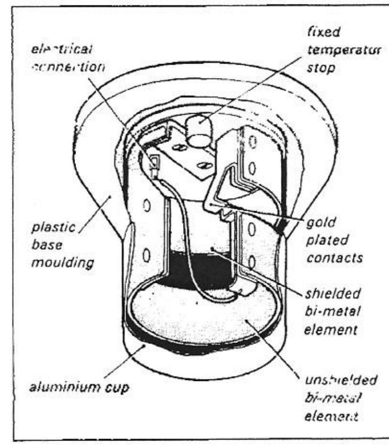


Fig 1: Rate of rise temperature sensor.

Fire-fighting equipment has come a long way since the fire bucket. Sophisticated techniques, catering to the whims of heat, smoke and combustion, provide electronic means to detect fires quickly and activate extinguishing systems to fight one of the marine industry's biggest hazards.

Shipboard fire prevention and detection

by R Foster, Engineering Manager, Special Hazards, Wormald International (UK)

Every year, more and more ships are lost through fire and collision. Between 1977 and 1978, the number of marine write-offs in this category increased dramatically from 57 to 85, and the mere growth of traffic means that 1979/80 could see even more disasters.

Shipboard fires pose a great threat to life, and an immense financial burden on the shipowner, both in replacement of machinery and lost contracts. Because of this, shipboard fire prevention techniques are advancing to keep pace with the new demands made by stringent safety regulations and greatly increased tonnage.

The most common causes of shipboard fire are the most obvious: maintenance burning and welding are responsible for nearly 40 per cent of all outbreaks. Surreptitious smoking leads to countless smouldering fires that break out when no-one expects; but a complete prohibition of smoking has proved far more dangerous than confining smokers to a specially allocated area.

Lack of attention (particularly in the galley), spontaneous combustion and electrical faults are other major causes. The engine room is at special risk from 'flashbacks' in oil-fired boilers, leaky gauges, overheated bearings – and even the mere accumulation of rubbish.

Prevention

The two weapons that will protect against unpredictable fires are awareness of the possibility and quick detection.

Regular fire patrols and familiarity with emergency procedures help ensure that fire is caught before it spreads. If the core of a fire can be reached promptly, it can be controlled. And there is less danger that excessive quantities of water will damage machinery and affect the vessel's stability.

Fire prevention begins with a ship's structural design. The International Convention for the Safety of Life at Sea regulates construction and operation of merchant ships of all signatory countries, applying minimum standards to various methods of fire protection.

Basic regulations require that: (a) passenger and crew accommodation is separated by thermal and structural boundaries; (b) fire can be detected, contained and extinguished in the space of origin; and (c) all means of escape are protected.

Detection

The most vital part of active fire protection is rapid detection. The faster an alarm is raised, the better chance there is to escape danger and prevent damage.

Most ships operate manual alarm systems for economic reasons, but electronic detection devices in machinery spaces or other unmanned areas are becoming more common.

Automatic detection systems are relied upon to such an extent that only the best workmanship and materials should be considered. Whether they are separate or incorporated into a sprinkler system, regular inspection of each device, electrical wiring and power supply, by the manufacturer or trained staff, is essential.

Early warning detectors can react to signs of heat, smoke, or any product of combustion. Combustion detectors react to changes within an ionisation chamber. Suspension detectors react to light changes in a photosensitive cell. Infra-red detectors sense the flickering flame, but tend to be over-sensitive to other local sources. Ultra-violet detectors act on radiation.

Heat-actuated detectors (Fig 1) are commonly used in ships. The electro-pneumatic type is reliable and stable, giving the alarm when rising air pressure in a sealed chamber deflects a diaphragm to make electrical contact; this indicates a rapid rate of temperature rise, whilst a eutetic-soldered strut caters for fixed temperature detection.

Perhaps the most advanced form of heat detector of its kind is the electronic "Intertec". This device incorporates sophisticated integrated circuitry as its sensing element, which provides such a consistent performance that the risk of false alarm is almost eliminated. It also guarantees fast, effective response when operating in either 'fixed temperature' or 'rate-of-rise' modes.

Flammable-vapour detectors determine the level of gas or vapour flammability in oil tanks and fuel stores and alert to any possibility of explosion. Continuous line-powered analysers draw samples of air by diffusion through tubes to a central point for testing. Portable indicators come in the form of lightweight, dry-cell-powered devices, with either a meter or audible alarm, and prove valuable for cargo ships with variable loads.

Detectors should be installed in spaces of high risk, at whatever interval the particular risk demands, and the manufacturer recommends.

