FIRE-FIGHTING & DAMAGE CONTROL IN SURFACE WARSHIPS

RECENT DEVELOPMENTS

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This article is based on papers presented by the authors at the Sixth Quadripartite Conference on Ship Defence at Norfolk, Virginia, in February 1983, and (with Commander R. A. Rowley) at the Institution of Fire Engineers Conference at Blackpool in September 1983 and the German Marine Engineer Officers Conference at Kiel in March 1984.

Introduction

The priorities of 'fight, float, move', are correct in that a warship must firstly be capable of fighting to remain an effective Fleet unit, and secondly for it to move it must remain afloat. Before the Falklands campaign—Operation Corporate—a body of opnion felt that a ship suffering a direct hit by a modern missile would be so devastated that her ability to keep fighting would cease, and even remaining afloat was highly unlikely. However, not all ships hit by missiles such as AM39 (Exocet) had their fighting capabilities seriously affected and some ships, albeit having lost their capability to fight, might have remained afloat to fight another day were it not for the damage controllers' principal enemies—fire and flood. A fire once out of control may cause a ship to be abandoned, possibly because of the threat from a magazine exploding or because flooding cannot be contained effectively when smoke prevents remedial action being taken. Good warship design and correct training in fire-fighting and damage repair are obviously essential in minimizing the dangers from fire and flood, but having the right equipment to do the job is also very important.

This article gives an indication of some of the efforts being made to improve warship design and equipment in respect of fire protection and damage control. Some of the suggested improvements are not yet MOD policy and in some instances they are personal views of the authors.

A warship design has to embrace a wide range of differing and in some cases conflicting requirements. The design is a compromise and were it even possible to design a fireproof ship it would be prohibitively expensive. A major challenge in any warship design is to contain systems and equipments in a minimum of space and this of course can create problems in the event of a fire. On occasions certain redundancies have to be sacrificed in order to achieve a workable machinery layout. Cost and weight restraints also play a part in arriving at a compromise.

A warship contains a number of high-risk compartments such as magazines, machinery spaces, fuel tanks, control rooms and operations rooms, where a hit could seriously affect the ship's capability to move or to fight. FIG. 1

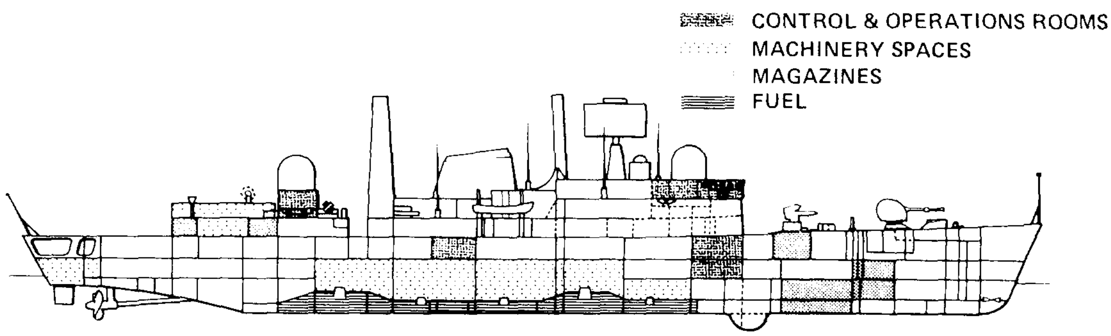

FIG. 1—HIGH RISK COMPARTMENTS IN A FRIGATE

shows there is a high probability that a hit will have a damaging effect on one or more of these vital compartments. In the case of H.M.S. *Sheffield* the missile pierced the starboard side of the ship as shown in FIG. 2. The most immediate and prolonged problem was the complete loss of fire-fighting water throughout the ship, combined with the rapid spread of dense black smoke between decks. The high pressure sea water (HPSW) system, the firemain, was fractured on the starboard side in the vicinity of the point of impact. Damage to the electrical supply system and the forward generators meant that two of the ship's fixed fire pumps were rendered inoperable. Determined efforts were concentrated upon making the necessary isolations to the system and upon restarting the remaining pumps so that firemain might be restored. These efforts were thwarted because in the dense smoke the identification of specific isolation valves was impossible. The loss of firemain meant firstly that a rapid attack by the fire-fighting teams was not possible and secondly that fire-fighting efforts were totally dependent upon portable pumps. These factors contributed to the eventual loss of the ship.

