SHIP FIRE FIGHTING

BY

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INTRODUCTION

In 1730, the *Navy Regulations and Instructions* contained the following order :—

> ' Such as smoke tobacco are to take it in the Forecastle and in no other place, taking all possible care to prevent accidents from fire '.

The order then goes on :—

> ' and for further preventing such accidents, care is to be taken every night that, immediately upon the setting of the watch, both fire and candle be put out in the cook room, hold, stewards room, cockpit and everywhere between decks, the master-at-arms or some other careful officer being sent out to see the same performed.
>
> ' Nor are candles to be used in any other part of the ship but in lanthorns '.

—or in twentieth century language, No Naked Lights.

A further paragraph in the book, in the instructions for the gunner, reads :—

> ' He is to take care that nobody enters (the powder rooms) with such things about him as may strike fire in falling '.

In present-day orders, special shoes must be worn in magazines, and steel tools are prohibited for the same reason.

By Nelson's time, the regulations about Fire had been amplified, and in the *Regulations and Instructions relating to His Majesty's Service at Sea* of 1806, we read :—

> ' (The Captain) is to be extremely attentive in taking every possible precaution to prevent accidents by fire '.
>
> ' He is not to allow any person to smoke tobacco in any other place than the galley '.
>
> ' He is strictly to forbid the sticking of candles against the beams, the sides or any other part of the ship '.
>
> ' He is strictly to inform the officers not to read in bed by the light of either lamps or candles nor to leave any light in their cabins without having some person to attend it '.
>
> ' He is to direct the carpenter to see that the holes in the decks through which the funnels of the stoves are passed are well leaded '.
>
> ' He is to give the most positive orders and most rigorously to enforce them, that spirituous liquors shall not be drawn off or moved from one vessel to another anywhere but on the upper deck and by daylight only. Any lights necessary for the occasion are to be in very good lanthorns and are to be kept as far from the spirits as possible '.

From these extracts, it is obvious that our naval forbears of 150 years ago were fire conscious and with very good reason. The wooden walls of Nelson's day presented an appalling fire risk. Built entirely of wood caulked with oakum and pitch, rigged with hemp and manilla and with a prodigious acreage of canvas, the ship itself was highly flammable. There were quantities of spare canvas and cordage below, to say nothing of barrels of powder. With no artificial lights but candles, the smoking materials of the crew and rudimentary fire fighting appliances, there is little wonder that fires in warships were frequent and disastrous.

In 1794–1800, for example, there are records of the total loss of six British warships by fire involving the loss of over 1,500 men. These were all accidental fires ; enemy action was not involved—it is difficult to discover whether battle casualties were caused by fire or other damage.

Our knowledge of the fire fighting equipment of those days is scanty. Ships were fitted with pumps of a primitive type and leather hoses were known, but there is no reference to pumps or hoses being used for fire fighting ; it is probable that fire fighting equipment was restricted to buckets and possibly wet blankets or canvas. It was known for the carpenter to be called on to bore holes in the ship's side below the waterline, which must have been a desperate measure.

The coming of steam introduced new fire hazards both from the fuel and the heat sources involved, but the dangers were more than offset by the iron or steel hulls and the fact that, for the first time, power pumps were available for fire fighting. There is therefore a marked fall in the number of fires during the latter part of the nineteenth century. The introduction of oil fuel into the Royal Navy does not seem to have raised the incidence of fires, possibly because the risk was so obvious that precautions were taken from the start.

Although fire must have been a contributory cause of many ship losses in the First World War, there is no information to show whether it was ever a principal cause. The damage and losses through fire were, to a great extent, overshadowed by the explosion disasters of this period. Although not due to fire in its general sense, these losses were in one respect fire losses because most of them were caused by the intense heat-flash from an exploding projectile penetrating to magazines containing cordite, which in those days was seldom in metal containers. By the end of the war, the danger had been appreciated and flash-tight doors and fittings made a magazine explosion unlikely except as a result of a direct hit.

Fire Loss and Damage in World War II

In the period between the two world wars there were few major fires and not a great deal of progress in naval fire fighting. The natural drive for economy put a brake on the development or provision of new appliances and the necessity of observing various treaty limitations made the saving of weight a matter of special importance.

During this period there was little change in ship fire fighting arrangements, which were based on the fire main as the principal medium against fire. Steam drenching arrangements for boiler rooms were introduced about 1926 and, in 1923, trials using foam were started. The growing numbers of aircraft carriers in the Fleet kept up the interest in fire fighting to some extent but, looking back, it is clear that the ships of these years were woefully short of equipment.

It did not need many months of the Second World War to pin-point the shortcomings. It is impressive, however, on looking at the reports of ships which suffered fires to see how often the words, ' Fire extinguished without difficulty ', occur. Even in the early days of the war, such reports were frequent, and bearing in mind the scarcity of equipment, it is apparent that the technique of fire fighting was very quickly learned, and that determination and ship knowledge are quite as important as equipment.

There is, however, a darker side. An accurate assessment of the severity of fire damage in action is impossible. Ships were nearly always damaged in other ways. However, it is estimated that out of the total number of ships sunk, excluding submarines and minor vessels, about 8 per cent were lost primarily because of fire. That is not to say that they were otherwise undamaged, but it is considered that these ships could have been saved had there been no fire. A few examples may indicate some of the lessons that were learned in ship fire fighting in the war.

In 1942, H.M.S. *Arethusa*, a cruiser of 7,000 tons, was struck by a torpedo on the port side forward. The ship took a list of 15 degrees—one can imagine what that meant to fire fighters—and an intense fire broke out, enveloping most of the fore superstructure. The fire was nourished by oil blown over the superstructure by the explosion and by paintwork, wooden fittings and clothing. Of the three pumps which were running at the time, two were immediately put out of action by failure of electric supplies ; within half-an-hour they were running again. The ship's foam equipment was used until all foam compound was exhausted, and first aid appliances were then brought to bear. The torpedo struck at 6 o'clock in the evening ; the report says simply, ' The fire was extinguished by daylight on the following day '. In spite of her injuries, H.M.S. *Arethusa* survived largely because of good training in fire fighting. She was certainly not lavishly equipped.

