Review of Engine Room Fires and Guide to Fire Prevention

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For seafarers, a fire aboard a ship is one of the most serious problems endangering human lives. Upon learning lessons from fire accidents, IMO and classification societies have been revising their rules and regulations for fire safety. Fires on ships occur in accommodation spaces, cargo spaces and machinery spaces. The occurrence rate of fires in these spaces are nearly equally split. Inter alia, however, fires in machinery spaces, where there are many flammable sources such as oil fules and lubricating oils in bulk, tend to develop into major fires in a short time, once a fire breaks out, involving loss of lives of crew members who failed to evacuate from the scene and with an eventual total loss or loss of self-propelling power. The Society established the Study Committee on the Prevention of Engine Room Fires comprising scholars, shipowners, shipyards and machinery manufactures, which undertook research and studies on engine room fires aboard ships with class in NK and countermeasures. This is a report on the results of the studies.

1. Introduction

The risk of fire always exists in ships where flammable liquids handled under severe operating conditions in confined space with the vessel being subject to vibration, rolling and pitching.

In particular , there is a always a high fire risk in engines room because large volumes of fuel oil, lubricating oil, hydraulic oil and thermal oil are consumed or used by the main engine, generator engine, boiler, thermal oil heater and hydraulic oil equipment. In addition, installed in the confined spases, exhaust gas pipes, turbo chargers, boilers and waste oil incinerators have hot surface, which are sources of ignition.

Engine room fires can easily cause more serious casualties, such as loss of human life and disabling condition of ships, compared with machinery damage.

In the marine field, in considering a succession of engine room fires, the Chairman of International Union of Marine Insurance recommended in his report that *IMO* and *IACS* take action to reinforce the Rules to prevent engine room fires.

According to the report, a large number of engine room fires have been caused by fuel oil leakages on to hot surfaces of exhaust gas pipes when fuel oil piping systems fail due to vibration, therefore, it was emphasized that special consideration should be paid to the construction of fuel oil piping systems and protection of exhaust gas pipes. It is also recommended that quick-closing fuel oil valves be capable of being operated from the control room.

Responding to the recommendations, *IACS* has prepared a Unified Requirement "F35 Fire protection of machinery space" in 1986 and *IMO* is preparing Regulations to extend the requirement of jacketed pipes for high pressure fuel delivery lines on smaller diesel engines.

Given this situation, the Society has investigated actual conditions and causes of engine room fires in 73 NK classed ships during the last 13 years from 1980 to 1992.

2. The Results of Investigation of Engine Room Fire Cases

(1) 73 ships were damaged by engine room fires during the last 13 years from 1980 to 1992.

(2) About 6 ships per year were damaged by engine room fires, which is 0.1% of all 6,000 NK-classed ships. (Fig. 1)
As a comparison, about 7 ships per year were damaged by fire of the hull compartments, which was nearly the same number as engine room fires after excluding ships damaged by projectiles during war. (Fig. 2)

(3) Engine room fires often occured when ships were under way, which accounted for about 75% of the total number of ships damaged by engine room fires.
52% of ships with engine room fires when underway became unnavigable. (Fig. 3)

(4) The main cause of fire resulting in an unnavigable condition is a main electric source failure caused by the main switchboard or the main electric cables under the ceiling burning due to a spray of fuel oil or lubricating oil igniting. (Fig. 4)

(5) On average, one crew member per year was killed and one crew member was injured or suffocated

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from carbon monoxide per year due to fires.
Engine room fires are mainly caused by flammable oil igniting and there are many cases of human casualties due to delayed evacuations from engine rooms where fire and smoke spread quickly.

(6) Fire often occured in daytime during maintenance work by the crew.
There were many fires caused by human error due to misoperation or overhauling of machinery, incorrect repair, etc.
Olternatively, it was found that in unmanned ships, fire often occured not only during daytime, but also early in the morning. (Fig. 5)

(7) There are no particular correlations between the number of fires and a ship's age and gross tonnage. (Fig. 6)

(8) Fire often occured on reefer ships and car carriers having small engine rooms.

(9) The fuel oil piping of main engines and generator engines and the main switchboard are the main source of fire followed by fuel oil piping of the boiler. (Fig. 7)

(10) Fires at the fuel oil piping of main engines and generator engines are caused by the fuel oil spray due to loose or broken fittings on fuel oil pipings coused by vibration.
The main cause of fire on fuel oil piping of generator engines is fuel oil spraying due to broken of fittings on the fuel valve cooling oil piping. (Fig. 17)

(11) Fires on lubricating oil piping account for 25% of fires on fuel oil piping.
Two crew members died after a spray-sourced fire occured on the casing cover of the main engine duplex lubricating oil filter. The construction of the filter cover should be reconsidered.

(12) It is necessary for the pipe connection between the fuel oil piping and the burner of a top firing boiler to have a flexible construction, because the burner of a top firing boiler is located at the upper part of the boiler and is subject to high levels of vibration.

(13) No cases of engine room fire caused by a soot fire in an exhaust gas economizer were reported.

(14) The number of machinery fires was twice that of electric equipment fires.

(15) No engine room fire extending to hull compartments was reported for ships having keels laid after lst September 1984, because, it is concluded, the 81' SOLAS Amendment was adopted and the regulations on fire protection for hull and electric cables were introduced from that date. (Fig. 9)

(16) The percentages of fire casualties between *MO* and Non-*MO* ships are almost the same.
However, the percentages of fires detected by a fixed detector fire alarm was 50% in *MO* ships and only 10% in Non-*MO* ships becauses, it is concluded, installation of fixed fire detection systems was not required for Non-*MO* ships having keels laid before 1st September 1984, in accordance with 81' SOLAS Amendment. (Fig. 10)

(17) There were fire caused by improper installation of machinery, exhaust gas pipes and electric cables.
The engine room arragement should be considered in a "Fire Risk Analysis."

3. Concluding Remarks

To apply an effective brake on engine room fires, the Study Committee investigated fires in 73 ships classed in NK during the past 13 years (1980 to 1992), conducted analytical assessments on probable causes, and proposed countermeasures to prevent engine room fires as viewed from ship and machinery design and maintenance. The proposals are summarized below:

(1) The principal causes of engine room fires were identified as connections of fuel oil and lubricating oil pipelines to the main engine and generator engines becoming either loose cracked or disengaged due to engine vibrations, with leaked oils splashing onto the high-temperature surfaces of exhaust gas pipes, turbochargers, etc., with consequent ignition. Engine room fires due to such causes account for approximately 60% of the total. (Photos 10 and 11)
To prevent the leakage and splashing of flammable oils, it is considered effective to improve the design of the construction of pipe fittings (special pipe joints, screwed-in pipe joints etc.) used in flammable oil pipelines, apply protective covers over hot spots or apply anti-splashing tapes on pipe joints. (Fig. 24, Photos 5 and 16)
In other words, the most important points for preventing engine room fires are to shied high-temperature spots in the engine room that are sources of ignition from fire-risks by suppressing the leakage and splashing of flammable oils. (Fig. 15)

(2) In one case, fuel oil that leaked from the fuel valve cooling oil pipeline splashed and caused an engine room fire. For safety reasons, fresh water cooling should be employed for fuel valve cooling instead of oil cooling. (Fig. 17)

(3) The greatest potential sources of ignition in the engine room are exhaust gas pipes and trubochargers. These high-temperature surfaces need to be

safely covered. All insulating materials which were stripped off for inspection and maintenance work should be restored the original state as soon as possible. (Photo 15)

(4) For flammable oil pipelines, non-metal pipes, not approved by the Society should not be used. (Photo 4, Figs. 22 and 25)

(5) In one case, a fire involving personal injuries and fatalities occurred due to lubricating oil leaking and splashing from a manual duplex lubricating oil strainer during the change over operation of bilter elements under pressure. Strainers for flammable oils should not be opened for cleaning while the ships is at sea. Instead, as far as practicable, maintenance and reconditioning work should be done in port, ensuring there is no positive pressure. It is also recommended for safety that sell-cleaning-type flammable oil strainers with higher internal pressures and less frequent overhauls be used as secondary strainers. (Photos 14, 15 and 19)

