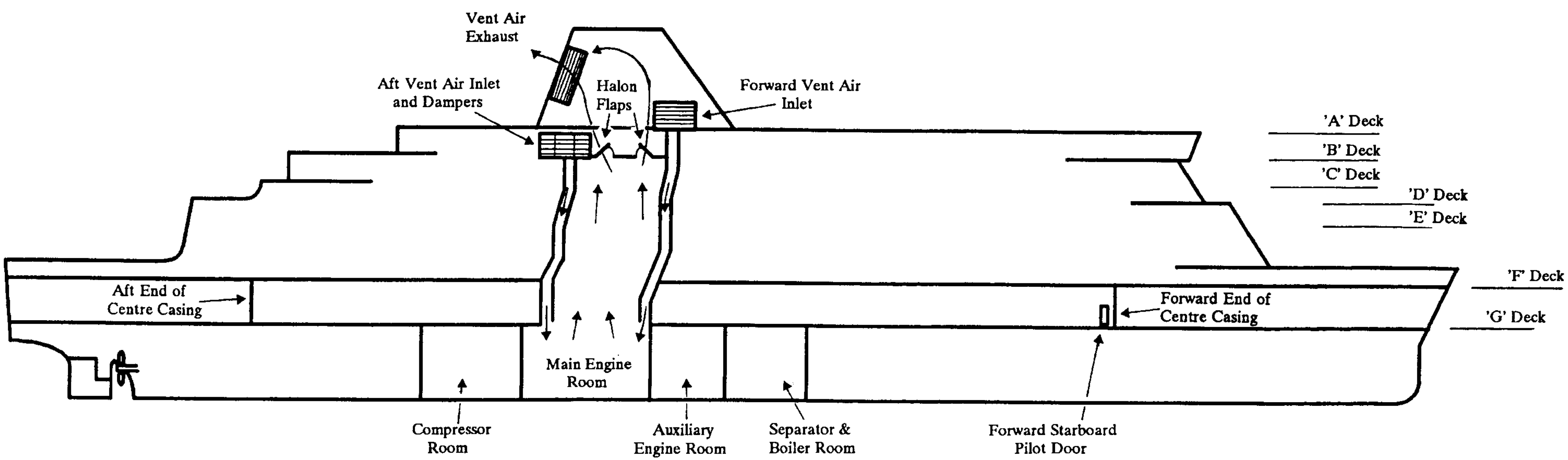
3. Address the task of maintaining a reliable running total for the number of their staff on board a vessel during an offshore incident.

10.4 **HM Coastguard is recommended to:**

1. Strengthen its ongoing efforts to involve all operators of passenger ferries operating from United Kingdom ports in regular live joint exercises with emergency services.

10.5 **The Kent Fire Brigade and HM Coastguard are recommended to:**

1. Consider, jointly, enhancing the communication systems available to the Kent Fire Brigade Liaison Officer at the Marine Rescue and Coordination Centre, Dover.



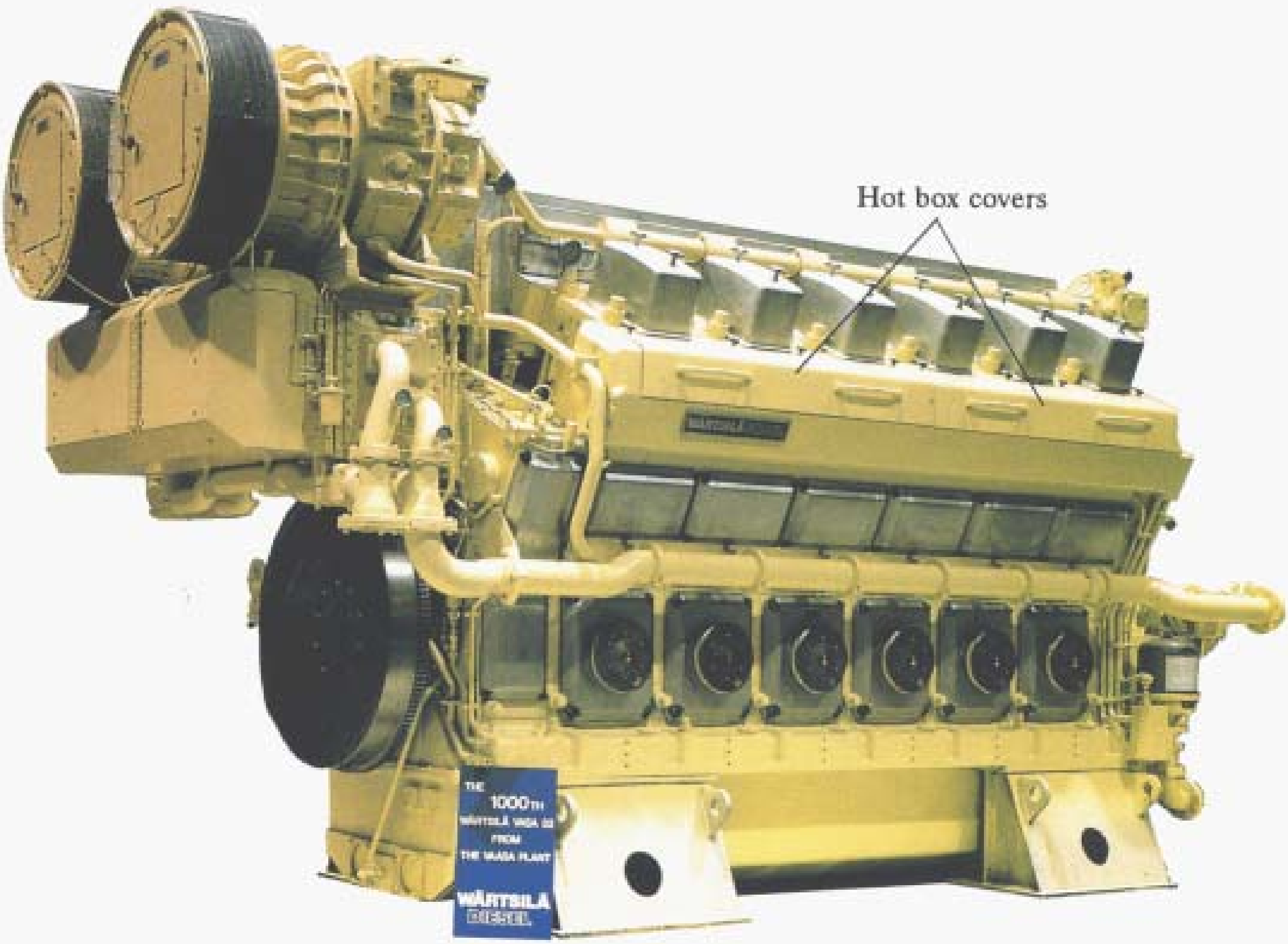
MV SALLY STAR

GENERAL ARRANGEMENT AND MAIN ENGINE ROOM VENTILATION

Not to Scale

FIGURE 1

Photograph provided by courtesy of Wartsila Diesel Service Ltd



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