A sterner lesson was learned in H.M.S. *Southampton*, a cruiser of 9,000 tons. At 3.20 p.m. on 11th January, 1941, she was struck by two or four 500 lb bombs. One or two exploded near the forward boiler room just abaft the bridge structure, the others aft, near ' X ' magazine. Both explosions started fires. The forward fire was soon under control in spite of the fact that only one pump was running and many key men in this area had been killed. The fire aft was never under control. The forward boiler room was out of action and the forward engine room ceased to function. The after engine room, which was intact, had to be evacuated because of the heat of the fire raging above it. The ship was thus left without power. Finally, a further major fire broke out forward due to oil on top of the water in ' A ' boiler room reaching the hot furnace. This was not noticed until the funnel was red hot. Eventually, the ship had to be abandoned and sunk by our own forces. Although this ship suffered severe damage, the primary cause of her loss was failure to extinguish the fires.

There were some losses where it is apparent that nothing could have saved the ship.

H.M.S. *Trinidad*, a 9,000 ton cruiser, was torpedoed in the Arctic and limped into Murmansk where temporary repairs were carried out. She then sailed for home and was struck by two bombs almost in the spot in the ship where she had been torpedoed. The explosion started a major fire just abaft the bridge, cut the fire main and killed the whole of one damage control party (a ship of this size would probably have three or four). Because of continuous attacks by torpedo bombers, the ship had to continue steaming at high speed and this fanned the fire through rents in the ship's hull. As a result of the previous damage, the area was full of timber shoring and, in spite of efforts to clear it, was covered in many places with oil fuel blown into inaccessible corners by the previous explosion. The fire parties were greatly hampered by smoke and the 10 degree list which developed. Eventually, the ship had to be abandoned and sunk by our own forces. In this case, although additional fire fighting equipment might have helped, it is doubtful if anything could have saved her.

There is no space to add further examples. It is a depressing tale, relieved by glimpses of the courage and tenacity with which innumerable fires were fought. However, by the end of the war, the fire losses were considerably reduced. The lessons had been learnt, and these lessons were : first, the vital importance of training in all aspects of damage control, but particularly fire fighting, and the fact that this training should be done as a team, with men working and learning under the officers and petty officers who will lead them in action. Second, there must be good and adequate equipment well distributed round the ship. Third, with the exception of fuel and ammunition, as far as possible everything that will burn must be kept out of warships. Finally—and perhaps the most important of all—every man must know his ship—this is of importance in all aspects of damage control, but nowhere more than in fire fighting, where dense smoke, wreckage and heavy list may accompany every fire.

The Post-War Period

Since the war, there have fortunately been no catastrophic fires in British warships. This is partly due to the excellence of the fire fighting equipment, which embodies most of the lessons of the war, and within the limitations of weight, space and cost, could probably not be bettered by any existing equipment.

An analysis is made and published yearly of all fires that occur in naval ships —the causes, effects and methods of extinction used. In 1955, there were 101 fires reported, of which six were classed as major, eight as medium, and eighty-seven as minor. There was no loss of life or serious injury directly attributable to fire. Welding operations were responsible for twenty-one of the fires reported and the disposal of smoking materials came second with seventeen, followed by the breakdown of cable insulation with eleven. In the last ten years, the use of gasolene in the Navy has been virtually eliminated except in aircraft. This is reflected in the fact that only one minor gasolene fire was reported in 1955.

The analyses, so far, have given no indication that the present equipment or methods are wrong. It must be remembered, however, that in war the causes of fires might be very different. Nevertheless, these statistics serve a useful purpose in keeping the danger of fire to the fore and enabling the Admiralty to issue warnings and recommendations to the Fleet of any dangerous trends in fire risk.

FIRE FIGHTING

Some Considerations

The administrative responsibility for fire fighting in the Navy is vested jointly in the Director of Naval Construction and the Engineer-in-Chief. Of these two departments, the former is responsible for the design and provision of fire fighting appliances and for the use of fire resistant materials, while the latter is responsible for fire fighting methods and for the special training of engineering ratings who form the bulk of the fire fighting man-power of the Fleet.

The basic policy for fire fighting is that it is a matter in which everybody is concerned. This is summarized thus in the *Admiralty Ship Fire Fighting Manual* :—

> ' To meet the menace of fire in H.M. ships, it is essential that all on board should be familiar with the principles of fire extinction and the handling of fire appliances '.

There are no professional firemen in a ship ; for this reason, fire fighting equipment must be simple to use and maintain. It is important that any man who discovers a fire should be able to pick up the nearest appliance and know that it will work. The size and weight of the fire fighting equipment is a matter of concern. A warship has to go anywhere in the world, so that it is no use having fire appliances which require a large number of refills of widely differing types and patterns.

The requirements for equipment can be summarized as simplicity of design and operation, ease of maintenance, small dimensions, and the smallest possible number of refills and replacements.

Fire Protection

Fire protection in a ship involves the provision of fire resistant barriers in the structural arrangements, the elimination of fire causes and the installation of means of detection and extinction. It is more than ordinarily important in a ship that a fire, if it occurs, should be contained and extinguished in the space in which it originates. It was in laying emphasis on this aim for passenger ships that the relevant portions of the Regulations of the International Convention for the Safety of Life at Sea, 1948, marked an appreciable advance on the corresponding section of the 1929 Convention. In warships, which are specifically excluded from the scope of the 1948 Regulations, a fire cannot always be restricted to the compartment where it starts. Action damage, for instance, would probably prevent this. As compared with merchant ships, however, warships have the advantage of a closer spacing of main transverse bulkheads and watertight decks, there is a much greater degree of subdivision, and there is the absence of commodious stairways and long passages. All this is inherent in the purpose for which warships are built, and in practice it adds up to a high degree of fire resistant construction since, generally speaking, the bulkheads and decks are of the standard required for Class ‘ A ’ and Class ‘ B ’ divisions as defined in the 1948 Regulations.

It may therefore be said that as regards the provision of fire resistant barriers, the normal structural arrangements in naval vessels meet requirements, and that emphasis only remains to be placed on fire prevention and the provision of equipment.

Fire Prevention

A warship has to carry a considerable fire-load, some of it extremely hazardous, but much can be done in the way of fire prevention by a reduction of flammable materials and by attention to potential risks in the design stage. This aim is steadily pursued, although it is not always easy in peace-time when the claims of habitability have to be given greater consideration. Where fire hazards cannot be eliminated, an endeavour is made to minimize them by a suitable retardant treatment.

There are many items in a ship susceptible to fire prevention treatment. One of them is paint which, in the past, has constituted a serious fire risk accentuated by the thickness to which it was allowed to accumulate. Fires may be spread into an adjoining space by the spontaneous ignition of vapours from blisters in the paintwork, which in turn ignites combustibles in the vicinity. This hazard has been reduced considerably by applying a fire retardant paint for interior use, based on a gum damar medium, to Defence Specification 1114. Samples of paint are tested for fire retardance in accordance with the procedure laid down in Defence Specification 1053.