(6) Among ships that had engine room fires, 75% occurred when ships were underway, and 52% lost self-propelling power. The prime causes of loss of propelling power after the fire was brought under control include burnt propelling machinery and loss of functions of electric cables soaked in sea water. Nonetheless, important causes can be found in the burnt electric cables laid on the upper ceiling of the generator flat with consequent loss of the main electric power supply. Laying electric cables on or underneath the generator flat, or distributing generator engines to both sides of a ship can be an effective alternative arrangement to ensure continued navigation even after a fire aboard the ship. Furthermore, if the possibilities of burn damage to cables in a bundle are reduced, the likelihood of crew members being suffocated due to a large bulk of toxic gasses produced by the buring cable insulations can be reduced. (Photos 12 and 13)

(7) Some cases suggest that fires or personal injuries were caused by soot fires in waste oil incinerating equipment. It is advisable that cleaning holes be drilled in the uptake where soot and sludge are liable to accumulate, and cleaning be carried out regularly. (Fig. 21)

(8) Most fires in electrical equipment and installations such as switchboards and generators were caused by the overheating contactors or connections of conductors with consequent burn damage. It is considered feasible to reduce electical fires aboard ships by enforcing regular checks on connected portions of electrical equipment and installations including additional tightening of screws. (Photo 17)

(9) To pervent fire accidents due to oil fuel overflowing from the short sounding pipes for fuel oil tanks, use of a sounding system capable of maintaining a sealed condition, even during the sounding process might be effective.

(10) It was revealed that the locations of engine room fires are not evenly scattering over the machinery space, but are concentrated within specific high-risk areas.

Specifically, spaces incorporating oil fuel pipes connected to the main engines and generator engines, oil fuel pipig to oil burners of boilers, exhaust gas pipes, turbochargers and main switchboards are considered to be dangerous spaces. It, therefore, is considered necessary to take concentrated fire prevention measures tailored to high-risk spaces. (Fig. 16)

(11) It was also revealed that the lower floor of the machinery space has the lowest risk of fire at sea. However, fires due to human errors are liable to occur during welding or gas cutting work when the ship is in port or in a shipyard. In this connection, verification of the present conditions of the space before starting maintenance/repair work is considered to be effective for preventing engine room fires. (Fig. 16)

(12) The results of an investigation on the times engine room fires occur show that many occurred in daytime when crew members were engaged in maintenance work. it is necessary to take the precautions, when maintaining equipment handling flammable oils listed below:

(a) Eliminate erroneous operations.
(b) Eliminate erroneous overhauling and restoration work.
(c) Eliminate erroneous repairs.
(d) When maintenance work is suspended, take precautions for preventing fire.
(e) Don't leave engine room doors open. Furthermore, it is nonetheless important for preventing engine room fires to keep engine rooms always oil-free and clean. (Photos 2 and 3)

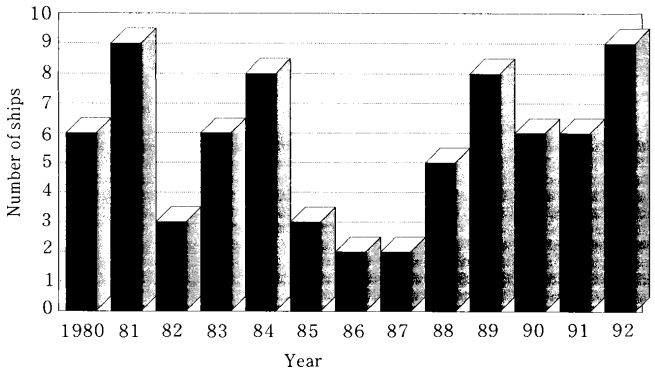


Fig. 1 Annual number of ships with fires occur

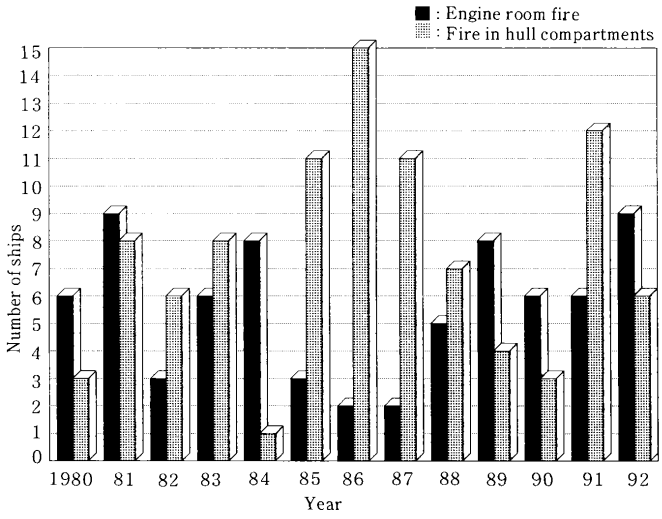


Fig. 2 Annual number of ships in which fires occur in engine rooms and hull compartments

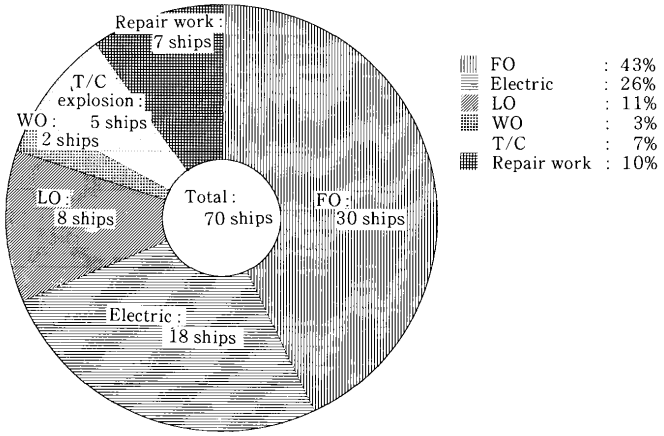
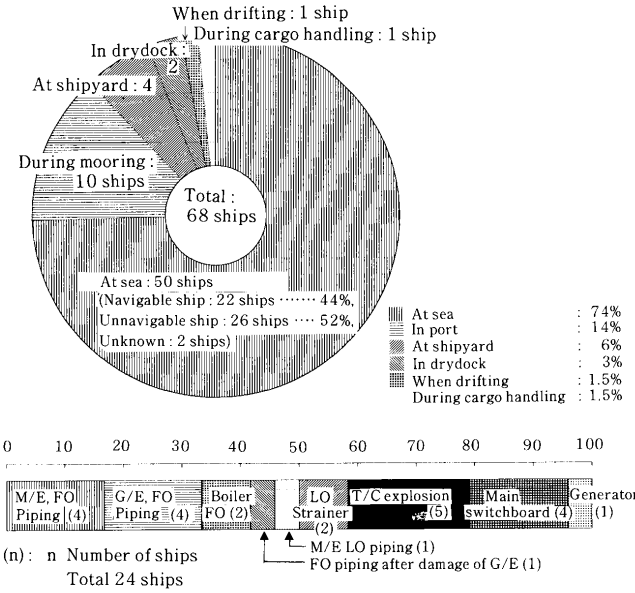


Fig. 4 Causes of fire



Percentage of ship fires at sea relating to cause of fire

* Sources of fires in port were 3 cases of aux. boiler burner in operation and one case each of short sounding pipe vapour when bunkering, T/G, main switchboard transformer and starter.
* Cause, of fires occured at shipyard were as follows.
  - Spark from welding : 2 ships
  - Spark from gas cutting : 3 ships
  - Electric spark from shore connection : 1 ship
* Causes of fires resulting in unnavigable condition of ships were as follows.
  - Explosion of main engine turbo charger : 5 ships
  - Leakage from main engine fuel oil piping : 4 ships
  - Leakage from generator engine fuel oil piping : 4 ships
  - Electric spark of main switchboard : 4 ships