There are several lessons to be learnt or re-emphasized from the loss of H.M.S. *Sheffield* and other incidents in the conflict, which are being taken into account in future fire protection and damage control philosophy. The

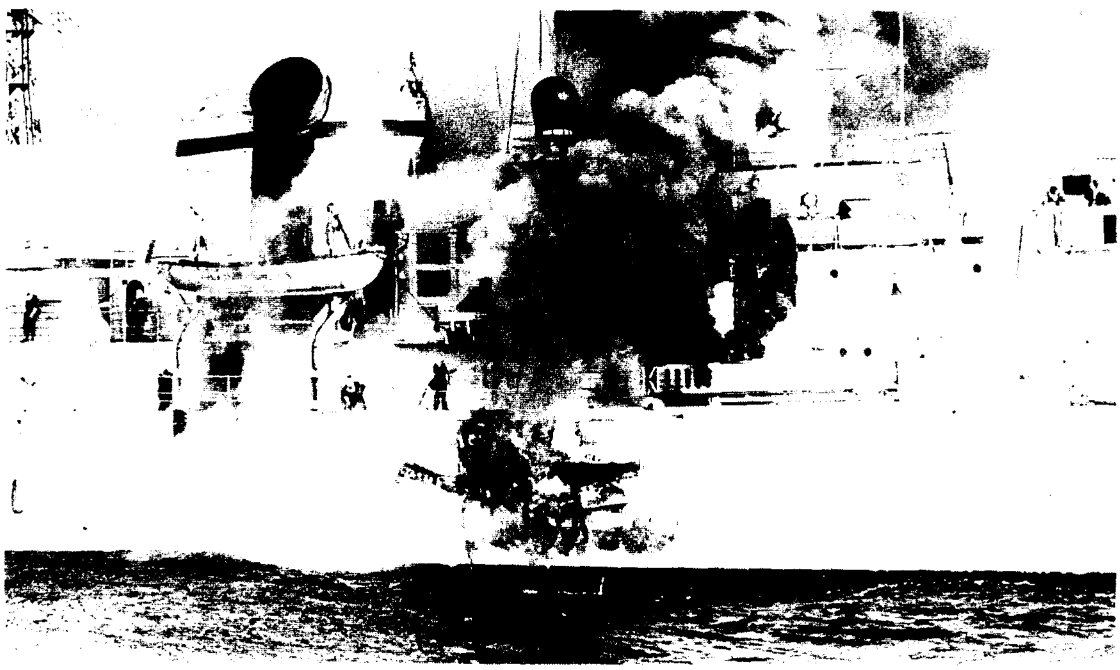

FIG. 2—H.M.S. 'SHEFFIELD', 4TH MAY 1982

following aspects are among those listed in the Defence White paper, 'The Falklands Campaign: The Lessons':

(*a*) Improve Fire Zones.
(*b*) Make bulkheads more smoke-tight.
(*c*) Provide additional fire pumps.
(*d*) Provide additional breathing apparatus.
(*e*) Reduce flammable material.

These and other recommendations are taken into account under the following headings in this article:

- The spread of smoke.
- High pressure sea water system (firemain).
- Fixed fire-fighting systems and portable equipments.
- Damage control organization and surveillance techniques.
- Materials.

The Spread of Smoke

Flammable materials are unavoidable in a warship so the likelihood of it catching fire when hit will remain high. Fuel and all other combustible materials when burning give off smoke which is lachrymatory, choking, dense, and poisonous, and which can fill a ship completely within minutes.

Preventing or minimizing the spread of smoke is therefore of paramount importance and a solution now being adopted is to zone the ship into discrete smoke-tight sections. It is essential that the smoke zone boundary bulkheads extend to the uppermost deck level and special attention must be given to bulkhead penetrations for pipework and cables. FIG. 3 indicates positions of smoke zone boundaries that could be used for a typical modern warship. In addition, smoke curtains will be fitted to doors on main communication decks as a back-up in the event of a door being distorted as a result of action damage.