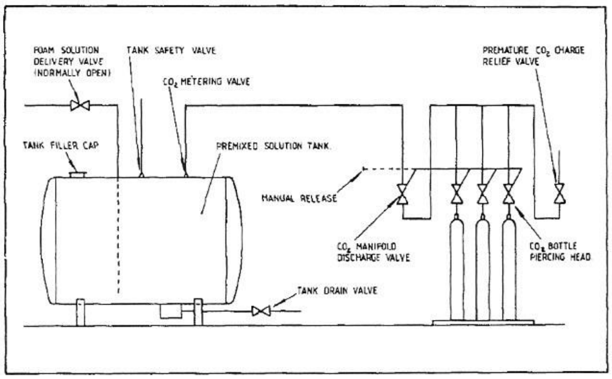


Fig 4: Typical pressurised premixed solution system.

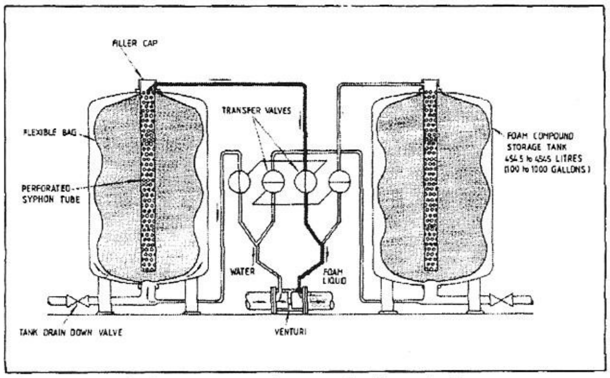


Fig 5: Automatic foam compound proportion by venturi.

foam liquid tank may be positioned a little distance from it. As with the two previous schemes, the operations necessary to work the system are simple and require the combined air and sump valves to be opened and the fire pump started. Thereafter, any change in the number of monitors or branchpipes in use (which means altering the amount of foam liquid induced) may be easily accomplished. The automatic system will cope with flow variations of 4 to 1, but is limited to a maximum of about 2040 litre/min.

The automatic inductor unit has one moving control mechanism which is constantly cleansed by the water flow and has a simple external free-movement check device. It is insensitive to back-pressures of up to 1 bar and so is able to tolerate variations in ship's draught. The manually adjusted units can each cater for solution flows of up to 12 050 litre/min when using 3 per cent concentrate.

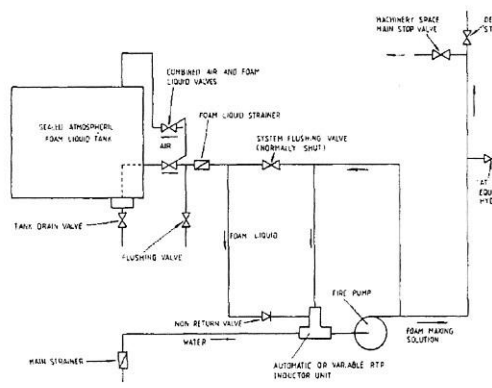


Fig 6: Variable round the pump foam liquid induction system.

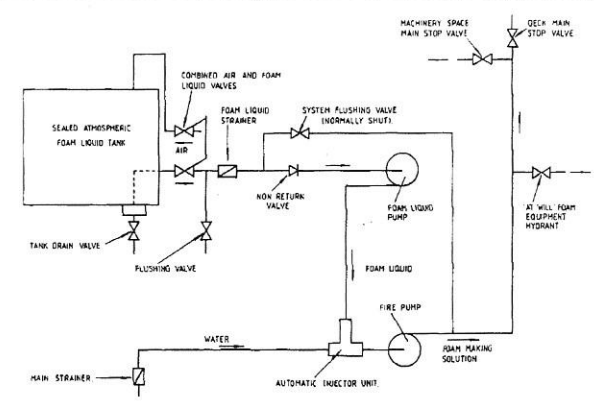


Fig 7: Automatic foam liquid injection system.

Injection

The latest way of introducing foam concentrate automatically into a water stream is by injection using a pump (Fig 7). This method was developed with tankers especially in mind and probably offers the best all-round system. Concentrate is drawn from the atmospheric tank by the foam pump and discharged to the automatic injector unit. Again, the main water stream flow is mechanically sensed and the unit controls the amount of liquid injected. The injector unit is capable of automatically controlling the quantity injected over a flow range of 9 to 1. Using 3 per cent foam liquid it can, when fitted with a bypass arrangement, cater for water flows of 13 640 litre/min.