Fig. 3 Number of ships in which fires occurred and ship operating conditions

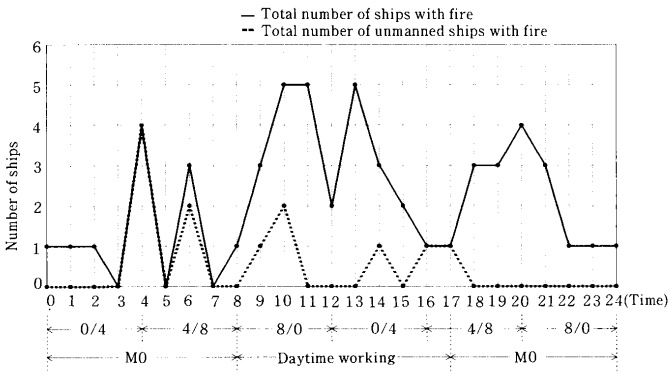


Fig. 5 Number of ships in which fires occurred and time of occurence

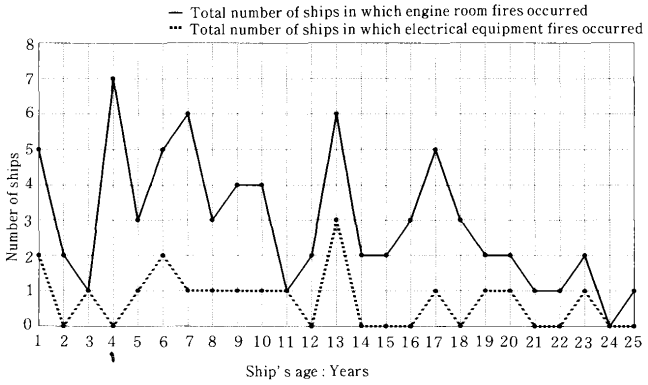


Fig. 6 Number of ships in which fires occurred and ages of ships

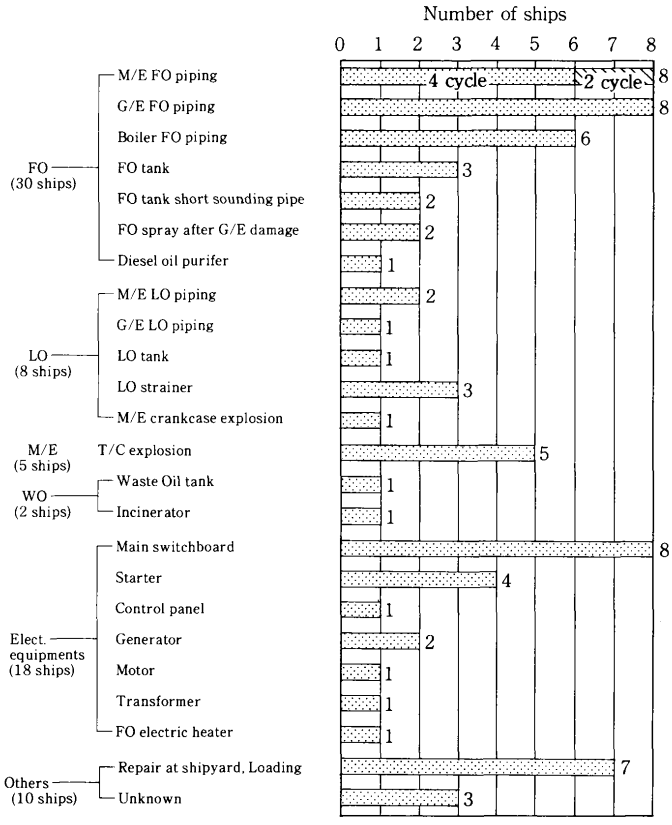


Fig. 7 Sources of ignition

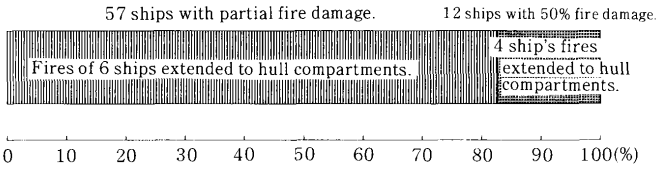


Fig. 9 Extent of fire damage

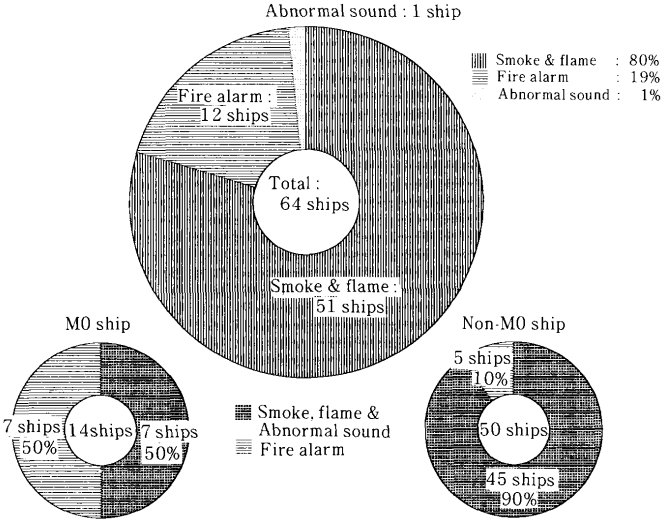
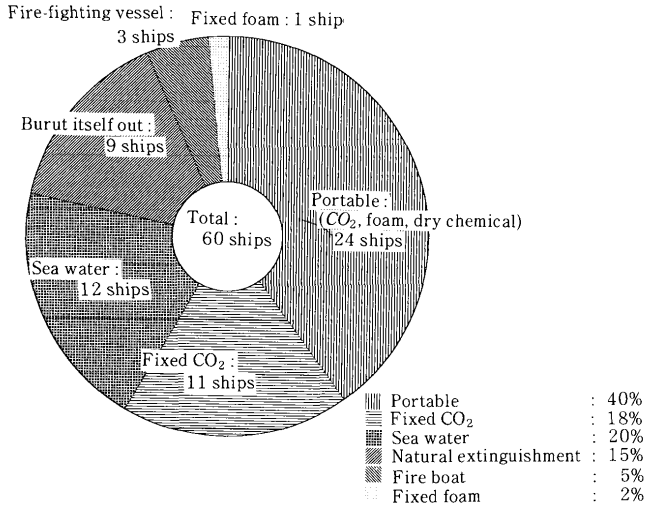


Fig. 10 Means of detecting fires



* 40% and 18% of engine room fires were extinguished by portable and fixed CO_2 fire extinguisher respectively.
* 20% of fires were extinguished by sea water, which increased the damage to electrical equipment.
* 20% of fires were extinguished by the fire-fighting vessel or themseles out naturally.