Wood, except that specially liable to come in contact with food, and wood spars, derricks, deck planking, and wood in magazines, is given a fire retardant treatment by impregnation. Timber so treated will not propagate a fire nor assist in its development. It will eventually char through, however, if heat is sustained. The possibilities of foamed plastics or neoprene are being considered for mattresses.

In general, linings are not now fitted to the ship's side. The steelwork is insulated with Navy Board made of resin-bonded glass fibre faced with glass cloth which is impregnated with a phenolic resin. The joins are sealed with a glass cloth tape. Wherever possible, fabrics are given a fire retardant treatment by immersing them in an aqueous solution of borax and boric acid in the proportions of 10 oz. of borax and 8 oz. of boric acid to one gallon of water. As the deposits are soluble in water, reproofing is necessary whenever the material has been laundered or exposed to damp. Plastic coated fabrics are pre-treated by the inclusion of a fire retardant medium, such as antimony oxide, in the plasticizer. Glass-wool fabrics have low abrasion resistance and therefore have not been introduced.

Electric cables, at present, are insulated with natural rubber or varnished cambric with a protective sheath of neoprene. This gives protection against small fires. Cables in later ships will be given a more complete protection by means of silicon rubber and glass fibre or tape insulation, again with a neoprene protective sheath.

The Fire Main and Its Pumps

In an age which can provide extinguishing media ranging from halogenated hydrocarbons to plain sodium bicarbonate, water still remains the most effective agent in general use for dealing with a fire. Water requirements for fire fighting take into account the possibility of having to fight major fires and spray a block of magazines concurrently.

Over the years, the tendency has been for bigger and better fire mains and smaller and better pumps. In the last war it soon became apparent that pump capacities and fire main pressures were inadequate and that existing jet nozzles absorbed so much water that the concurrent use of a small number led to overall inefficiency of the fire fighting system. Steps were taken to increase the standard working pressure from 50 to 75 lb/sq in by providing higher duty pumps in larger numbers. At the same time the nozzles were reduced in size and, as it had become evident that something more than plain jets was required, ships were also supplied with nozzles which could give either jet or spray.

Fire mains today run to 3½ in. in frigates, and up to 6 in. in large ships, with respective total pump outputs of 160 and 1,500 tons an hour. At the outbreak of the war, pumps could only be started locally, but war experience showed the necessity for a remote control position on the lowest communication deck. War casualties also indicated the need to maintain pressure in the fire main at all times by running some of the pumps continuously. This was at first resisted on the grounds of excessive maintenance and the danger of pumps becoming overheated. However, the latter problem was solved after careful tests by fitting leak-off arrangements which give a constant discharge flow of 4–5 gallons per minute from each pump.

Fire hydrants in ships in 1940 were few and far between. Later ships were more generously equipped on the basis that a fire in any compartment should be capable of being dealt with by a 40-ft length of hose from each of two hydrants. To achieve conformity with the Shore Fire Service, whose co-operation with ships in ports was often essential, the 2½ in. instantaneous coupling to B.S.S. 336 was adopted in new construction, replacing the bayonet joint connection.

The standard working pressure for future carriers and cruisers will be 100 lb/sq in and it is likely that this pressure will be adopted for other ships in view of the contemplated use of eductors for general suction duties. The higher pressure will lead to greater fire fighting efficiency without a marked increase in water consumption, since a general purpose nozzle has recently been introduced which has a smaller water capacity than its predecessor. This is an aspect which has to be borne in mind in all ship fire fighting, to lessen the risks arising out of loose water. Having provided for high working pressures in fire mains, it becomes another problem to maintain them in face of deterioration of the pumps and piping systems. Maintenance can partially cope with the first, but the second is an ubiquitous marine problem, the solution of which is still being sought. Copper-nickel-iron has been adopted for the piping concerned. This material has a good resistance to impingement attack at acute bends where water velocity increases considerably, and it has a close relationship with the gunmetal still used for valves. The possibilities of aluminium bronze are also being investigated. Trials have been undertaken of a system for injecting sodium hypochlorite into fire mains to prevent fouling by animal life, but the associated difficulties may make this method impracticable. It may well be that the ultimate solution will be plastic piping.

At present, pumps supplying the fire main can also serve the suction main via a suction valve chest, but the trend is towards single duty pumps with drowned suctions, and the use of portable pumps to deal with purely pumping problems. This will involve the abolition of self-priming arrangements, and also of the suction main. All recent pump developments have involved smaller and lighter units with improved performance.

For a long time hoses supplied to the Fleet have been of unlined canvas, which has the disadvantage of being liable to damage by abrasion, has a tendency to deteriorate in spite of rot-proofing treatment, and has a fairly high resistance to flow as compared with smooth bore hoses. It has recently been decided to introduce rubber-lined hoses and trials are being carried out on a plastic hose with a P.V.C. cover and lining fused on to a synthetic reinforcing fabric, for which great claims have been made.

The standard hose size is 2¾ inches. War experience showed that with a hose of this diameter the very restricted space available for fire fighting below decks made manœuvrability extremely difficult and so it was decided to use a 2 in. diameter hose in such congested areas. It is hoped that when the rubber-lined hose is in service, it may be possible to effect an all-round reduction in hose diameters.

Foam

For dealing with fires involving flammable liquids, foam probably constitutes the most effective extinguishing medium and has been used in H.M. ships since about 1923. At that time it was of the type produced by the chemical reaction between aluminium sulphate and sodium bicarbonate, in powder form, when mixed with water. The installations were capable of continuous operation and were supplied with water from the fire main at a pressure of 25 lb/sq in.

Early in the war attention was drawn to the superior qualities of mechanical foam, and twin tank generating units were installed in ships which carried gasolene. Their operation, however, was a little complicated, and there were mechanical difficulties, notably through gumming-up of valves in contact with the liquid foam compound. As, by this time, the value of foam application was being more fully realized, it was decided to introduce equipment on a more lavish scale and to change to the much simpler method of generating it by using foam branch pipes in association with suction pick-up assemblies. There are no moving parts in this system and therefore few maintenance requirements, other than washing through after use.

Mechanical foam is produced by turbulently mixing the three constituents in a foam branch pipe. The aerated product consists of about 12 per cent water and 88 per cent air. A gallon of water can be converted to six or eight gallons of foam according to the design of the branch pipe.

The foam compound used is a protein liquid usually derived from hoof and horn material, or from hydrolized blood. Slaughter-house refuse is the description euphoniously applied to the basic ingredient.