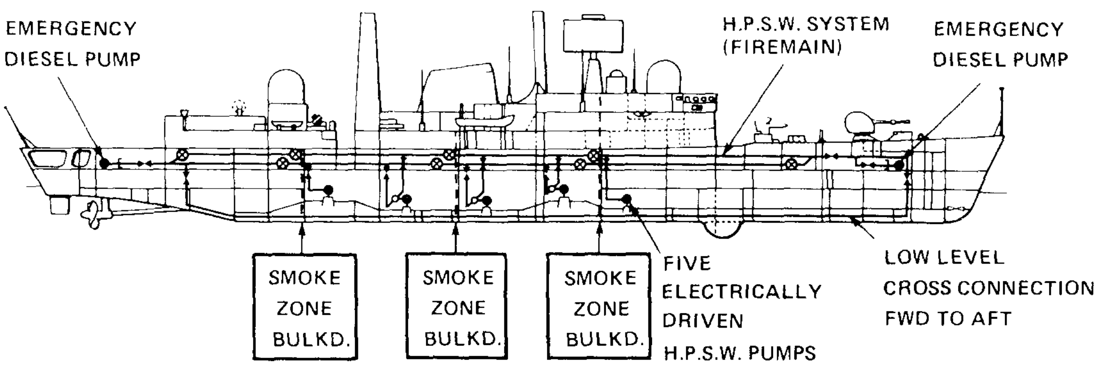

FIG. 3—HIGH PRESSURE SEA WATER SYSTEM FOR A MODERN FRIGATE

It has been recognized that ventilation systems enable smoke and fire to spread throughout ships where smoke boundaries are not effectively designed into the structure and main passageways are used for recirculation. In future, ventilation systems will be autonomous within each zone. However it will still be essential to crash stop fans to prevent the spread of smoke. Consideration is being given to fitting dedicated smoke clearance fans which will be independent of the ventilation system. Smoke clearance techniques are being

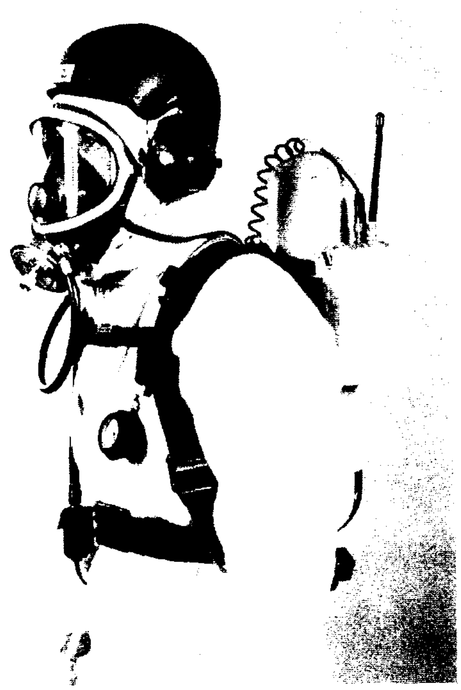

FIG. 4—SINGLE-BOTTLE POSITIVE PRESSURE FIRE-FIGHTING BREATHING APPARATUS

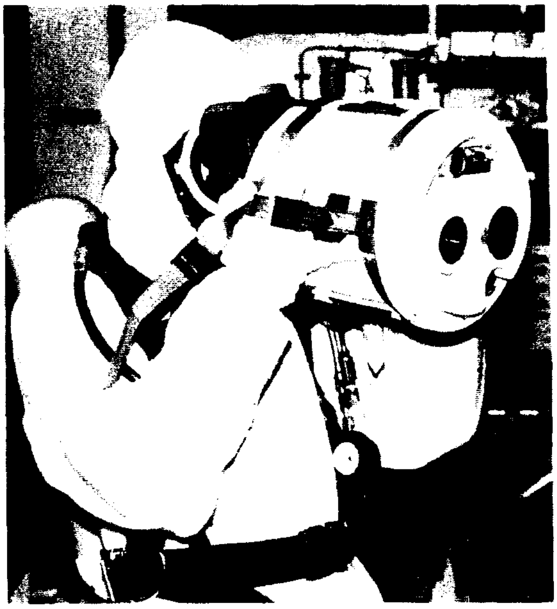

FIG. 5—THERMAL IMAGING CAMERA

evaluated on a full-scale test facility but results to date definitely show that the volume of smoke from any large fire is difficult to remove except with prohibitively large capacity fans. Smoke must therefore be contained within the fire zone as effectively as possible and the fire extinguished rapidly.

To fight a fire successfully it is essential to locate the source quickly, determine its extent, assemble the fire-fighting teams and their equipment, and achieve a good overall control of the team. The team controller and fire-fighters must have the ability to work in a smoke-filled environment and therefore must have the ability to breathe, to see, and to communicate.

Breathing Apparatus

During Corporate it was soon apparent that the number of Breathing Apparatus (B.A.) sets carried in ships was inadequate for prolonged fire-fighting. This, and the number of B.A. recharging points and their locations, therefore needed reviewing. Any large fire can spread in all directions, and the number of fire-fighters requiring B.A. will increase. Consequently allowances of B.A. sets are now being increased and the recommendation is that a typical frigate will have 36 sets with a 50 per cent. back-up of compressed air cylinders on board. Extra B.A. recharging points are being provided, including one on the upper deck.

A positive pressure single-bottle B.A. (FIG. 4) is being introduced to replace the in-service twin-bottle negative pressure B.A. It provides extra safety for the operator by preventing ingress of toxic fumes even though his mask may be damaged or not sealing correctly. Breathing under heavy work load conditions is far easier and bottles can be recharged and replaced much faster than with its twin-bottle predecessor.