The concentrate tank and pump may be positioned in any convenient space, the only consideration being that of frictional loss in the concentrate delivery line. Likewise, the automatic injector may be piped into either the suction or delivery line.

The sequence necessary to bring this system into operation is the same as that for the inductor method with the addition of starting the concentrate pump.

The injector unit adjusts automatically to changes in main water flow or pressure, or to foam liquid pressure, provided that a minimum differential pressure of 4 bar is achieved at the maximum flow condition. The unit proportions at 3 or 6 per cent according to the type of liquid in use. One disadvantage of this system is that a second pump is required, although it is of small capacity.

Type selection

It is difficult to generalise on the type of system for particular sizes of tankers because costs, space, siting and owners' preference must be considered. The following is offered as a guide.

Smaller tankers of about 25 000 dwt may be fully protected by one premixed solution system having one or two pressure storage tanks.

Vessels of 60 000 to 70 000 dwt may have a premixed system coupled with a venturi proportionator or automatic inductor system of sufficient capacity, for protecting the whole machinery space and deck areas.

Tankers of 100 000 to 200 000 dwt should be equipped with two premixed foam solution systems, one forward and one aft, coupled directly to the deck foam main.

The major fire protection foam liquid supply would be provided by automatic injectors or venturi units. All foam solution supply systems would be coupled so that each could feed the foam makers on the deck or those in the machinery spaces.

As with medium-size vessels, the premixed system would be operated first when a fire was beyond the control of portable fire extinguishers. This would allow time for the pumps and proportioning devices of the major system to be brought into operation.

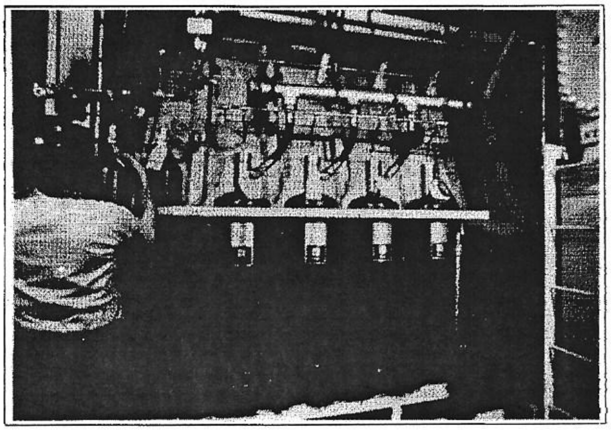
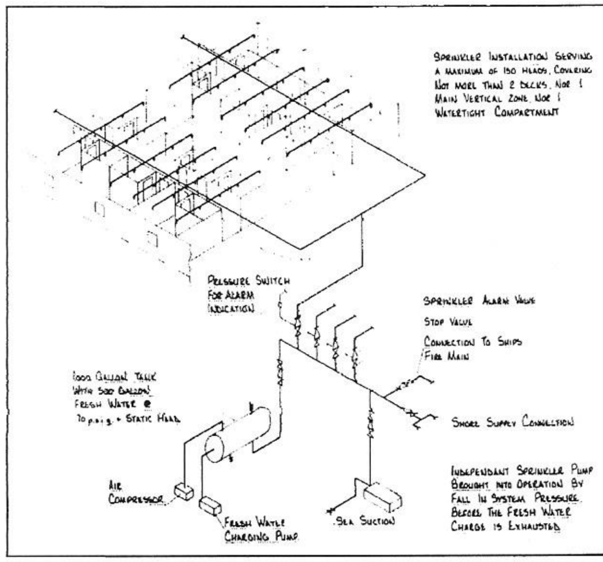


Fig 3: Halon 1301 system with CO_2 (unmanned). ▲

Fig 2: Sprinkler system for accommodation areas. ▶



Whichever type of detection device is chosen, however, it will activate an audible alarm or automatic extinguishing system, or alert a display panel on the bridge.

Extinguishing

The first move made aboard any ship, in the instance of fire, is toward portable extinguishing equipment. Fire buckets, for many years the cheapest and most easily recognised equipment, have been replaced on all but the smallest vessels with more effective portable extinguishers – expelling water, foam, CO_2, Halon or dry powder.

Portable extinguishers can contain a fire before it escalates. Whilst water-filled extinguishers, for instance, should be directed at the core of a rubbish fire, their effect on a flammable liquid fire would not only be useless – it would spread the fire further. The appropriate agent must be applied to each kind of fire, and in the correct way. Foam (the agent often used to smother flammable liquid fires) should always be aimed at a nearby obstruction and allowed to flow across the burning surface.