Mechanical foam consists essentially of a homogeneous mass of air-filled bubbles which possess sufficient tenacity to provide a resistant blanket screening the surface of the burning liquid from the heat which radiates from the fire, thus reducing the evolution of the vapours by which the flames are fed. For some time after its introduction, there was some belief that the air content would feed the fire. However, it is recorded that successful tests were carried out with foam filled with oxygen, so no doubt the disbelievers were converted.

Most warships which have a reasonable pumping capacity are supplied with foam branch pipes operating off the fire main. In view of the possibilities of action damage they are required to work satisfactorily at pressures down to 35 lb/sq in. Outputs vary according to size, ranging from 350 to 450 gallons per minute of foam in the type most commonly used, to 800 gallons per minute in the case of those intended for use on flight decks of aircraft carriers. A fairly stiff foam, that will stay where it is wanted, is generally required, but in the machinery bilges, which have obstructions, a free-flowing blanket is necessary and this is provided by means of a special branch pipe which generates a sloppy foam with a somewhat higher water content. A typical aircraft carrier has twenty-eight larger type appliances on the flight deck, fourteen of the same type in the hangar, twenty-six sloppy foam producers for machinery spaces and five of the smaller 350/450 gallons per minute variety placed around the ship for dealing with flammable liquid fires outside machinery spaces.

Spray Systems

Spray systems are fitted in those compartments in a warship where a severe hazard exists and where an early and overall attack is essential to prevent an incident becoming catastrophic, e.g., magazines, oxygen compartments, gasolene control compartments, flammable stores, spirit rooms and hangars in aircraft carriers.

Some of these compartments, notably magazines, are also fitted with flooding arrangements, but the protection so provided is not fully effective until the compartment has been filled. It is required that magazines can be flooded direct from the sea in fifteen minutes with the ship floating at the load waterline, but this is a long time for a fire to rage. Spraying gives immediate protection and its effect on buoyancy and stability is less drastic. Furthermore, it does not necessarily put a magazine out of action. When flooding is carried out, spray valves are, or should be, operated first. Spraying is also a valuable preventive measure in the event of a fire in an adjoining space.

Except in hangars, all spray systems fitted in naval vessels operate off the fire main and water requirements for this purpose are taken into account when pumping capacity is being determined. Systems are normally non-automatic, the grids being fitted with $\frac{1}{2}$ in. orifice sprinklers, usually spaced 7–9 ft apart. In magazines, care is taken to ensure that the tops and fronts of stowages can be well wetted as well as bulkheads. Under fire fighting conditions, a pressure at each sprinkler of between 10 and 15 lb/sq in can be realized and this is sufficient to ensure complete coverage throughout the compartment. Control valves can either be operated locally by hand, or remotely by rod gearing and handwheels. In the latest ships, spray valves can be operated hydraulically from two remote positions as well as manually at a local position. It is relevant to note that one of the lessons learned in the last war was the danger of fitting aluminium handwheels which were liable to melt if involved in a fire.

With the introduction of more advanced weapons, involving an increase in the combustibles carried in the associated magazines, it has been decided to introduce electrically-operated fire detectors, and an automatic spray system in the spaces concerned. The detection system selected is based on rate of rise of temperature, and as soon as a detector functions a relay causes the solenoid spray valve to open.

Spray systems, except those fitted in hangars, are dependent on the fire main and this could be a serious disadvantage in the event of action damage. There seems no easy way out of this difficulty, but some work has been done on a scheme for spraying magazines sited low down in the ship, direct from the sea. It has been demonstrated that with heads of water as low as 4 feet, spraying requirements can be met provided an efficient means of distributing the water can be devised. The obvious advantage of direct sea spray is the unlimited availability of water, although problems of heel and trim in damage conditions would clearly have to be considered when defining the minimum head acceptable in the intact condition.

Automatically operated spray arrangements are fitted in the passenger accommodation spaces of the Royal Yacht *Britannia*. The system is similar in all respects to that fitted in passenger ships. The sprinkler heads are of the quartzoid bulb type. The bulb is frangible and is nearly filled with a highly expansible liquid. When fire occurs, the heat causes the liquid to expand, shattering the bulb and releasing a valve, thus allowing the water to pass. Systems such as these contain water right up to the sprinkler. Initial water supplies are from a tank containing about 500 gallons of water pressurized with air to 100 lb/sq in. As the water level in the tank drops, a centrifugal pump, taking suction from the sea, automatically cuts in. A feature of the automatic system as fitted in *Britannia* is that only those sprinkler heads affected by the fire are operated. Sprinkler systems of this type are essentially first-aid appliances, the aim being to deal with a fire in its very early stage.

Machinery Spaces

Even in a congested engine room a fire probably starts in a small way, so first-aid fire fighting appliances are kept handy. These are two-gallon foam extinguishers fitted with short hoses because of the probability that fires will be inaccessible.

There are fire hydrants in all main machinery spaces and hoses attached to them. Since fires in these compartments are always likely to involve oil, a special branch pipe is provided which gives a spray only.

With this equipment it is considered that all but very large fires can be extinguished. Machinery space fires can very rapidly become uncontrollable by ordinary means, so further arrangements are made by which the fire can be fought after the compartment has been evacuated.

In every machinery space, tubes are built into the structure, extending from the deck at the crown of the compartment, or thereabouts, down to about 4 feet from the bilge. Four tubes, roughly at the corners, are normally fitted to a large compartment and one or two in a small one. If the compartment has to be evacuated, foam can be poured down these tubes, using the ship's main foam appliances, until the compartment is almost filled with foam—it would, of course, be expected that the fire would be out long before this. The tubes are directed against a bulkhead or other flat surface at the bottom and holes are left at the top to allow the foam to escape if the bottom of the tube is submerged.

The second major appliance is a steam drenching system, by which steam can be distributed over the machinery space through open-ended pipes near the crown of the compartment. The valves for operating this system are outside, or just inside, the compartment.

Arrangements are also fitted for shutting off the fuel supply to the boilers from outside the compartment.

A new problem has arisen with the advent of boilers totally enclosed in their own air casings. It has always been well known that the area under a boiler presented a particularly acute fire risk—especially if, as sometimes happens, a certain amount of oil accumulates there. With enclosed boilers, this fire is inaccessible and could easily damage boiler casings seriously before it could be reached. Ships with this type of boiler are now having a permanently fixed foam installation fitted in the boiler room which will discharge foam into the air casing of the boiler through a fixed pipe system. The extra weight and space is regarded as justified for such a potent source of trouble.