Thermal Imaging Camera

Where the smoke is so dense that normal vision is impossible then the fire-fighter needs a device that will 'see' for him, and for this purpose the Thermal Imaging Camera (FIG. 5), which uses part of the infra-red spectrum to provide vision in smoke, has been introduced. It is a self-contained battery-operated unit, incorporating a miniature display monitor and will discriminate temperature differences down to 1°C.; it is capable of locating a fire source in the thickest smoke. It is easy to use, substantially increasing the fire-fighters' mobility and improving their personal safety by making obstacles and hazards visible. It can also be utilized for identifying key isolating valves in pipe systems and in locating injured personnel in search and rescue operations.

The lens has a field of view of 55°. The complete unit weighs 8¾ lb (4 kg) and gives at least 1 hour of use on fully charged batteries. It has successfully completed environmental trials including spray and immersion tests. Investigations are currently in progress to improve picture definition and reduce the weight of the present model by 50 per cent.

Wire-Free Communications

Although the new B.A. has an improved speech device and the operator can be heard quite clearly when talking to anyone close by, he needs to shout if he is to be heard from even a short distance away. At a fire this is unacceptable and a need has been clearly established for a reliable wire-free communications system to enable the fire-fighters, damage controllers, and thermal imaging camera operator to talk with each other and all of them to communicate with the Fire and Repair Party Post (FRPP). These requirements have now been fulfilled by using the Slim Tank Helmet Mark Two (STH Mk. 2) in conjunction with a standard short range radio portable (SSRP) as illustrated in FIG. 6.

The STH Mk 2 is a compact lightweight helmet providing a high degree of impact protection and it incorporates specially designed earshells which give high noise attenuation, particularly at low frequencies. It is provided with communication facilities compatible with SSRP. The stability of the helmet makes a chin-strap unnecessary even when wearing B.A. and heavy duty anti-flash gear. The helmet's boom microphone is easily adjusted into position near the speech device of the B.A. and the wearer now needs only to talk to pass his message. To transmit he operates a 'hands free' pressle switch which is an obvious advantage particularly for the hose operators. Speech is clear and unaffected by wearing of B.A.

Summarizing, the introduction of the thermal imaging camera, the improved design breathing apparatus, and the wire-free communications system has greatly enhanced the capability of firefighting teams. Psychologically the benefits are considerable, and the confidence of the teams will be greatly improved.

Emergency Life Support Apparatus (ELSA)

Everyone below decks needs some form of self-contained B.A. to enable them to evacuate a damaged area through toxic smoke in safety. ELSA (FIG. 7) was therefore imtroduced into service. It consists of a small rechargeable compressed air cylinder which, when fully charged to 3000 lb/in^2 (207 bar), provides a continuous air supply for 8 minutes. A 150 per cent. ship's complement allowance provides one for each man at his action station and one in his accommodation area in a two-watch defence system.

Hitherto, only machinery spaces were fitted with escape devices, of United States design—the Survival Support Device (SSD). Having a working pressure of 6500 lb/in^2 (448 bar) they were not rechargeable on board so regular practice in their use was difficult to achieve. The statutory five-year testing of the pressurized coil to Defence Standards also presented problems. The ELSA overcomes both these disadvantages.

FIG. 6—WIRE-FREE COMMUNICATIONS SET

FIG. 7—EMERGENCY LIFE SUPPORT APPARATUS (ELSA)

Photoluminescent Coatings

Photoluminescent coatings have the property of absorbing light energy and transmitting light when normal lighting fails. Peak brilliance lasts for about 20 minutes. Trials have been successfully conducted using photoluminescent signs for escape route direction arrows, escape ladders, escape hatches, and ELSA and B.A. stowage positions. Photoluminescent paints will be used for the marking of firemain isolating valves, damage control tool boxes in machinery spaces, and quick-acting door handles. To date the results have been very encouraging and photoluminescence is seen as a viable back-up to automatic emergency lanterns.

High Pressure Sea Water System (Firemain)

A complete review of the high pressure sea water (HPSW) system was undertaken after events prompted the following questions:

(*a*) Is there sufficient redundancy in the number of installed pumps?

(*b*) Are the pumps strategically positioned?

(*c*) Should pump prime movers be solely dependent upon the integrity of the electrical generating and distribution system?

(*d*) Can the routeing of the firemain be improved?

(*e*) Is there a sufficient number of isolating valves?

It is axiomatic that some improvements were necessary since it is essential that the firemain system should be designed to provide greater flexibility for reconfiguration when damaged. As a result of a more disciplined approach at the design stage, taking into account the recent lessons learned, the Command will be provided with a series of fall-back options that were not hitherto available. Many of the following improvements were influenced by the zoning concept now being incorporated into ship design. All of them are proposed for future ships and wherever possible some improvements to existing ships are being made retrospectively.

Some of the lessons learned in World War II have had to be relearned, after being inadvertently forgotten over the years in the pressure to improve habitability, save weight, and reduce costs.