The capacity of any portable extinguisher is limited, however, and the backing of a fixed extinguishing system is necessary – as shown in this extract from a Fire Report:

> 'On board a certain passenger/vehicle ferry fitting out in a Spanish shipyard, a workman dropped his cigarette end into a tin of gasolene, which caught fire. He carried the blazing tin into an alleyway, with the idea of dropping it overboard, but was burnt and forced to drop it. Extinguishers were used, without effect. At this stage the sprinkler in the alleyway came into action, and extinguished the fire in a few seconds.'

Automatic sprinkler systems provide the highest level of safety for passengers and crew. A number of sprinkler heads (in ceiling or on exposed pipelines) are situated to protect all areas of risk, and supplied with water under constant pressure (Fig 2). When the air temperature rises to a predetermined level (usually 155°F), liquid in a glass bulb expands, breaks the glass and releases a diaphragm seal to allow water to flow.

The advantage of this system is that only areas of direct heat are wetted – more distant heads remain inactive. The water flow can be shut off by a manual valve (once the fire area has been inspected and declared safe), so water quantities are kept to a minimum and the ship remains as operational as possible.

Sprinkler systems incorporating automatic shut-off are also available but their use is confined to light fire-load areas ashore, and they are not suitable for marine requirements.

Water supply, obviously, poses no problem. Most ships are required under international regulations to have at least two fire pumps with suction inlets, power sources etc, located separately so that one fire will not immobilise both pumps. A simple network of pipes carries the water in sufficient quantity to sprinkler heads, passing through control valves.

Gas

Gas extinguishing systems have proved themselves vital in enclosed spaces, such as machinery rooms, electrical panels, and cargo holds (Fig 3).

CO_2 starves fire by reducing the oxygen content of air. Halon 1301 (a high speed suppression agent, otherwise known as Halogenated Hydrocarbon) contains Bromotrifluoromethane, which interrupts the chemical chain reaction of combustion. Both gases are widely used in machinery spaces with distribution nozzles being placed throughout the protected area.

The effective use of either gas, however, depends upon the area being totally sealed off. Any draughts, open ventilators etc render gas inefficient.

CO_2, being dangerous to humans, involves operating a manual release system with isolating valves. Its advantages over the newer Halon 1301 system lie in lower recharge costs, better worldwide availability and greater design flexibility – although the situation is already changing as Halon becomes more available and economical.

Halon 1301 is far safer for all personnel aboard. Concentrations needed to extinguish flames on most surface burning materials are only 5–7 per cent by volume, so exposure for up to 5 min will cause no harmful side effects. It discharges, and thus extinguishes the fire faster, weighs about 65 per cent less than CO_2, uses much less space, and costs less, both initially and in maintenance.

Fixed foam extinguishing systems are used to smother flammable liquid fires. The foam, working on the principle of excluding air from any burning surface, must be made to flow gently across burning liquid pools. Dropping foam from any height merely serves to agitate and spread the burning fuel.

Outlets are always arranged to discharge foam at low velocity close to the liquid surface. In oil tanks, outlets allow foam to flow down the sides of the tanks.

The production of foam relies on efficient proportioning and discharger equipment. Portable equipment incorporates proportioners in the nozzle and is connected to a foam and water supply by hose.

Training in the application of foam is essential, as misuse could spread fire. Fixed equipment usually aerates the foam in the pipe just before it reaches an outlet.

More advanced foams include AFFF (Aqueous Film-Forming Foam), which seals the liquid surface with a film of water under a foam blanket, and high-expansion foam (with expansion ratios of up to 1000:1), which will totally flood an enclosed area. Breathing apparatus and lifelines are necessary when fire-fighting personnel enter a foam-flooded room, as even non-toxic foam causes disorientation.

Dry chemicals

Dry chemical extinguishing systems provide the quick response and wide-power range necessary to combat Class B (flammable liquids and gases) and Class C (electrical) fires. In marine application, portable, wheeled and fixed dry chemical