Fig. 11 Means of extinguishing fires

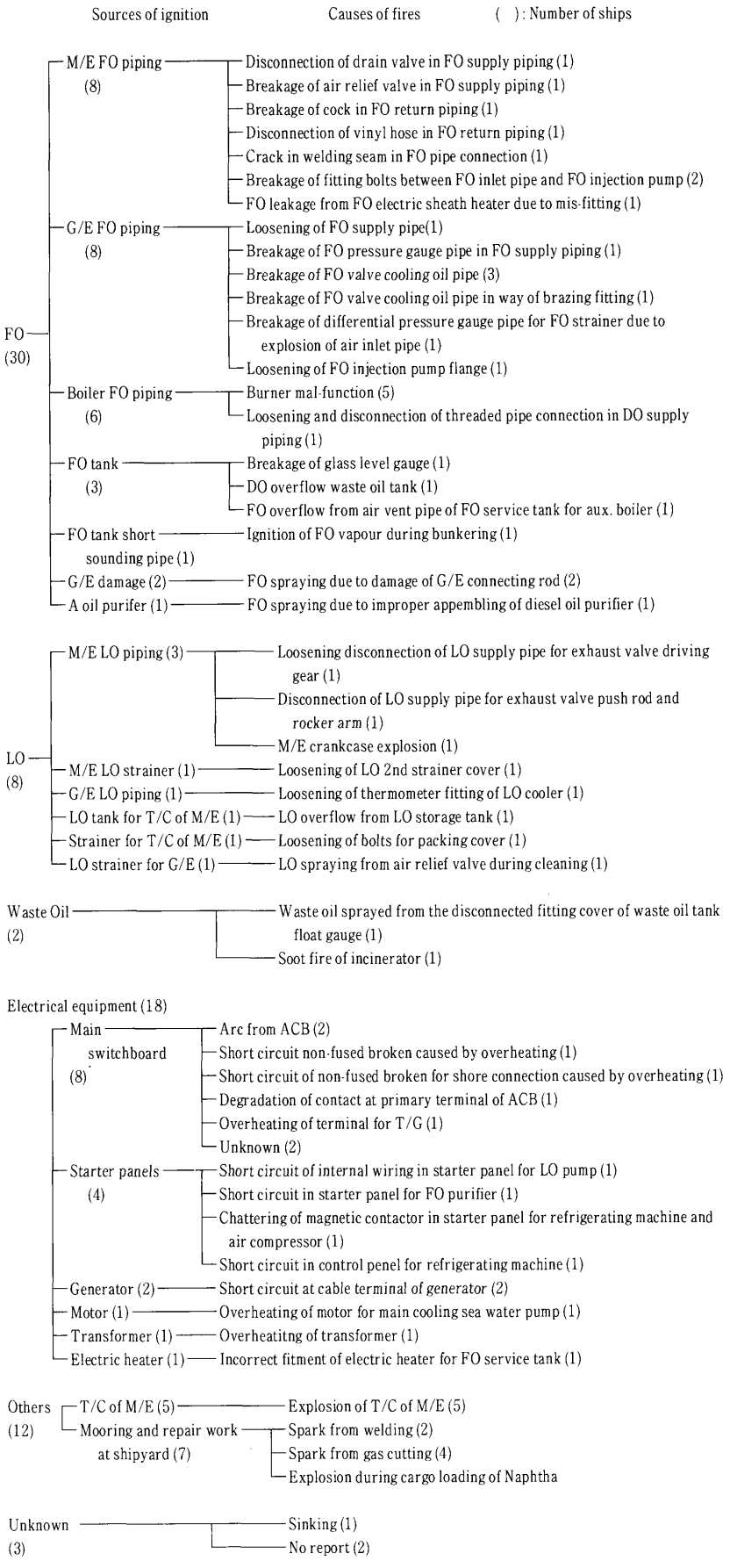
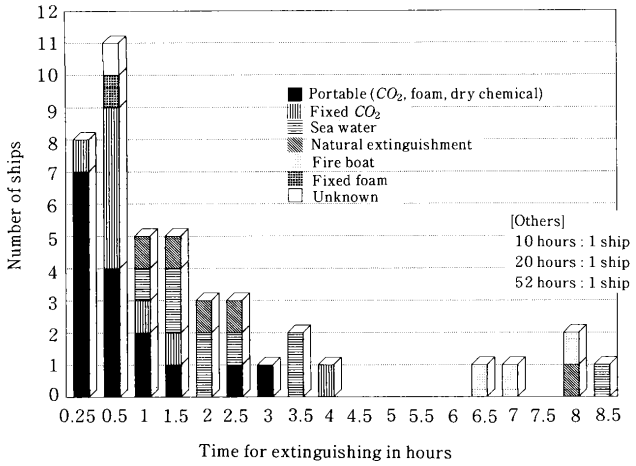
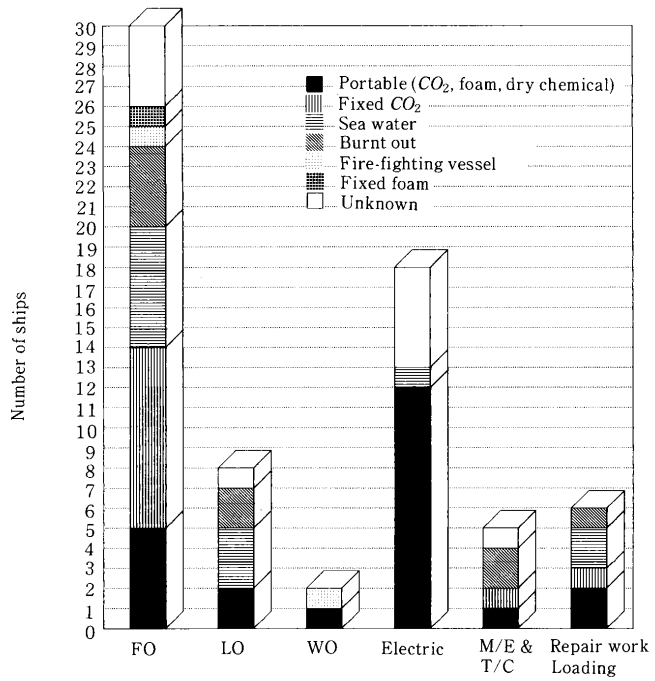


Fig. 8 Breakdown of causes of fires



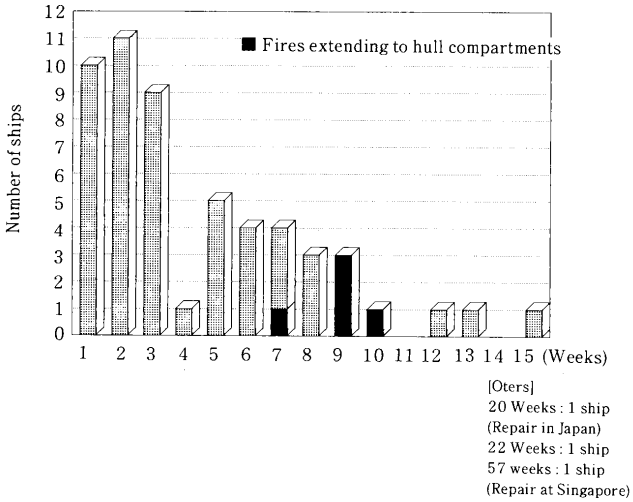
* 19 (41%) of fires on 47 ships were extinguished within half an hour and 24 (51%) of ship fires in one hour.
  Almost all of the fires were extinguished by portable fire extinguishers within a quarter hour.
* The graph above shows the relation between extinguishing time and means of extinguishing a fire. Depending on the hours, the means of extinguishing a fire changes from portable to fixed CO_2 fire extinguisher and sea water and finally, fire-fighting boat or is hurnt out naturally.

Fig. 12 Time and means of extinguishing fires



* Fixed CO_2 fire extinguisher and sea-water in particular are often used for extinguishing fuel oil and lubricating oil fires, because the fires often extend to the whole engine room.
* There are many cases of electric fires extinguished by portable fire extinguisher, because such fires often occur locally in the engine room.

Fig. 13 Number of ships in which fires occure, causes of fires and the means of extinguishing fires



* In almost all cases fire damage was repaired within 1-3 weeks, and 5-9 weeks for virtually all other cases.
  Nearly one year was necessary to repair one rare case.
* As a result, it is revealed that more than half of fire damages can be repaired without replacing machinery, or by replacing machinery within a short time.
* Alternatively, more than 7 weeks were necessary for repairs in many cases of engine room fires extending to hull compartments.

Fig. 14 Number of ships in which fires occurred and number of weeks for repairs

FIRE RISKS
* FO injection pipe, FO service pipe and FO valve cooling oil pipe attached to diesel engine
* LO service pipe and hydraulic oil pipe attached to diesel engine
* Flammable oil pipe
* Flammable oil pump and strainer
* FO heater
* LO heater and cooler
* FO purifier
* LO purifier
* FO burning unit for boiler, thermal oil heater, inert gas generator and incinerator
* Level gauge, fittings and oil tray of flammable oil tank
* Sounding pipe head of double bottom FO tank
* Special pipe joint (threaded pipe joint, compression fitting joint etc.) and expansion joint in the flammable oil piping

Flammable oil means FO, LO, hydraulic oil, thermal oil, waste oil and FO additive.

⇩

LEAKAGES AND SPRAY OF FLAMMABLE OIL

⇩

SOURCE OF IGNITION
* Exhaust gas pipe
* Steam pipe
* Turbo charger
* Electric equipment
* Boiler, thermal oil heater and incinerator
* Welding spatter, cigaretts etc.