Pump Redundancy

In future ship designs it is essential to ensure that the total number of installed pumps is capable of providing the full sea water system load when fighting a major fire. The total pump complement should also include a redundancy factor of two additional pumps, to allow for one pump being under maintenance and another lost as a result of action damage. It is important that during the ship's life as new weapons or aircraft fits are introduced the pumping capacity should be reviewed and additional pumps fitted to meet any significant increase in demand for a re-designed magazine or hangar spray system.

Adopting this philosophy, a Type 42 destroyer should have 7 installed pumps and FIG. 3 is a diagrammatic impression of a HPSW system which meets these current design standards.

Pumps—Strategic Positioning

To ensure against total loss of the HPSW System, pumps should be strategically positioned, i.e. well distributed throughout the ship and with at least one pump in each smoke zone as shown in FIG. 3. Pumps should not be sited immediately adjacent to either side of a bulkhead, even if in different zones, as with such an arrangement even localized action damage could effectively eliminate both these pumps.

Pumps—Prime Mover and Control

Installed pumps should not be dependent upon one source of motive power. There is a definite requirement to provide independent (non-electric) pumps, preferably diesel driven, as follows:

(*a*) An installed high performance pump connected to the HPSW System with a rating of 100 tonne/hour at 7 bar (100 ton/hr at 100 p.s.i.).

(*b*) A readily portable pump with an output of 35 tonne/hour at 2.5 bar (35 ton/hr at 36 p.s.i.) capable of sustaining two fire hoses, one to provide a protective jet/spray waterwall and the other to supply a spray/jet fire-fighting nozzle.

Electrically driven pumps should be provided with alternative electrical supply from a different generator or the electrical distribution system (EDS), with an automatic change over switch. Control of all installed pumps should be from three positions: locally, from the Ship Control Centre (SCC), and from a remote position on the upper deck. The development and selection of pumps for the fire-fighting and salvage roles are described in the article by J. Dunford elsewhere in this issue[2].

Firemain Routeing

A hit above the waterline, as in *Sheffield,* can severely damage a ring main system that is, by convention, installed in the horizontal plane on the communication deck. In future ships, an additional low level forward-to-aft loop will be provided running as near to the centre line as possible (see FIG. 3). To improve the integrity of the firemain, the electrically driven pumps should be connected by a 'Y riser' to both port and starboard sides of the ring main.

Firemain—Isolating Valves and Control

More bulkhead valves and other isolating valves are to be fitted to allow greater flexibility in isolating and reconfiguring the firemain in NBCD State 1 or after damage. All the key isolating valves are to be capable of being operated both locally and remotely and are to be coated with photoluminescent paint so that they can be more easily identified and actuated in a smoke-laden environment.

Fixed Fire-fighting Systems and Equipments (FIG. 8)

Main Machinery Spaces

The current requirements for installed fire-fighting systems comprise:

(*a*) A 2-'shot' Halon 1301 bromotrifluoromethane (BTM) high level spray system capable of providing a compartment drench for first action in the event of a serious fire. This system requires that facilities be provided to close the boundaries of the protected space rapidly before activating.

(*b*) A high level fixed water spray system with 6 per cent. Aqueous Film Forming Foam (AFFF), fitted with non-aspirating nozzles to make the most efficient use of the wetting ability of AFFF and to maximize the cooling effect. This system will cater for a non-intact machinery space boundary and be a back-up for the BTM system.

(*c*) A Halon 1211 bromochlorodifluoromethane (BCF) system is fitted in the gas turbine modules.

Diesel generator modules and gas turbine modules will in future use Halon 1301 (BTM) as an extinguishant. As it may prove difficult to activate the BTM or water spray systems from a position close to the machinery spaces in a smoke-laden environment, additional remote operating positions are being provided on the weatherdeck. The following design improvements are also being investigated:

(*a*) The feasibility of including a dual manual/automatic mode for BTM systems.

(*b*) An explosion suppression system. This type of system is used in armoured fighting vehicles, where it detects the inception of a hydrocarbon explosion caused by fuel tank rupture and suppresses the fire very rapidly. It is, though, doubtful whether this type of system could be successfully engineered and effectively activated in large machinery spaces, where fuel fires can emanate from a variety of sources once an explosive or incendiary projectile has entered the compartment.

Magazine Water Spray Systems

As a result of a series of magazine trials on torpedo warheads and guided missile motors it was demonstrated that the conventional quartzoid bulb system failed to activate the spray system within a reasonable time. This was considered to be due to the air temperature around the bulbs not exceeding the design figure of the bulb (68°C) probably because of shielding by the contents of the magazine prevent the heat plume from acting directly on the bulb or bulbs nearest the incident. Also, when a spray does activate it may have a cooling effect on adjacent quartzoid bulbs, thus preventing them from operating.