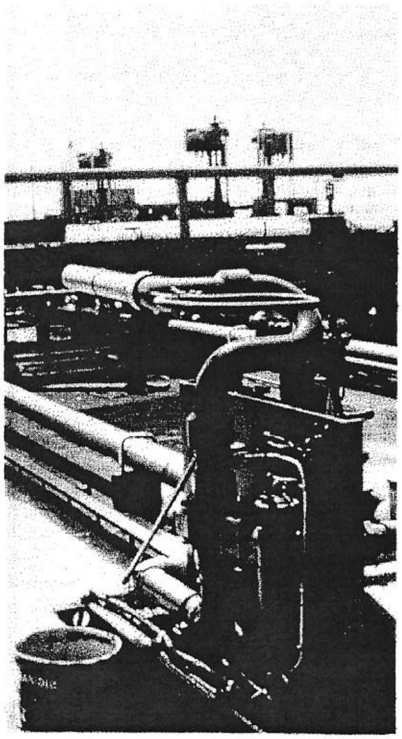


Fig 4: Monitor section of a skid mounted dry chemicals system for pipelines.

systems are found on loading docks, tanker decks, cargo holds, machinery spaces; in fact any area where fuels, flammable vapours or electrical equipment are present and where fire will expand and spread especially fast.

Dry chemicals respond quickly, have the capacity to control unusually large fires, and can be discharged at tremendous flow rates. Most portable and wheeled equipment can be handled by one man, so is applicable to LNG carriers, for example, where the number of crew on board is minimal. Long-range nozzles help distribute the agent over the vast expanse of a tanker deck, and can reach the heart of a fire without endangering the lives of the crew.

A basic skid-mounted system (Fig 4) consists of: a dry chemical agent storage tank; nitrogen cylinder to pressurise the tank and fluidize the agent; hose lines and a nozzle to control and direct the flow onto a fire.

This sytem is useful in carrying out 'first aid' attacks on selected areas, as it can be moved easily.

Alternatively, fixed systems distribute dry chemicals through total flooding, overhead application, tankside application, or a combination of all three. Ships fitted with bow or stern loading arrangements are recommended to keep an additional dry chemical unit (with at least one monitor and hose line) at hand.

The fire-fighting systems mentioned here, once applied by experts to suit differing needs, will protect any ship. However, certain marine categories have their own special hazards, and need extra protection.

British Navy and NATO fighting ships (aircraft carriers, gunboats etc) carry special pre-wetting spray systems that will wash nuclear fall out from the entire superstructure, and cool in the event of fire.

Oil tankers, weighing up to 500 000 t and carrying various flammable cargoes, experience a real danger of explosion when vapours remain in emptied tanks. Therefore, an intrinsic part of their fire protection system are explosion detection devices. One such device consists of a sensitive but stable pressure switch which closes electrical contacts as soon as pressure build-up is sensed. In some conditions, the setting may be as low as 0·1 lbf/in^2g. Another commonly used device is a surveillance detector that senses either the radiation or visible light from an incipient explosion through a photocell of high spectral response. All types activate a suppression system immediately through electronic circuits.

As well as these explosion detectors, most oil tankers install inert gas generators and extra fire protection (ie foam, dry chemical systems on decks and water sprays on all fuel pipes) as a matter of course.

The engine room of a typical bulk oil carrier is recommended to install: thermal and combustion detectors; a fire hydrant pump with hydrant points, hose and adjustable spray nozzles; foam, dry power and CO_2 portable extinguishers; and a fixed system of either foam, low or high pressure CO_2, or Halon 1301.

The accommodation area should have either a thermal fire detection system, or sprinklers throughout, plus hydrant points, water/dry and powder/CO_2 portable extinguishers.

Deck areas need foam/water monitors that combine to apply 0·6 litres/min per m^2 of the deck for a period of at least 20 minutes. These monitors are normally spaced 25 m apart along a central catwalk. Foam proportioning equipment is normally a ratio flow system with pump and storage tank in the aft accommodation, and a pressure proportioning system in the forecastle area. Water pumps in the engine room supply the main system, and an emergency pump in the forecastle supplies the forward system.

Cargo pump rooms should have gas detection equipment with either overhead foam sprinklers, open-nozzle manual waterspray, or Halon 1301. The forward store should have a manually-operated open sprinkler, and the accommodation superstructure needs a manually-operated open drencher to provide a water-curtain if necessary.

Conclusion

Fire prevention and protection is an ever-advancing subject. But one factor will always remain constant: the essentiality of advice and proper training.

Fire-fighting equipment is best supplied by experienced specialist companies who can provide a complete service, from hazard assessment and supply of appropriate equipment to back-up servicing and prompt refill of used agent.

Such companies will also provide training. No amount of detection or extinguishing equipment can help as much as proper crew training in prevention measures, emergency procedures and the handling of equipment.

Foam versus shipboard fire

There is more to foam than bubbles! It offers perhaps the best fire-fighting medium but its efficiency, and therefore, ship safety, is dependent on foam quality, correct proportioning and an effectively positioned distribution network.