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ENGINE ROOM FIRE

Fig. 15 Fire risk identification

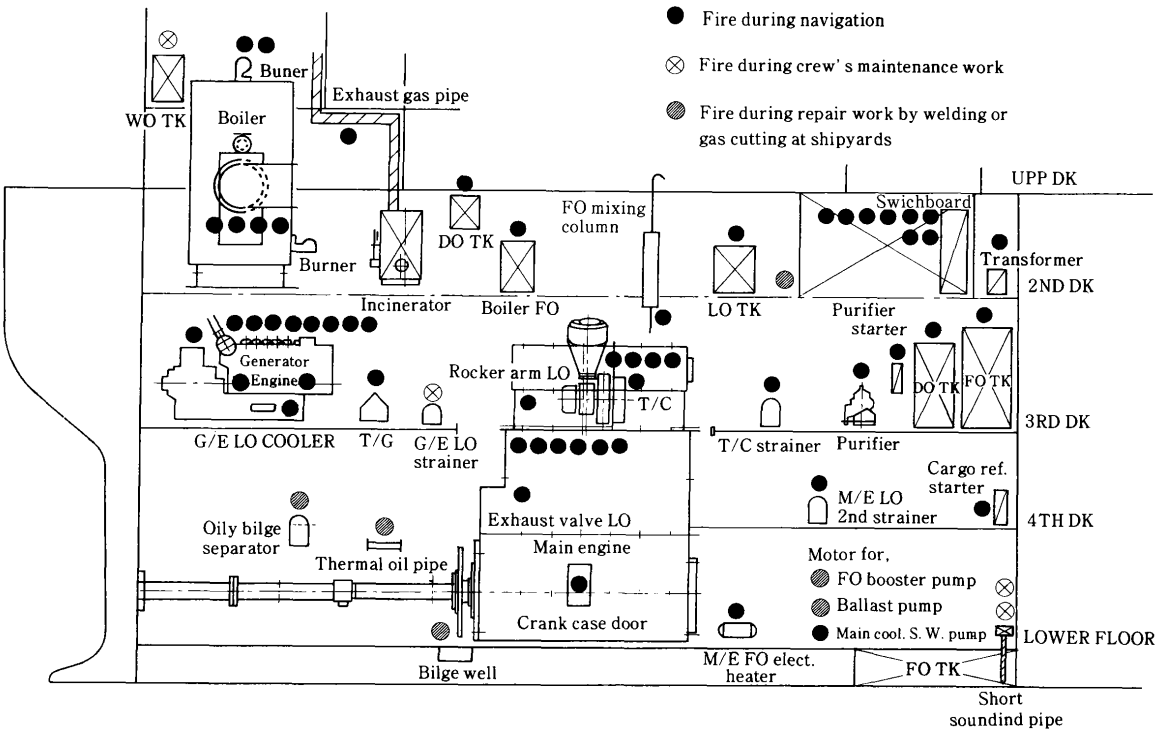
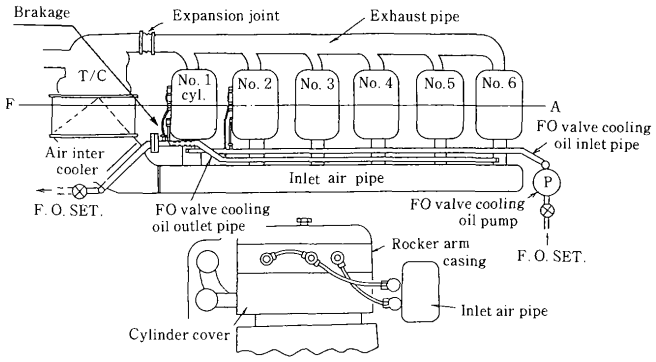
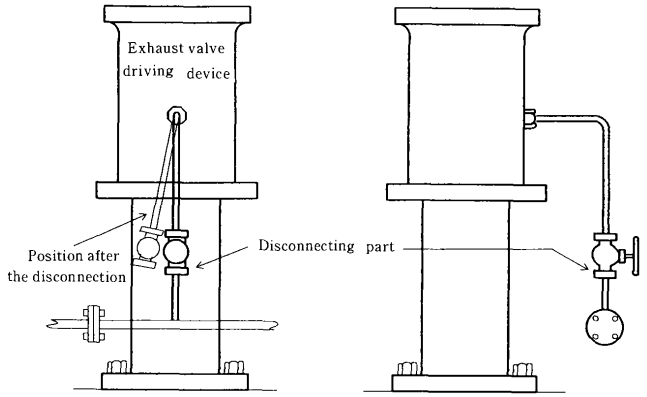


Fig. 16 Sources of fire in engine room



FO sprayed out from the No. 1 cyl. FO valve cooling oil outlet branch pipe of the No. 2 G/E because the pipe at the brazing fitting was broken due to vibration and resulted in fire.

Fig. 17



LO Sprayed out from the LO supply pipe for the No. 1 cyl. cxhaust valve driving gear of the M/E, because the pipe at the threaded fitting for the stop valve became loose and was disconnected due to vibration, resulting in fire.

Fig. 18

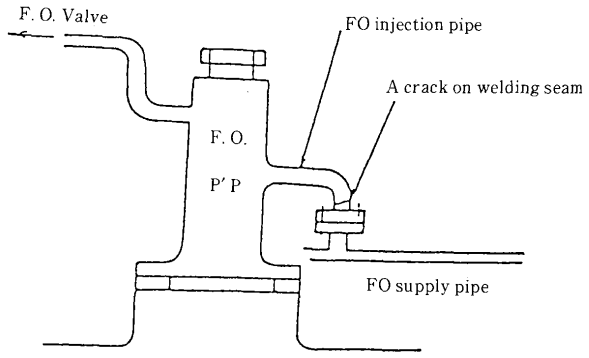
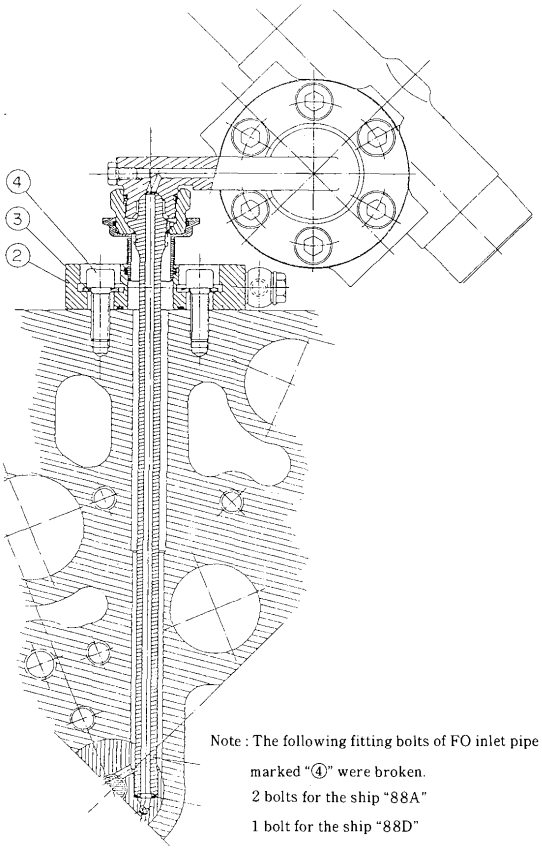
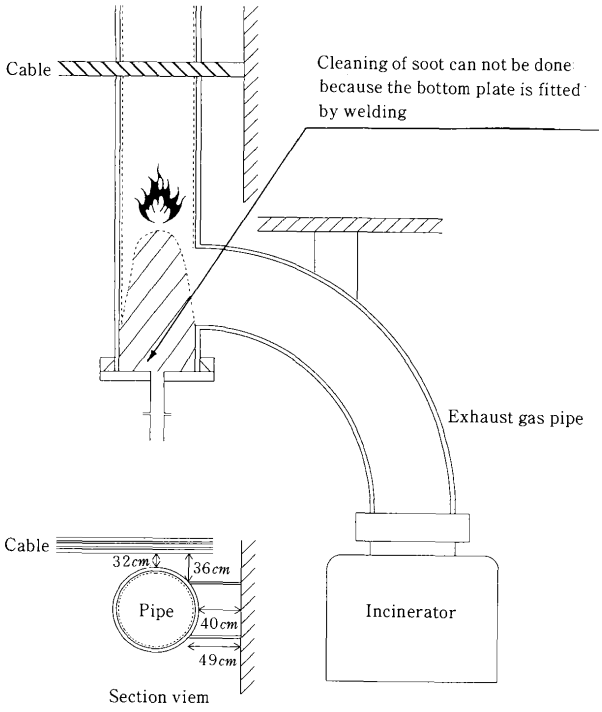


Fig. 19



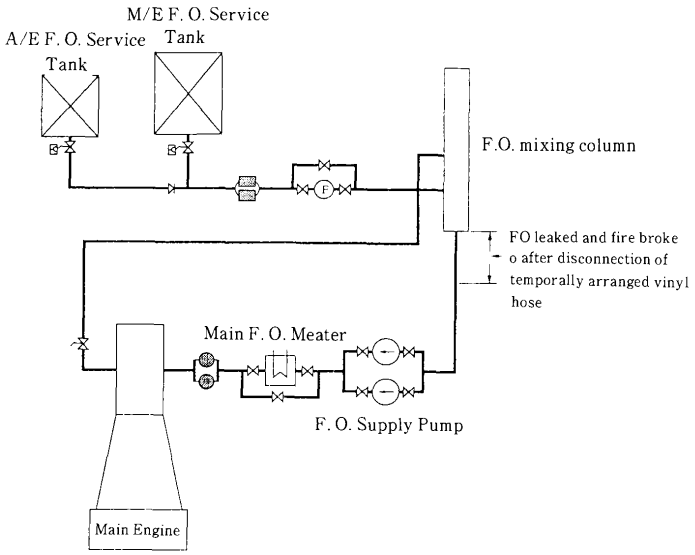
The fitting between the FO supply inlet pipe flange and the FO injection pump.