A prototype rapid reaction spray system was designed and successfully tested at the Proof and Experimental Establishment (P.E.E.) Shoeburyness. In this system the water supply to the open-ended spray nozzles is controlled by a valve actuated by a signal from fire detectors sited within the magazine.

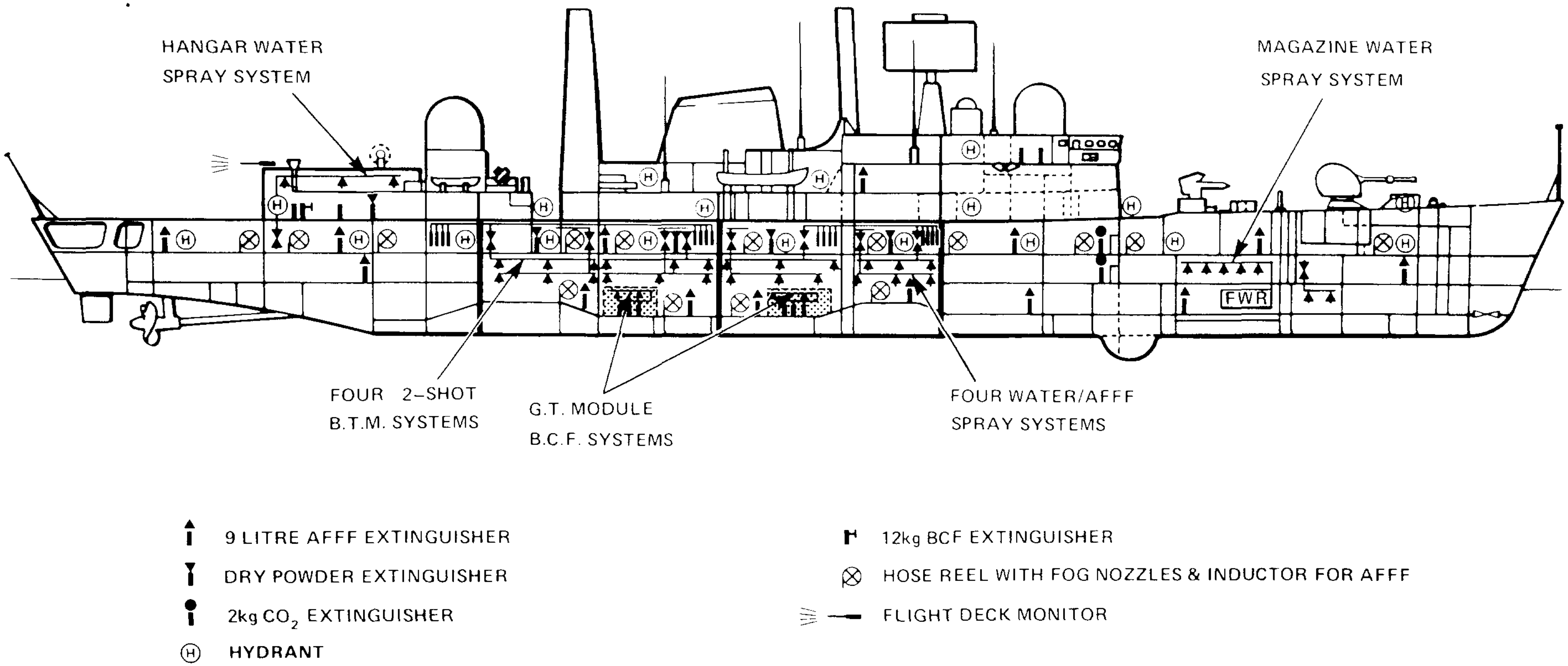

FIG. 8—FIXED FIRE-FIGHTING SYSTEMS AND PORTABLE EQUIPMENTS

List of equipment:
55 hydrants
63 hose baskets
71 jet sprays and spray jets
67 20 ft. hoses
57 40 ft. hoses
4 foam branch pipes
4 portable in-line inductors
3 FB10 branch pipes
50 20 litre drums AFFF
84 9 litre AFFF extinguishers
85 2 kg. CO_2 extinguishers
6 dry powder extinguishers
1 12 kg. BCF extinguisher
30 hose reels with fog nozzles and AFFF inductors

This system is now being further developed for inclusion in the Type 23 frigate and other new design warships.

It has also been recommended that there should be a capability to manually override the quartzoid bulb system. Consideration is now being given to fitting a thermo-electric 'Quartzoid' bulb sprinkler. This bulb is similar to the conventional quartzoid bulb, but includes an actuator mechanism fitted on one half of the sprinkler yoke. This actuator can be brought into action manually when connected to a control panel outside the magazine, or automatically when connected to a fire detection system.