Wherever flammable liquids are handled, transported or transferred on board or from ship to shore, fire-fighting equipment must always be instantly available in order to contain and extinguish any outbreak.

Foam is one of the best fire extinguishing media and many types may be made from the range of available concentrates. Foam-making equipment is designed to produce the most effective type for a given risk. Ships require a fluid foam in the machinery spaces so that the area is quickly covered and obstacles negotiated without difficulty. It must also remain stable for as long as possible. Stiffer foams have a longer life and, if tank deck areas are to be protected with manually-operated foam monitors, equipment capable of producing this type of foam can be used to advantage.

Foams are categorised according to the characteristics they exhibit. These factors are termed expansion, drainage and critical shear stress. Foam expansion is the ratio between its volume and the volume of the solution from which it is made. Knowing the expansion figure obtained from a particular foam maker enables foam quantities and depths for given areas to be calculated from a known solution flow.

Quality

The measure of a foam's ability to remain stable is obtained by determining its drainage rate. This figure is arrived at by recording the time taken for 25 per cent of a given sample to break-down and return to its solution state. A poor quality foam will drain quickly and record a figure of under $1\frac{1}{2}$ min.

Critical shear stress is a measure of a foam's stiffness at a particular time, and has units of dynes/cm^2. Foams for boiler rooms, for example, may have critical shear stress values of 150 dynes/cm^2 and those for decks about 210 dynes/cm^2 when using regular protein foam.

Most foam-making concentrates are manufactured from a protein based material which, to date, has proved to be the most resistant to radiant heat. New concentrates have recently been developed which use synthetic compounds and, although expensive, may offer excellent fire-fighting in some areas. Protein foam liquids are dark brown in colour and virtually neutral with pH of 6 to 7·5. Specific gravities of about 1·12, and viscosities of 7 centistokes at 20°C are normal and they are easily handled by pumps and pipework. Foam liquids are manufactured to withstand large variations in ambient temperature without deteriorating and some types may be stored in a diluted state. This condition would be required for a 'premixed' foam installation, mentioned later.

Oil tankers

Several methods for protecting crude carriers are allowed and include inert gas, foam, water spray and steam. Opinions vary as to the best medium to be used although generally, for fighting fire, the choice is between CO_2 and high-expansion foam for machinery space and low-expansion foam for decks and tanks.

Water spraying and low-expansion foam systems require similar pipework distribution networks. Water spray, however, does not offer a permanent fire smothering blanket and therefore the system must continue to operate until all traces of fire are extinguished and cooled if flash-back is to be avoided.

Whereas CO_2 and high expansion foam are total flooding systems, low expansion foam need cover an area only to a relatively shallow depth. Foam offers the very real advantage over CO_2 that personnel need not vacate the machinery spaces before it is discharged. Also, ventilation machinery may be kept running to reduce smoke and heat because dilution air is no problem when applying low expansion foam.

Once foam has been applied and the fire extinguished, it maintains a positive seal and prevents flash-back. Machinery not involved in fire may be brought back into use and the ship returned to some degree of control, depending upon the damage sustained. CO_2 is unable to offer either of these advantages, although flash-back can be prevented, but only if air dilution is low. This, in turn, means that the entire machinery space may remain out of action for several hours until the materials subjected to fire have cooled.

Another problem associated with CO_2 is that of venting the machinery spaces so that there is no danger to personnel of asphyxiation from small pockets of gas at low levels. The natural draught ventilators, connected to flexible hoses, may be used or a large fan drawing gas from the bilge, but both are tedious operations. Foam, on the other hand, may be dispersed by water jets and drained into the bilge where it finally returns to its solution state. It can then be discharged overboard.

CO_2, however, is particularly effective in confined spaces at low level where it would be difficult to protect with foam.

To protect cargo, CO_2, steam or other inert gas or foam can be used provided it is distributed over the surface of the cargo. In addition, a foam or equivalent system is needed to cover the cargo tank decks.