The foregoing arrangements are designed for steam-driven ships with oil-fired boilers. Until recently, the Navy had few Diesel-driven ships except submarines, but with the introduction of Diesel-driven surface warships and possibly of gas turbine ships, it has been necessary to seek an alternative to steam drenching. The first-aid and major foam arrangements remain as they are.

With a certain amount of reluctance, it has been decided that Diesel ships must have a CO_2 drenching system. The reluctance is not due to the medium itself—there is no finer non-toxic extinguishant than CO_2, but this has the disadvantage of being a one shot system. It could be made a two-or-more shot by having more bottles, but the weight cannot be accepted. The CO_2 system has not been made automatic nor is it allied to an automatic alarm, because the machinery spaces are frequently patrolled when not in use and automatic devices are open to failure in action or under the effect of underwater explosions, or even the ship's own gunfire.

The question of automatic alarms has been reconsidered recently because the machinery in new construction is designed for operation from a remote machinery control room. However, this is really a battle arrangement and, although it will also be used in peace-time, the engine room will then be patrolled, if not actually occupied. In action, the machinery spaces may be deserted for some time, but there will be small windows for visual inspection and a complicated system of alarms does not seem to be justified.

Fire Fighting in Small Craft

The large numbers of small vessels in the modern Navy have their special problems. Many craft are driven by machinery using high octane gasolene and they are frequently constructed of wood or other combustible material. Weight and space limitations are particularly severe.

Practically all our small craft are fitted with a fixed installation using methyl bromide. A typical layout consists of four 24-lb cylinders of compressed gas communicating with pipes led to the engine room and the gasolene tank compartment and arranged for remote operation from the entrance to the compartment and from the bridge.

Because of its toxicity, methyl bromide is being replaced, in the same installation, by chlorobromomethane mixed with 20 per cent freon. Although CB/freon is safer than methyl bromide, it is still toxic on a fire. Investigations are in progress to evaluate the use of dry chemical on small ship fires. It is certainly effective on the fire—it also stops the engines.

Closely applied to the problem of small ship fire fighting is that of submarines, where the outstanding feature of fire fighting is that in every compartment there is electrical apparatus which is vital to the existence of the ship. Gas/water extinguishers are provided for first-aid fire fighting and specially insulated hand foam extinguishers are available for dealing with small oil fires. In anything approaching a major conflagration, the most effective measure is to seal the compartment and smother the fire—that is, of course, much easier in a submarine than in any other ship. A major fire in a submarine is not very probable. The men in the vessel are working, living and sleeping in every compartment and it is almost impossible for an outbreak to be undetected. In action, for obvious reasons, fire is less likely than flood.

SPECIAL HAZARDS

Avgas Stowages

Avgas, or gasolene, is one of the most dangerous flammable liquids in general commercial use and constitutes a special hazard when carried in a ship. The flashpoint, the temperature at which the liquid gives off sufficient vapour to form an ignitible mixture with air, is always well below normal ambient temperature. The vapour is much heavier than air and may flow or drift a long way from the liquid source, and if the train of vapour encounters a flame or other form of heat a flashback will occur resulting in the ignition of the liquid source with, possibly, an explosion. It must also be realized that a cupful of gasolene has the potential explosive effect of 5 lb of dynamite ; that one gallon yields about 25 cu ft of pure vapour, which is sufficient to produce nearly 2,000 cu ft of a flammable mixture ; and that the optimum concentration will give an explosive force of 120 lb/sq in. During the war, every navy suffered loss directly attributable to damage to gasolene stowages. So far as the Navy is concerned, it is a happy thought that the introduction of jet aircraft using kerosene as fuel will mean a very great reduction in shipboard hazards. However, since the turnover to jets is not yet complete, the risks associated with gasolene must continue to be met.

Stowage of gasolene in warships is mainly restricted to aircraft carriers but there are some other vessels, such as surveying ships and landing craft, which require to carry this fuel in bulk. Until recently, the stowage in carriers consisted of drum type tanks fitted in the fore end of the ship below water level, piping connections being made flexible enough to allow for a certain amount of vertical movement as a result of shock. These gasolene compartments were not in the first place kept filled with water, but as a result of an explosion in 1936 in the Italian cruiser *Goritza*, which carried drum tanks of gasolene in the fore peak, it was decided to keep them permanently flooded in war-time. This later became peace-time practice. To meet operational requirements for an increased stowage of gasolene, bulk stowage has now been adopted, with welded tanks forming part of the ship's structure. Surrounding each tank is a ventilated cofferdam fitted with a number of small bore tubes through which samples of its atmosphere can be drawn for test by explosimeter. Cofferdams can, in an emergency, be flooded direct from the sea. Ventilation is by fan exhaust and natural supply, with duplicate exhaust fans each having sufficient capacity to give twelve changes of air per hour. It is interesting to note that the Joint Committee on Fire Grading of Buildings which recently investigated the precautions necessary against fire and explosion in underground car parks, recorded that the lower limit of flammability would not be reached until 100 per cent of the floor area was covered with gasolene, provided the ventilation was at the rate of ten changes per hour.

An alternative method of protection by inerting the cofferdam with the nitrogen by-product from the oxygen-producing plant in the ship has been considered. This, however, involves complicated and vulnerable instruments for the detection of gasolene vapour in such an atmosphere and for the determination of the degree of inertness provided.

Although the ventilation method is thought to be slightly less positive than inerting, its simplicity is greatly in its favour, and it is therefore likely to be retained in H.M. ships, especially in view of the diminishing requirements for gasolene stowage.

Air driven portable pumps and fans are supplied to clear away liquid gasolene or gasolene vapour in compartments affected by action damage involving gasolene stowages. The pumps weigh only 56 lb and, when operated at an air pressure of 80 lb/sq in, each will deliver 140 gallons per minute through 50 feet of hose to a height of 40 feet, with correspondingly greater outputs at a reduced lift. The pumps and fans are operated from the L.P. air system.

Flight Decks

In older carriers, flight deck hydrant pressures are, generally speaking, low. Water supplies in these vessels are taken from the ship's fire main ; when this is new and with the pumps working at full speed and all extraneous services shut down, a reasonable pressure of 50–55 lb/sq in can be realized. In practice, however, pumps are seldom run at full speed, domestic and other requirements from the fire main fluctuate considerably, and the fire main system, including the pumps, tends to deteriorate in efficiency. Pressure at flight deck hydrants therefore tends to be low, often approaching the minimum necessary for the satisfactory operation of foam branch pipes. The latest carriers will have a special flight deck fire main not connected to the ship's fire main or any other service, and supplied by three or four independent pumps used for no other purpose and capable of giving 100–110 lb/sq in at flight deck hydrants. It is intended to use an in-line inductor at each hydrant, the loss of pressure across it being acceptable since 60–70 lb/sq in will still be available at the branch pipe.