Hose Reels and Hydrants

Hose reels are currently sited in machinery spaces only, but their use will be extended to the main communication deck and they will be fitted with fog nozzles. These hose reel and nozzle assemblies are being evaluated by Captain NBCD's staff. Hydrants (hose connections) are fitted to branches off the firemain in all parts of the ships.

Oscillating Monitors

One suggested improvement was to provide portable fire-fighting oscillating 'monitors', delivering foam solution. The use of monitors has been considered in some depth; it is felt that they can be most effectively used as a fixed installation on flight decks and they are being introduced in the Type 23 frigate.

Portable Equipments

(*a*) *Fire Extinguishers.* The 9 litre 4½ per cent. AFFF extinguisher is the main general purpose shipboard extinguisher. The version currently in use is discharged by means of a carbon dioxide cynlinder which is an integral part of the extinguisher. Every extinguisher in the Fleet is supported by 2 spare charges. A rechargeable stainless 'stored pressure' extinguisher is now preferred and evaluation tests have been completed on a number of commercially available products. The unit cost is lower and the through life costing is considerably reduced. A Naval Engineering Standard (NES) has been prepared for procurement contracts now being placed.

(*b*) *Carbon dioxide (CO_2) Extinguishers.* These are used in compartments where electronic cabinets and computers are sited.

(*c*) *Dry Powder Extinguishers,* used for quick knock down of flammable liquid fires. They are fitted adjacent to main machinery spaces and the helicopter flight deck.

Damage Control Organization and Surveillance Techniques

Three important needs arose from the experience of *Sheffield* and other ships. These were:

(*a*) To provide an upper deck fall-back position for damage control headquarters (HQ1).

(*b*) To make wider use of modern surveillance techniques in displaying and monitoring damage control states.

(*c*) To review whether the current damage control equipments fulfil their purpose and whether the carried-on-board allowances are adequate.

Secondary HQ1 and Upper Deck Fire and Repair Party Post

In the event of HQ1 being evacuated due to action damage or smoke, there is a need to provide a fall-back position on the upper deck. The bridge will generally be the optimum location for the secondary HQ1, but in new design ships the position selected may be outside the bridge, laterally and vertically displaced from HQ1, with direct access to the open air. An upper deck FRPP is also being provided as a base for re-entry into the ship and it may be combined with the secondary HQ1 in future ships.

Modern Surveillance Techniques

The essential information on ship damage control status is provided at HQ1. HQ1 is the focal point for receipt of information, communication, and displaying status, so that co-ordinated actions can be taken to attain a high state of readiness at action stations, with an indication of the extent of damage.

The current methods for surveillance of status are primarily manual, relying upon voice communications and 'runners' for collecting damage status information, then using incident boards and chinagraph pencils to display it. Feedback to HQ1 can be slow and often unreliable. This and the poor ergonomics of existing automatic indicators of status can prevent quick, accurate assessment of ship status when closing up to Action Stations and in the confusion immediately following action damage.

The adoption of modern techniques and technology in producing an integrated system of detection, display surveillance, and control of fire-fighting and damage control systems is now being investigated for the Type 23 frigate. Systems of this type are already fitted in Royal Netherlands Navy S Class frigates and are being considered for the Canadian Patrol Frigate. The development of this system will be significantly influenced by the zoning concept in maintaining zone self-sufficiency and integrity in the event of damage.

States to be monitored on central mimic display panels are:

(*a*) Boundary door and hatch states.

(*b*) Ventilation system status.

(*c*) Firemain pressure and valve isolation state.

(*d*) Heat and smoke detectors.

(*e*) Flood level detectors.

Chilled water system and HP air system parameters will also be monitored.

One can adopt the traditional approach and hard-wire the system or alternatively use multiplex cables for interconnecting sensors and actuators with the display and control positions. This would allow wider distribution of data, together with greater redundancy, resulting in an improved post-damage capability for the damage control and surveillance system. Whatever system is adopted it will provide:

(*a*) Information in a clear, simple, and quickly absorbed presentation.

(*b*) More information at the Damage Control Headquarters concerning the internal environment of the ship.

(*c*) Better control and indication of status of systems associated with fire-fighting and damage control.

Damage Control Equipment

Analysis of reports on the performance of equipments has shown there is a need to introduce new equipments and provide increased on-board allowances. Improvements being implemented, in addition to those already mentioned, are:

(*a*) Smoke Generators: an improved design for training purposes on board ship. The smoke is medically safe and compatible with electronic equipment.