Machinery space

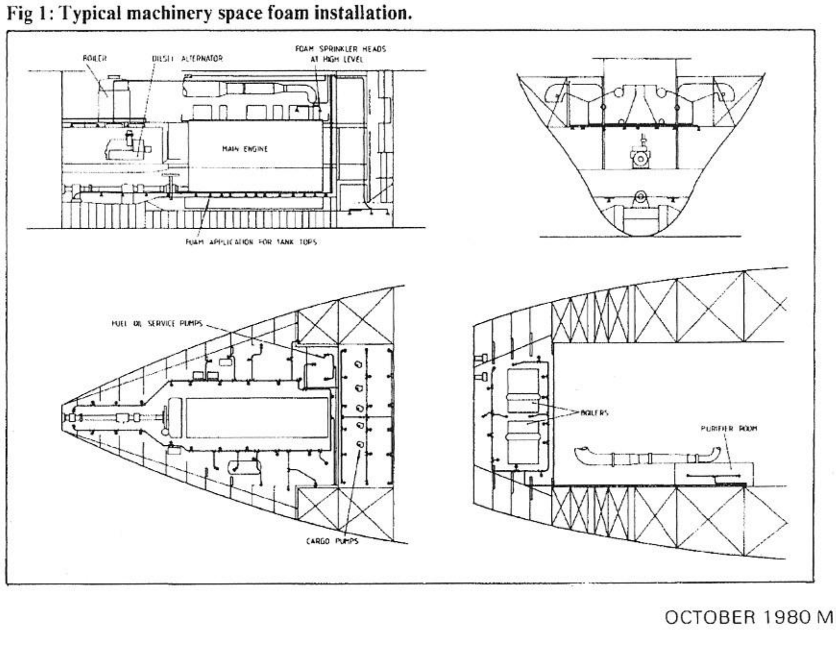
Foam extinguishing systems in these spaces may be likened to those for CO_2, in that a grid network may be employed to distribute the foam solution. Combined foam makers and sprayers are screwed to the end of each pipe run and positioned so that the whole risk area is covered in foam soon after the system is operated.

The machinery space may be divided into zones protecting the cargo pumps, tank top, purifier room and fuel oil service pumps. Each has its own grid network controlled from a distribution manifold so that one or all grids may be operated. This arrangement prevents the otherwise unnecessary use of foam liquid and the nuisance of foam in areas unaffected by the fire.

Fig 1 illustrates a typical foam extinguishing system from which can be seen the protection afforded to the boiler flat, tank top and fuel pumps.

If for any reason a fuel fire occurs above the level of the foam makers, it can be dealt with by portable foam-making branchpipes

Fig 1: Typical machinery space foam installation.



with outputs of 2270 litre/min. This 'at will' equipment should be provided with sufficient hose to enable an operator to reach any part of the engine room. Fig 2 shows one type of foam maker and sprayer as installed in a pump room and Fig 3 shows an 'at will' foam branchpipe.

The only attention necessary to fixed foam makers is to ensure that the strainer is not blocked and this should be checked yearly or after a test run.

Each unit delivers 90 litre/min of solution at 7 bar and produces about 640 litre/min of foam at 7× expansion, enought to cover an area of 9·3 m^2 when positioned 3 m above the floor.

The portable branchpipe delivers 227 litre/min of solution at 5·5 bar and produces 2270 litre/min of foam which it can project a distance of 21 m. The 25 per cent drainage time would be about 3 min. This branchpipe may be supplied with a premixed solution from a foam hydrant or operate from the ship's water fire-fighting solution main and induce its own foam liquid supplied from a container.

Deck systems

It is common for low-expansion foam equipment, which protects the deck and manifold areas, to consist of several monitors fed from a central main. Each monitor is positioned so that the area it covers is overlapped by the next. This arrangement ensures that foam may be applied to every part of the deck and into any deck opening.

Hydrants are positioned half-way between the monitors so that portable branchpipes may be set to work to supplement the monitors if some are enveloped in fire. Other fire-fighting media are not suitable for deck use as they can be affected by wind and do not offer a long-lasting protective blanket.

There are many monitors with various outputs available, some of which are capable of producing 64 000 litre/min with jets projecting up to 90 m.

All monitors should be capable of rotating through 360 deg with adequate elevation and depression. They should also be capable of being locked in any desired position when discharging foam, thus allowing the available manpower to vacate the danger area.

Proportioning

The simplest method of introducing foam concentrate into the water stream in the correct ratio is that shown in Fig 4. This is a pressurised premixed solution supply system and, as its name implies, the foam liquid is mixed with the water when the plant is commissioned. The tank is then sealed to prevent air entering and, when required, the contents are discharged by pressurising the tank with CO_2.

Such systems are usually positioned in the forecastle and/or aft sections at the end of the deck foam main. They are the first systems to be operated in the event of a fire and come into operation rapidly, although their capacity is limited to tank size.

The solution strength is usually 10 per cent by volume which is necessary for prolonged storage. All other systems provide a 3 per cent or 6 per cent concentration and this is adequate when the foam liquid is stored without dilution.