Hydrants on flight decks are sited at 60-ft intervals at each side of the ship, to give ample coverage. They are fitted in convenient positions in walk-ways and in the vicinity of the island, together with the associated hoses, foam branch pipes and drums of foam compound. In existing carriers, where the foam compound is induced at a branch pipe on the end of a line of hose, the drums of compound must be trundled across the deck. In carriers fitted with in-line inductors, the drums of foam compound will remain at the hydrant position, the compound itself being induced by means of a short length of suction hose connected to the inductor.

The branch pipes in older carriers produce 800 galls. per min. of foam· With the increased pressures available in vessels fitted with the separate flight deck fire main, it will be possible to introduce an improved appliance generating 1,050/1,100 galls. per min., with the added advantage of a special flaking device by means of which a snow-fall effect can be produced, as well as the normal jet. Directing jets against the fuselage of a burning aircraft leads to a considerable run off. The flaker will, if conditions are right for its use, help to conserve foam by ensuring that most of it falls on the fire.

It is usually reckoned that about 45 seconds is the maximum time available in which to rescue a pilot from an aircraft crash fire. Until recently, rescue equipment consisted of a wheeled unit carrying a 40-lb. cylinder of CO_2 at 850 lb/sq in. The gas provided protection to the rescue personnel. For some time, however, it has been thought that CO_2 was not the best medium for the purpose and carriers have now been equipped with mobile units, each containing 150 lb of dry chemical which can be discharged through a 50-ft length of hose by compressed CO_2. The standard dry chemical is sodium bicarbonate, although other and, reputedly, more effective powders are available. A cloud of powder discharged under pressure has a remarkable extinguishing effect and also provides excellent protection from the heat of the fire to the personnel operating the unit.

Hangars

In naval phraseology, hangars are known as dangerous areas. They are more or less enclosed spaces with centre line lifts, in most carriers. Lifts are normally fitted with gas seals. A gasolene fuelling line runs each side of the hangar with fuelling points at intervals. Except when aircraft are being fuelled or defuelled, the lines are empty, but during fuelling operations with the lines under pressure and aircraft tanks full, there is always the possibility that leakage or spillage of gasolene or gasolene vapour may occur. Every precaution is obviously necessary to avoid the presence of a source of ignition.

During fuelling or defuelling, aircraft are bonded to the deck, and the special hoses for the purpose are bonded to the aircraft. In order to provide suitable facilities for maintenance work in hangars, two security conditions are observed, (i) Fuel Danger State, and (ii) Fuel Stowed State. Generally speaking, the Fuel Danger State is proclaimed during fuelling and defuelling, when spraying with dope, if a leak has been discovered, or if fuel has been spilled.

Hangars are kept well ventilated at the rate of twelve changes of air per hour, with forced exhaust and natural supply. The system is separate from the ventilation of any other part of the ship. Fans are fitted with flame-proof motors and special arrangements are made to prevent sparking in the event of fan rotor blades touching the casing. It is general experience that under normal ventilated conditions there is little danger of gasolene vapour collecting in explosive quantities. The last reported instance of an incident in a hangar arising from gasolene was in 1946.

All the foregoing relates to fire prevention, which is the basis of all fire protection. Should an incident occur, however, equipment to combat it is well disposed about the hangar. Fire hydrants are spaced port and starboard, usually with double hose connections. At each hydrant is stowed a large-size foam branch pipe, drums of foam compound, an 80-ft length of hose and a jet spray nozzle.

A spray system is also fitted in the crown of the compartment, consisting of a series of non-automatic ½-in. flat star sprinklers arranged 10 feet to 12 feet apart. The sprinklers are supplied through a suitable piping system by three or four single-speed centrifugal pumps sited below the waterline. The pumps can be operated by switches in each hangar access lobby and from a Hangar Control Position. Spray valves are operated by large handwheels in the access lobbies. The capacity and delivery pressure of the pumps is such that any two sections of a hangar can be sprayed concurrently with an average sprinkler flow pressure of about 15 lb/sq in.

Essential features associated with the hangar spray system are the fire curtains and the scuppers. The fire curtains are of reinforced asbestos cloth and can be either hand or power operated. They divide the whole hangar into sections 120–160 feet long. Their function is to afford a firebreak and also to reduce the air supply to a fire. At one time, the fire curtains were roller shutters made of steel slats, but war experience showed that an explosion in a hangar could disintegrate the slats, and cases were reported of serious casualties among personnel from flying fragments. Asbestos curtains are not susceptible to this hazard and also respond more easily, without being damaged, to changes in atmospheric pressure when spray is used on a fire.

Adequate scuppers are fitted in view of the large area which can become flooded. In order that they can function adequately, they are provided with long perforated covers as a protection against choking by debris.

SOME GENERAL ITEMS

First-Aid Equipment

Shakespeare said that ‘ a little fire is quickly trodden out, which, being suffered, rivers cannot quench ’. On a lower level of phraseology, most fires if tackled at once can be dealt with by hand appliances, if these are available, together with personnel trained in their use. It is the aim in H.M. ships to provide both these requirements. Neither of these, however, was conspicuously present in the Fleet in 1939. There were chemical foam extinguishers in boiler rooms and a few carbon tetrachloride appliances for wireless rooms. Elsewhere there were buckets of water, but these, although useful, were inadequate for coping with the many small fires which so often followed a shell or bomb explosion.

The position was radically altered by introducing a water-type portable extinguisher into the Service in sufficient numbers to provide good distribution and by increasing the allowances of those types already in use.

In the Fleet today foam-type extinguishers are supplied to cover flammable liquid risks, water-type for carbonaceous fires and CO_2 for electrical fires. This is more or less in accord with practice in merchant ships.

No piece of equipment is accepted for use in the Fleet without undergoing extensive trials at the Admiralty Fire Test Ground at Haslar. Although there has been no marked change in design of portable extinguishers for several years, considerable work is now being carried out by various commercial interests on the development of new types.

Portable Fire Pumps

Early in the war it became clear that there was an urgent requirement for a self-contained pump for fire fighting. Before 1939, the only portable pumps carried in warships were small motor-driven reciprocating pumps of 5 tons per hour capacity, and electric submersibles of 50 tons per hour capacity. The first were too small for most purposes and the second very heavy.