Fig. 20



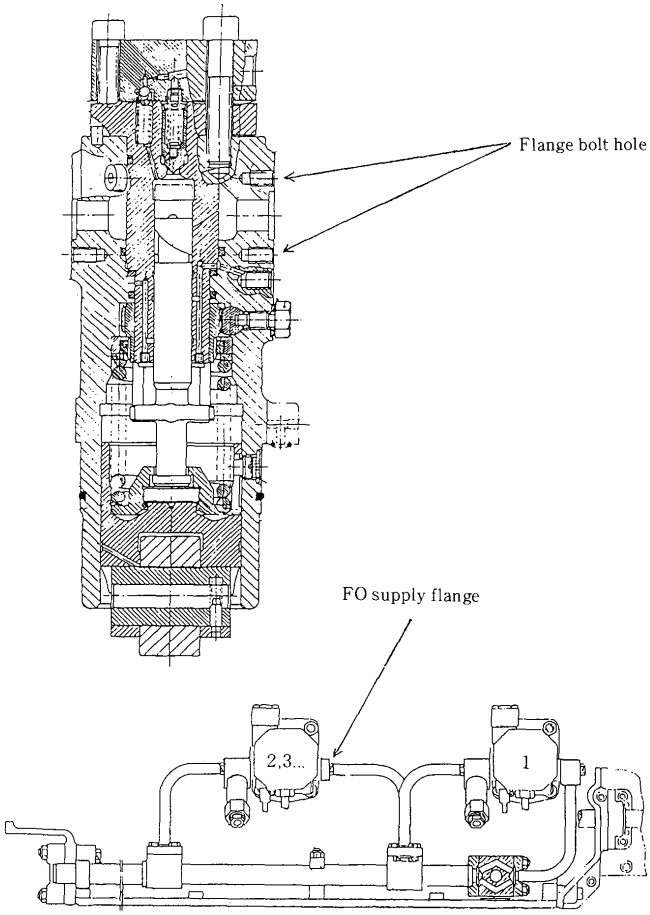
Fire broke out at the electric cables (38 *pcs.*), which were overheated by a soot fire in the exhaust gas pipe of the incinerator located near the cables.

Fig. 21



Main Engine F.O. Service System

Fig. 22



FO sprayed out from the flange between the No. 4 cyl. FO supply pipe and the FO injection pump because 2 fitting bolts became loose and disconnected.
Leaked FO touched a 400°C hot point on the exhaust gas manifold, resulting in fire.

Fig. 23

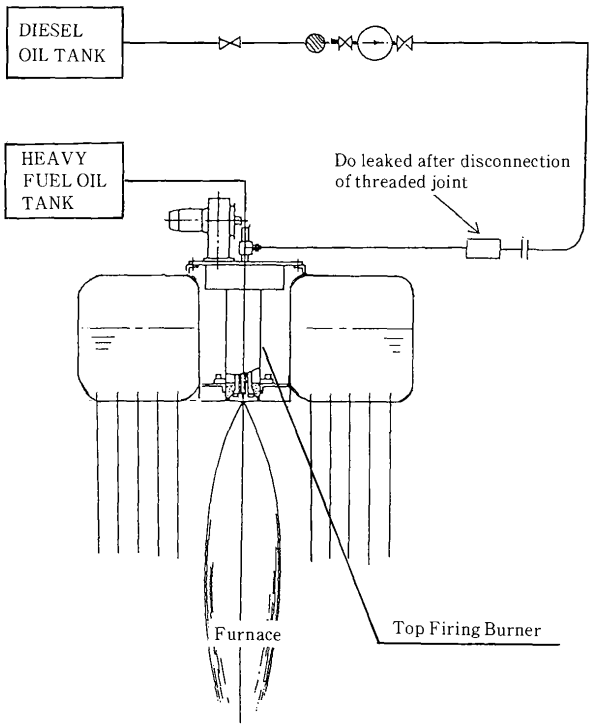


Fig. 24

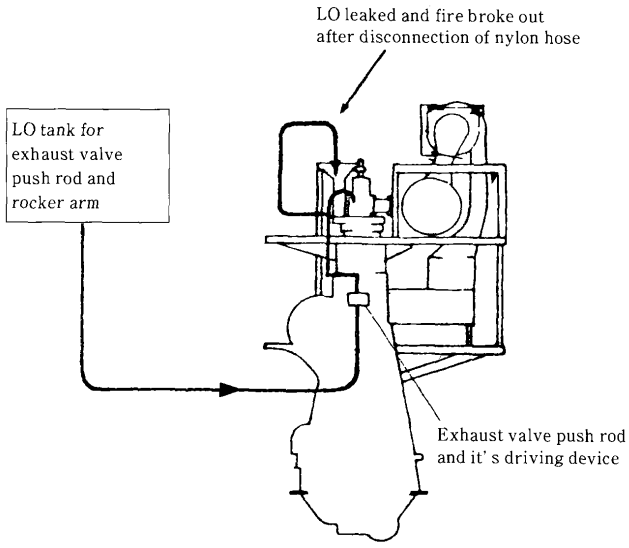
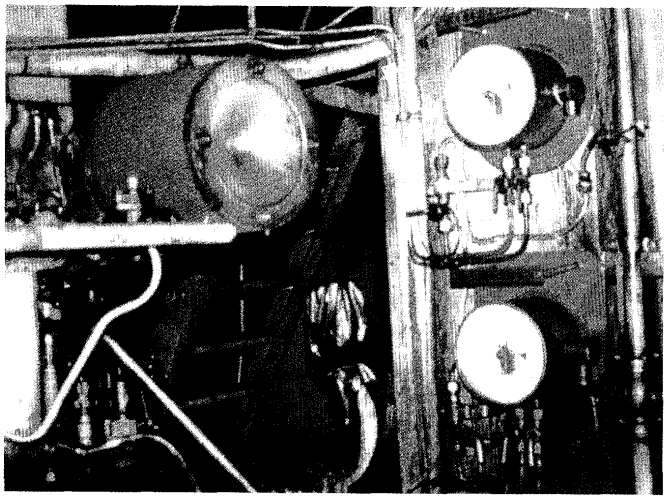
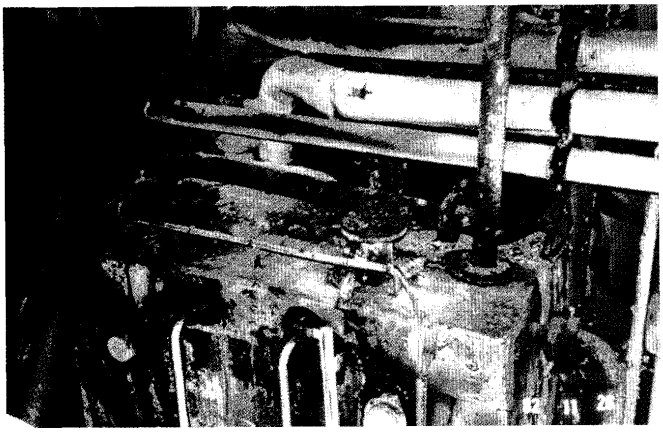


Fig. 25



FO sprayed out from the FO starainer differential pressure gauge pipe of No. 2 G/E, because the end cover of the inlet air suction manifold hit the pipe due to an explosion in the manifold resulting from an abnormal condition of the air inlet valve of No. 2 G/E, resulting in fire.