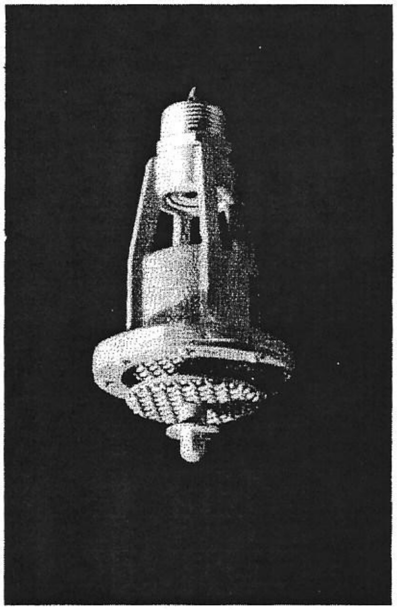
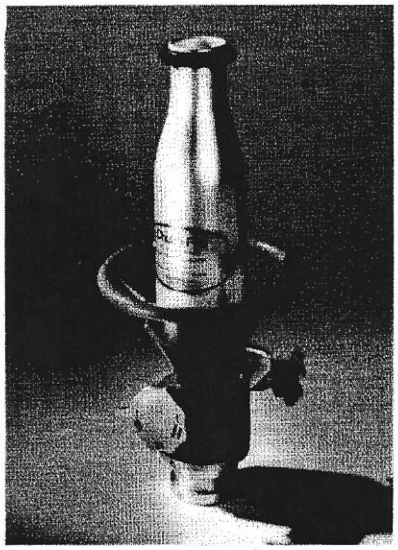


Fig 2: This foam maker and sprayer is typical for a pump room.

The merits of the premixed system are that it is brought into action quickly and has its own energy source for discharging. It obviously maintains a fixed concentration irrespective of the foam maker demand, and a CO_2 metering valve controls the operating pressure which remains constant throughout the discharge. This valve reduces the CO_2 pressure in the bottles to that required by the tank without the freezing problems which are encountered by the use of normal reducing valves.

On the debit side the unit is bulky, heavy and requires a pressure vessel. Because the concentrate is in a diluted state, it needs to be checked regularly to ensure that its properties have not deteriorated.

Fig 3: Portable foam branchpipe with a capacity of 2270 litre/min.



A second method (Fig 5) depicts a displacement proportioner system. This equipment is placed between the fire pump and foam maker network and operates from the pressure drop obtained across a venturi. The system is simple and versatile. It is often used on board ship and for jetty protection as either a single or twin tank system.

In the latter, foam liquid is contained in two flexible bags, one in each tank. When the system is operated a small percentage of the mains water stream is by-passed to the bottom of one or other of the tanks. The by-passed water squeezes the flexible bag which displaces foam concentrate via the perforated syphon tube back to the downstream side of the venturi. When flow increases, the pressure drop increases and more water is by-passed, thus introducing more foam concentrate into the main water stream.

These units are able to supply large foam-making grid systems for periods usually between 15 min and one hour. The system automatically proportions the foam liquid in the correct ratio when the main flow varies due to fluctuations in mains pressure and grid network demand. Several foam grid networks may be connected to this unit and any combination of these may be run from it.

Water flows of up to 13 650 litre/min are currently being catered for, using 3 per cent fluoroprotein foam liquid. A foam output of 73 000 litre/min at 8× expansion, produced from 9125 litre/min of solution, would be sufficient to cover a deck of 21 440 m^2 to a 50 mm depth in 15 min.

As with the pressurised premixed system, this unit requires pressure vessels to store the foam concentrate. However, these are not so bulky nor does the liquid require much attention.

Induction

A cheaper, and in some ways more versatile, method is the 'round-the-pump' inductor system. From Fig 6 it can be seen that the inductor unit is positioned in the pump suction line. Water is discharged from the ship's fire pump and a small quantity bypassed to feed the inductor jet. The velocity of this jet entering the throat of the inductor creates a vacuum condition in the induction port, thus drawing in foam liquid from the tank. The heavily concentrated solution then recovers some of its pressure energy before returning to the pump suction line.

Concentrate induction may be controlled automatically by sensing the flow of water in the suction line. This sensor in turn operates a metering valve which increases the flow of foam liquid as the mains water flow increases, and vice-versa, in the correct ratio. A manual arrangement is often used for high flow rate systems and is especially suited to tug operations. An atmospheric, light gauge, foam liquid storage tank is used which can easily be replenished whilst the system is in use. Thus, if necessary, foam may be delivered to a fire until all the ship's foam liquid supplies are exhausted.

The induction unit is compact and the