Both these types suffered from being electrically driven ; if the ship lost power they were therefore useless and, at this time, there were many ships in service which had only steam-driven generators. Damage to the steam installation in one of these ships, if it started a fire, could cause the loss of the vessel from fire alone, since without steam no pumping capacity was available.

There is, moreover, in war—and indeed in peace—a fairly frequent demand for a fire pump to be sent to another ship, or away in a boat as an improvised fire float, or to be landed for fire fighting or salvage work, and for any of these duties the pre-war pumps were useless.

It was therefore agreed that a self-contained pump must be provided and, as it was necessary to do away as far as possible with gasolene engines, it was inevitable that the new fire pump should be Diesel-driven. The pump selected was two cylinder Diesel-driven, with a capacity of 27 tons per hour at about 50 lb/sq in discharge pressure. It has proved to be robust and reliable and well up to its work. Ashore and afloat it has extinguished fires and pumped out floods all over the world, and practically every ship in the Navy from frigates upwards has at least one of these pumps. Its serious disadvantage is in its weight and size. It weighs 625 lb and is about 4 ft 6 in. × 2 ft 6 in. × 2 ft 3 in. It is difficult to manhandle between decks—almost impossible if the ship is listing—and with the increasing congestion of the modern warship, it is virtually immobile unless stowed on the upper deck.

As a last resort, most small ships are provided with a two-man manual pump capable of operating one quarter inch nozzle at 30 lb/sq in., principally intended for use with an FB(O) foam-making branch pipe. This pump is readily portable and can be used anywhere, provided the suction lift is not more than about 10 feet.

As a result of complaints from sea about the weight and clumsiness of the Diesel fire pump, efforts are being made to find a substitute. A Diesel pump weighing about 400 lb looks the most promising and is undergoing trials at present. It is unfortunate that because of the fuel fire risk, use cannot be made of the many light and efficient gasolene-driven pumps available. As a second string, trials are being started on a gas turbine driven pump, which only weighs about 200 lb and the containing cradle is 2 ft 10 in. long × 1 ft 9 in. wide × 2 ft 2 in. deep. It has an output of 150 tons per hour at 100 lb/sq in and is simple to start and run ; but it has two disadvantages—the noise, which is probably acceptable in emergency, and the exhaust gases, which are not. The simple exhaust hose solution is impossible because of the temperature. The possibility of cooling the exhaust sufficiently to make a hose practicable is being examined.

A development which has rendered portable pumps of less vital importance is that in many new construction ships at least one of the ship's Diesel generators is fitted outside the main machinery compartments. This means that a total loss of electric power is much less likely and there would seem to be a case for a reduction in the number of pumps carried. The Diesel pumps cannot all be got rid of because experience has shown their value for use outside the ship—indeed, they have been used much more for this than inboard.

Personal Equipment

During the last seventy years, much thought has been given to the personal protection of men engaged in ship fire fighting. The object was to devise a garment easy to put on and wear, which would enable a man to approach sufficiently close to a fire to have the best chance of putting it out. It is not intended in ship fire fighting that a man should be able to go into the flames. After many trials and experiments, nothing has been found better than fear-nought, usually in the form of a loose jacket and trousers. It is durable and easy to stow ; it can be worn, with some discomfort, for quite long periods and it is cheap. It gives good protection in a fire and although it will char it burns with difficulty, especially if given a fire retardant treatment.

Fearnought gauntlets are worn with this suit. Special anti-flash gear consisting of a steel helmet and hood is supplied for protection from flash burns in action, and this equipment is also used for fire fighting. The equipment can be worn over the salvus or smoke mask face-piece.

Practically every fire in a warship is accompanied by very dense smoke, usually black, which no light will penetrate. Although various forms of emergency and portable lighting are available, men in fire parties must be trained to move about in darkness. Ship knowledge is essential.

In addition to obscuring the vision, the dense smoke makes breathing difficult or impossible. Warships are provided with two kinds of breathing apparatus ; the salvus—a self-contained oxygen set—and the smoke mask, which is a service anti-gas respirator face-piece attached to a long tube which can be led away from the smoke to a clear atmosphere.

The salvus is a first-class piece of equipment, comfortable to use and with a good endurance. Unfortunately, it is not very easy to operate and requires a trained wearer. For this reason a compressed air breathing apparatus is being developed which, it is hoped, will be simple to wear and have a fairly good endurance. Logistically, it will be an improvement, since refills of air are available wherever there is a compressor.

The smoke mask has recently been modified by replacing the face-piece with one similar to that used by shallow water divers and it is hoped that this will give better vision.

One refinement of the smoke mask is that in ships with L.P. air supplies, a connection is provided in the boiler and engine rooms to enable men on watch to connect their face-piece to this air supply and continue their work even though the boiler room is full of smoke. This arrangement was provided after several boiler rooms had to be abandoned because of smoke, although caused by a comparatively minor fire elsewhere in the ship. In most existing boiler rooms, of course, it is impossible to shut off the air from the fans as this is also the combustion air.

Training men in the use of breathing apparatus and smoke masks can best be done in their own ships. A popular method is to arrange a suitable obstacle course and then put the victims in the salvus or smoke mask with the eyepieces blacked out. This gives the wearer practice in feeling his way round, while his instructor can prevent him from coming to any harm. It is also vastly entertaining to the onlookers.

Training

Every officer and rating receives during his initial training a short course in the basic principles of A.B C.D., including fire fighting. Of necessity, this training is elementary and must be backed up by ship training at the earliest opportunity. It is impossible to over-emphasize the importance of training men in their own ship under their own senior ratings. Ship knowledge is all-important. Most men can be taught in a few minutes how to put out quite a large fire in a tray in the open with extinguishers ready to hand. To extinguish a much smaller fire in some inaccessible part of a congested warship is a very different thing unless men are thoroughly familiar with the ship and its equipment.

Some instruction in aircraft fire fighting is given at fire fighting schools, but the Fleet Air Arm has its own fire fighting section in the School of Aircraft Handlers at Gosport, where instruction is given in the technique of aircraft fire fighting ashore and afloat. Although strictly the subject is outside the scope of this paper, it should be mentioned that the organization for fighting aircraft fires on board ship is separate from the Damage Control organization. Its man-power is drawn from aircraft handling ratings of the Fleet Air Arm and the methods used are similar to those used ashore, except that mobile crash tenders are replaced by equipment operated from a flight deck fire main system.