(*b*) Portable Headlamps: improved design and increased allowance.
(*c*) Damage Repairs Kits for hydraulic, high pressure air, and vital low pressure systems.
(*d*) A new design clamp to support damage control timbers.
(*e*) Softwood plugs: re-introduction.
(*f*) 'Subrella' leakstopper. This device has been successfully evaluated (see FIGS.9 and 10). It was invented for use in sailing yachts and utilizes the water pressure on the outside of the hull to assist leakstopping. The Subrella is pushed through in the closed position and drawn backwards towards the user; in doing so the device opens out. The water pressure now presses the reinforced cloth over the hole and stops the ingress of water or at least reduces it to a manageable flow until a more substantial repair is made. The Subrella comes in various sizes and a long split, rather than a hole, can be temporarily repaired by fitting them together along the split. It is not claimed to be a panacea for damage repair but for such a small unit cost it can contribute greatly to the control of floodwater.

Other items of equipment recommended in various Operation Corporate reports are still being evaluated.

FIG. 9—'SUBRELLA' LEAKSTOPPER BEING INSERTED INTO DAMAGE

FIG. 10—'SUBRELLA' LEAKSTOPPER IN POSITION

Materials

During and after the Falklands conflict there was much publicity given to the use of aluminium, flammable materials, and PVC cables.

Aluminium

The Defence White Paper[1] summarized the position as follows:

> There has been comment on the use of aluminium in the construction of ships. The facts are that aluminium was used in the superstructure of the Type 21 class of frigate but not in Type 42 destroyers, such as H.M.S. *Sheffield*. By use of aluminium it is possible to make significant savings in the weight of ships above the water-line but it . . . loses strength in fires and therefore its extensive use in the construction of R.N. warships was discontinued several years ago. Nonetheless, there was no evidence that aluminium contributed to the loss of any vessel.

Foam Plastics

(*a*) Foam polyurethane mattresses are being replaced with interior sprung mattresses, using fire-retardant natural fibre fillings and covers. For foam polyurethane upholstery replacements an investigation is under way. At present a composite material of core foam and barrier foam is used.

(*b*) Rigid foam insulation: search for alternatives to rigid PVC and polyisocyanurate insulation foams continues; some candidate phenolic and polymide materials are under consideration.

(*c*) Foam refrigeration insulation: new methods of insulating cold and cool rooms with phenolic foam block material are being developed.

Plastic Linings

(*a*) Polyvinyl chloride (PVC): The use of PVC as a material for lining bulkheads and deckheads was discontinued some years ago but some older ships still have PVC linings. Metal linings (or in special cases GRP linings) are to be used instead. New designs of lightweight, honeycomb-cored, easily removable linings are under development.

(*b*) Melamine Plastic Laminate (MPL): Unsupported MPL was a splinter hazard and is being replaced with MPL/aluminium/MPL sandwich material.

Deck Coverings

(*a*) PVC deck tiles: roll linoleum is now specified instead of PVC tiles, where deck covering is necessary. Bare steel decks are used elsewhere.

(*b*) Underlay: a lightweight fire-resistant underlay is on trial.

Electric Cable Insulation

Experience of fires in ships and submarines over the years has established the need to eliminate or significantly reduce smoke and corrosive fumes generated from cables involved in fires. The majority of sheathing on ships is chlorosulphonated polyethylene (CSP) with minor quantities of PVC used for certain services. Limited Fire Hazard (LFH) cables have been developed in conjunction with industry and are being fitted in the latest ships.

Conclusions

Important lessons have been learnt about the spread of fire and smoke. The improvements in ship design to minimize the spread of smoke by dividing a ship into discrete zones, together with fire-fighting teams having the capability to see (thermal imaging camera) and to communicate (wire-free communications) with each other in a smoke environment, are considered to be the major improvements which have come about through lessons learned from Operation Corporate.

Improvements in line with the Defence White Paper 'The Falklands Campaign: The Lessons'[1] are being designed into future classes of ships (e.g. Type 23 frigates) and retrofitted where practicable in ships building and the running fleet. Some of the improvements mentioned were under consideration before the conflict but financial restrictions prevented their introduction. There have been numerous offers of help from industry and the public. Every suggestion has been or is being reviewed to ensure that no-worthwhile proposal is overlooked.

Because of post World War II requirements to improve habitability, save weight, and reduce intitial ship building costs, some lessons previously learned have been inadvertently forgotten or overlooked. After a number of years without a major conflict, reasons for established design standards become unclear and questionable, and changes are sometimes made without their significance being apparent.

There is always an incentive and a need to control or reduce initial shipbuilding costs, but in doing so future warship designers should carefully consider what effect any proposed relaxation or departure from design standards will have on the ship's capability to survive.

References

1. 'The Falklands campaign: lessons'; Cmnd.8758, H.M.S.O., Dec., 1982.
2. Dunford, J.: Portable pumps—improvements; *Journal of Naval Engineering,* vol. 28, no. 2, July 1984, pp. 331-341.