Photo 1

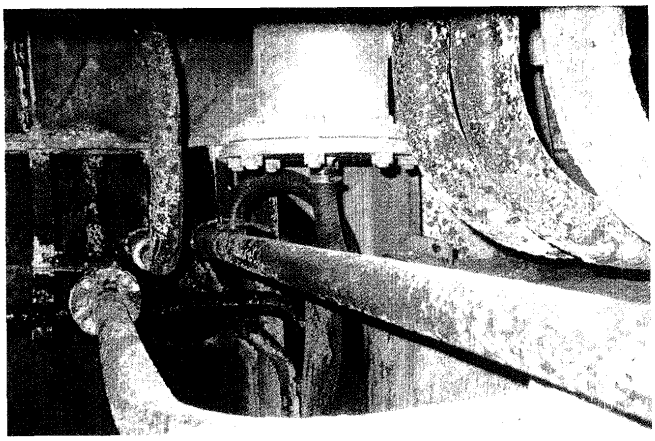


Waste oil sprayed out from the fitting cover of the waste oil tank float gauge, because the cover bolts had not been tightened and the steam cleaning valve opened due to mis-operation, resulting in fire.

Photo 2

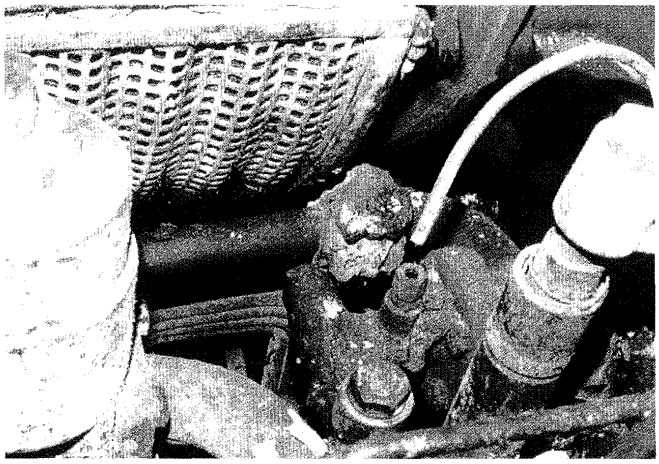
The float gauge cover of the waste oil tank was blown off.

Photo 3



FO leaked onto the M/E exhaust gas pipe and fire broke out because the vinyl hose, which was temporarily fitted to the bottom cover of the FO mixing column was disconnected.

Photo 4



FO leaked onto the T/C and exhaust gas pipe of of the No. 1 G/E from the pressure gauge pipe fitted to the FO supply piping because the cupper pipe at compression joint was broken due to vibration and resulted in fire.

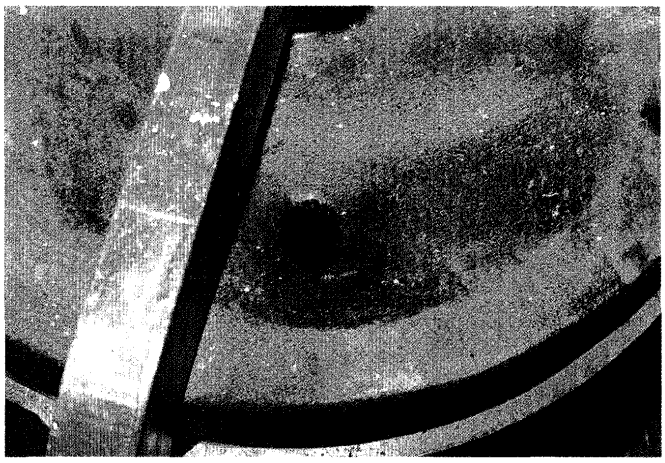
Photo 5

The T/C casing of the M/E was broken and all of the turbine blades were detached by an explosion.

Photo 6

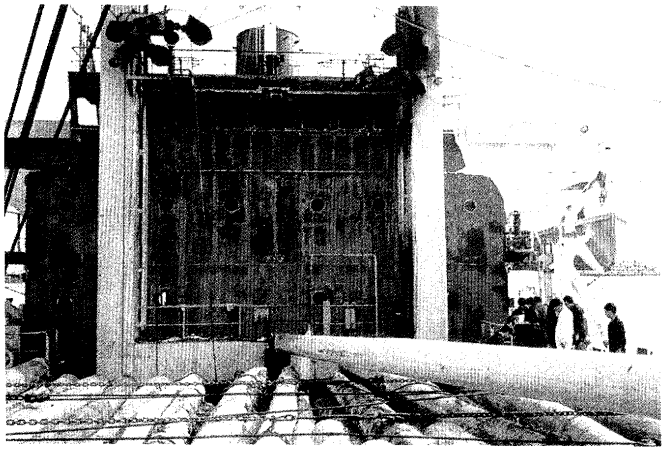
The exhaust gas pipe was holed by the pieces of the T/C casing of the M/E blown off by an explosion.

Photo 7



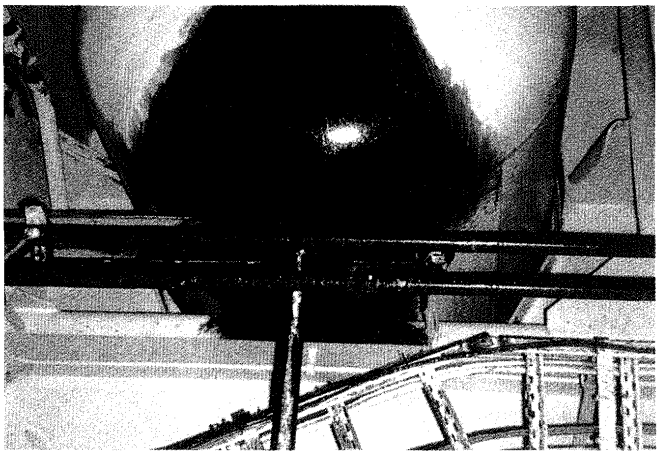
The turbo charger of the M/E exploded and fire broke out because the M/E No. 6 cyl. piston crown was holed and piston cooling LO leaked.

Photo 8



Accomodation on the poop deck was completely burnt out due to an engine room fire when fully laden with timber cargo.

Photo 9



FO sprayed out from the FO supply pipe flange of the No. 2 G/E, because the fitting bolts were disconnected, resulted in fire.

Photo 10

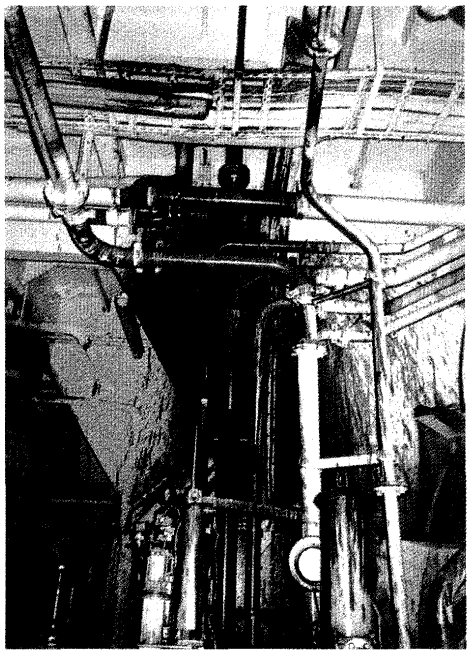
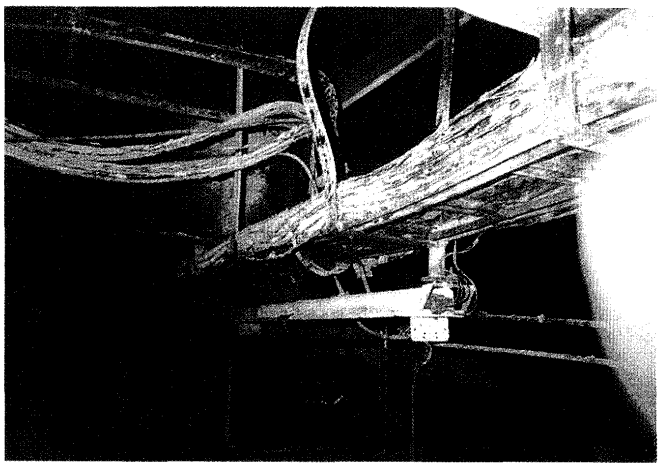
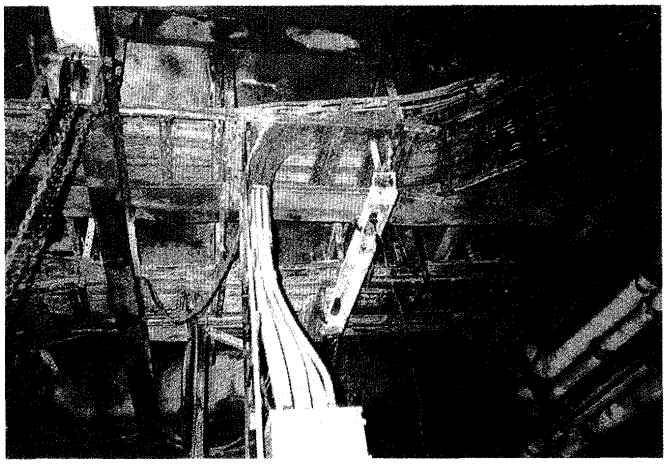