Cold Weather and Arcticization Arrangements

Ships which operate in cold weather or under arctic conditions are as liable to fires as any other ; perhaps more so, since there is much greater emphasis on heating. The problem is to ensure that water and appliances can be used in the temperatures likely to be experienced. Admiralty requirements are based on 25 degrees F. for cold weather and 10 degrees F. for arctic conditions, but it is possible that the latter figure will be superseded by a new N.A.T.O. standard.

The cold weather arrangements can be described briefly in general terms. Exposed pipes and flanges and spraying arrangements are lagged, as are the ring main and rising mains of hangar spray systems. Weather deck hydrants are fitted with an additional valve in the supply branch, well inside the main structure, so that exposed lengths of piping can be drained. Alternatively, these hydrants are fitted with steam coil heating and both pipe and steam coil well lagged. The latter method is used for flight deck fire hydrants. Where necessary, stowages for foam and water-type portable extinguishers are insulated and fitted with steam heating. This treatment is also applied for drums of foam compound at exposed hydrants. The arctic precautions include the foregoing, with the added requirement that fire pumps must take their suctions from the discharge side of the main condenser or drain cooler or similar discharge, so that warm water can be delivered to the fire main. Where the extreme fore and after ends of the fire main are exposed, ½-in. diameter leak-offs are fitted to ensure a continuous circulation of water. The leak-offs discharge either directly overboard or into a scupper with a warmed storm valve.

Air escapes and ventilation openings to gasolene compartments and compartments which contain other low flashpoint liquids are fitted with anti-flash gauzes, with steam-heated coils to keep them free from ice, the coils being shrouded from the direct influence of wind, snow or spray.

Standardization

Because it is desirable for all three Services to use common equipment if this can be arranged, and since at present this is by no means the case, an Inter-Service Committee is considering the possibilities of standardization over the entire range of fire fighting equipment. The prospects of standardization between nations were investigated by N.A.T.O., but it became clear that little could be accomplished, or was necessary, other than an exchange of appliances, including portable pumps, in an emergency. To enable main equipment fitted with one type of hose coupling to be used in a ship of another navy fitted with a different coupling, it was agreed that a standard flange should be adopted. Ships in the Fleet are therefore to be equipped with adaptors consisting of their type of hose coupling at one end and the standard flange at the other. When equipment is loaned or received, the standard flange will be offered up to the corresponding flange on the adaptor similarly supplied to ships of foreign navies.

Research and Development

To a great extent, the fire fighting equipment used in the Navy is of commercial design and most of the fire risks are of a conventional nature. Fundamental research by the Navy into fire fighting is scarcely necessary and can be done more economically by specialists. There are, however, a number of strictly naval problems in which a certain amount of experiment is necessary. In order to assess the merits of new items of fire fighting equipment, to carry out tests of materials suggested for use in the Navy and to experiment with new methods of dealing with particular hazards, a small establishment, the Admiralty Fire Test Ground, is maintained at Haslar, staffed by one lieutenant and four civilians.

Equipment is tested functionally and the mechanical details examined from the point of view of ease of operation and maintenance. Materials are, where possible, given tests in which the fire severity accords approximately with the first five or ten minutes of the ' standard time/temperature curve ' as defined in B.S.S.476/53. The test rig for this purpose usually consists of an oil fuel register burning kerosene under pressure which can be regulated.

Although the Test Ground is not a scientific establishment in the usual sense and has few facilities for precise experiment, the work is carried out under realistic conditions with necessary attention to detail, and careful records are always taken. The following examples illustrate the scope of the work :—

Trials of maintained pressure extinguishers.

Trials of the fire retardant properties of various materials for deck coverings and bulkheads.

Trials to investigate the danger of fuel spillage being ignited by rocket-assisted take-off aircraft.

Trials of various paints for coating asbestos lagging.

Trials of a new P.V.C. hose.

Apart from the wide variety of appliances, the Test Ground is equipped with a full scale mock-up of an engine room of a *Dido* Class cruiser, and also of an M.T.B. engine room. The former was the scene of investigations which resulted in much of the Navy's present knowledge of fighting major fires with foam and steam.

At the moment, the staff is engaged in a series of trials to evaluate the usefulness of dry chemical in naval fire fighting and to establish the best chemical and equipment for our purpose. Close touch is being maintained with the Fire Research Station at Boreham Wood, who are carrying out similar work, to ensure uniformity and avoid duplication.

Liaison is maintained with the fire research establishments of other Services and departments, including the School of Aircraft Handlers, who deal with aircraft fires, and the fire fighting school at Portsmouth which, in view of its function as a training ground, is frequently called upon for user trials.

In addition to keeping in close touch with the research authorities at Boreham Wood, contact is also maintained with the R.A.F. Fire Fighting Establishment at Kenley and with the War Office and Ministry of Works, and the Admiralty is represented on various J.E.S.C. sub-committees associated with fire fighting problems.

Finally, it would not be proper to leave this subject without paying tribute to the members of the fire fighting trade who assist the Admiralty with trials and carry out tiresome modifications to their standard trade equipment at their request. It sometimes happens that the Admiralty are able to suggest modifications which can be incorporated in production models to the advantage of all.

CONCLUSION

Plans for the future depend on the lessons of the past and on changes in the make-up of the Fleet and on the effect of new hazards and new weapons. The Navy is becoming predominantly one of small ships and probably most future developments will be in appliances and media suitable for smaller vessels. Considerations of weight and space are becoming more and more important. Furthermore, the increasing complexity of a modern warship means that little training time can be spared for defensive tasks and maintenance jobs must be reduced to a minimum. Simplicity of maintenance and operation is therefore very important indeed.

There are considerable problems posed by the advent of thermo-nuclear weapons, but most of the subject is bedevilled by security considerations. Within a certain distance of one of these weapons, a ship and everything in her will be vaporized, to use the unpleasantly precise words of the physicist. Beyond that distance and in varying degrees, depending on the range, ships are likely to suffer all-embracing damage varying from complete disruption to mere scratches. Among ships so damaged, inevitably there will be some that will be set on fire and these fires are likely to break out simultaneously all over the ship. The work of fire fighting will be more difficult than ever before and much will depend on the way in which individual men and fire parties make immediate use of the equipment at their disposal—everybody will have to be a trained fire fighter.

In Virgil's *Aenead*, it is said that when the Trojan warships were set on fire by the enemy the unfortunate victims called upon the gods, who came to their rescue by turning the ships into sea nymphs. For the ship unfortunate enough to get too close to a thermo-nuclear explosion, this is probably as good a solution as any.