Photo 11



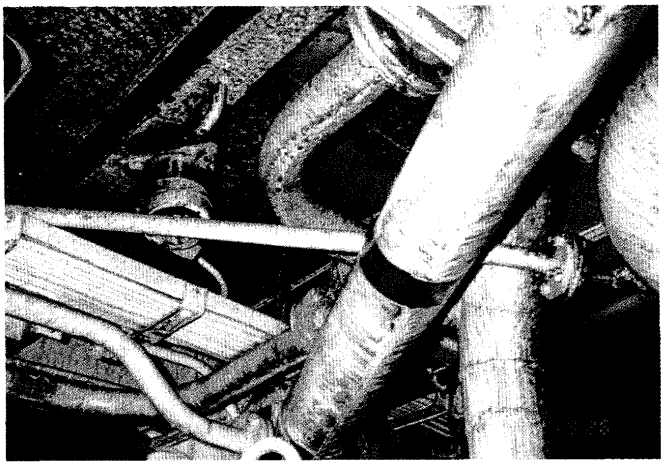
Electrical cables were burnt by a FO spray fire in the No. 2 G/E.

Photo 12



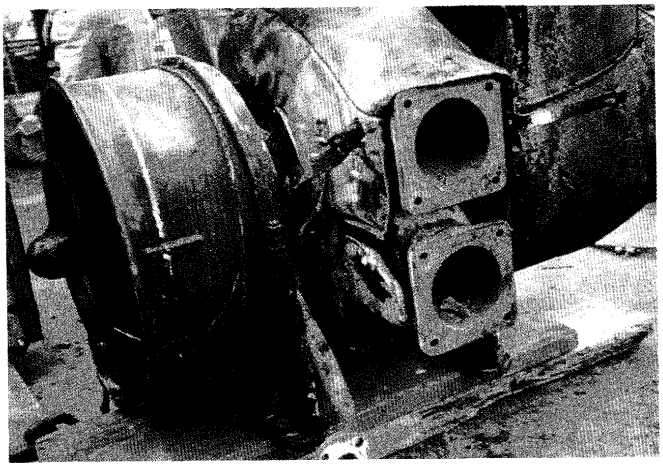
Same of electric cables arranged under the ceiling were burnt, but none of the cables arranged vertically from the generator terminal box were burnt.

Photo 13



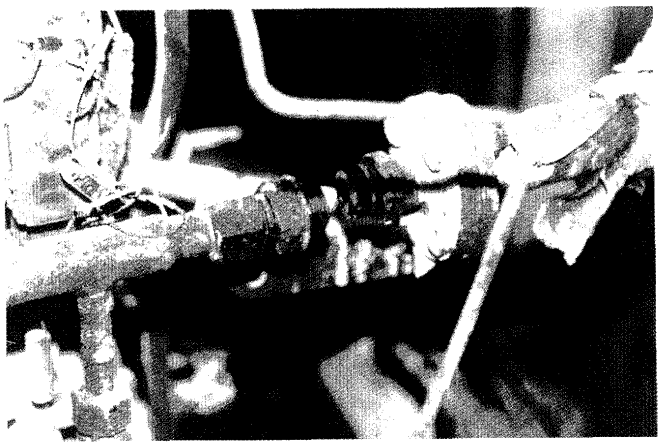
The trace of LO spray

Photo 14



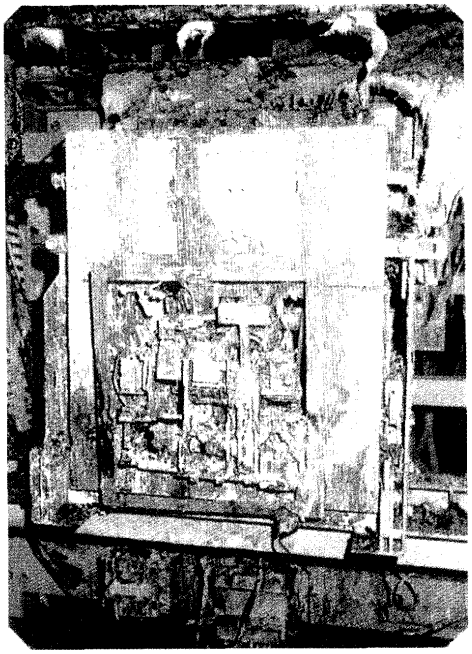
Leaked LO touched a hot-point on the T/C casing.

Photo 15



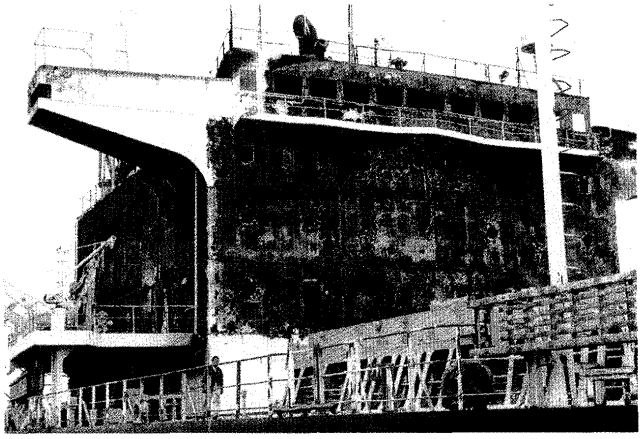
DO sprayed out from the DO supply pipe of the aux. boiler top firing burner because the union fitting in the pipe had become loose and disconnected due to vibration, resulting in fire.

Photo 16



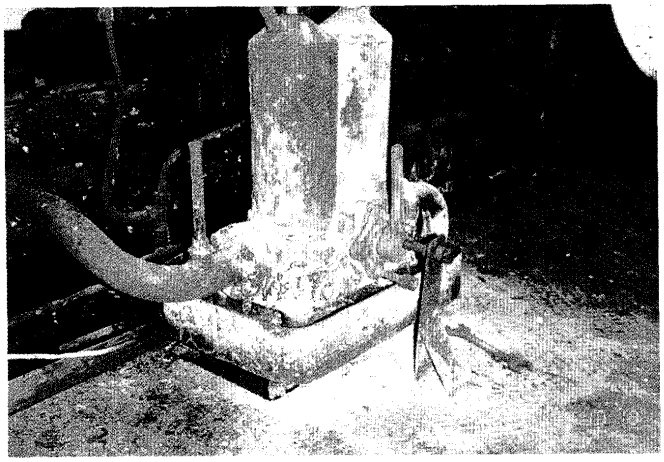
Fire broke out at the ACB contactor of a T/G due to overheating.

Photo 17



Accomodation completerly burnt.

Photo 18



LO sprayed out from the T/C LO strainer, because the fitting bolts of the packing retaining cover of the change over cock were loosened during operation, resulting in fire.

Photo 19

Melted and carbonized rubber packing protruded slightly from around the manhole cover of a waste oil tank .
The sight glass in the overflow pipe melted.

Photo 20