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BY

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This inaugural address was delivered by Commander Pidgeon to the Institute of Marine Engineers on 4th October 1982 and is reproduced here with the consent of that Institute.

Introduction

Over the years, the Presidential Address has taken several varied forms but has generally been a statement concerned with the President's career and his experiences. For me the choice was predetermined. My experience is entirely in the Royal Navy and, with the events in the South Atlantic during 1982, the importance of the Royal Navy has been highlighted and brought very much into the public eye. So, I decided to speak about the Royal Navy: about its ships; the way they have developed; about the way they are maintained; and about the future.

I realized at the time I was preparing this Address that there would be some aspects of the Falklands activities which I would not be able to cover or indeed to comment on. There will be many investigations and enquiries to which I shall not be a party. There will be controversies and comments in the media which will catch the public interest and stimulate much discussion. I hope that, by the time this Address is published, many of the issues will have been resolved, many decisions justified, and most doubts removed. It is of course necessary to appreciate that ships are not built for a particular area of operation. The ships that had to be used to protect our interests in the Icelandic Cod War were not right for the task; they had to be adapted and operated with great skill by their crews. Equally there were some inadequacies during the Falklands campaign. It is most probable that, whenever or wherever a need for ships to undertake a particular task arises, there will be some inadequacies and consequent risks to be considered and possibly taken.

My Address therefore comments on some of the practical marine engineering considerations and brings us up to date on developments. I decided to focus attention on the frigate and destroyer navy but many of my comments also apply to the whole Fleet.

It is worth recalling that the term 'destroyer' comes originally from the 'torpedo boat destroyer'—a ship used to protect a Fleet group. The term has continued in use, although the ships it applied to now have several various roles. There is also general use of the term 'frigate'— originally a light, fast ship—again for ships with various roles. The designated types frigate and destroyer are now used for similar ships often fitted with basically the same propulsion machinery.

I have not attempted to discuss submarines, nuclear or conventional propulsion, and specialist role ships, e.g. mine countermeasure vessels. Nor have I considered ships' weapon outfits in any detail.

In order to give you a perspective and to set the scene I believe it necessary to make some points about my career. I have been in the Royal Navy for over 35 years. I have been thoroughly well trained along with many others and, although such training is expensive, it is a national investment. I have been afforded an excellent, satisfying career and a full life. A naval apprenticeship and all that went with it gave me youthful independence and great happiness. Promotion from the lower deck as an Upper Yardman was a stimulating and exciting period in my life as it must be for many others who follow similar promotion routes. Some 40 per cent. of the Royal Navy's engineer officers are promoted from the lower deck. After qualification and specialist courses at the Royal Naval Engineering College, Manadon (RNEC), my early seatime was spent mostly in aircraft carriers—H.M. ships *Ark Royal* and *Victorious*. These ships were excellent vehicles for learning and widening one's experience. I was also involved in training ashore with jobs in H.M.S. *Raleigh* and *Caledonia*.

Whilst at the RNEC I learned about the Institute of Marine Engineers and, when qualified, joined as an Associate Member. I took a strong view that the profession needed support from young engineers and that the young engineers needed to 'belong' to the profession. Many others joined too and have of course since progressed to Members and Fellows of the Institute. Like many members, I enjoyed the Institute's publications and was able to attend some technical papers but life at sea often prevents a deep involvement with an Institute based in London. It is here that the Branches come into their own.

It was in Hong Kong that I first really appreciated the benefit and involvement of the Institute of Marine Engineers on a massive international front with people from all parts of the world and from all aspects of engineering, but all to do with the sea. The Institute in Hong Kong was the focal point of engineers; technically, professionally and socially. People were keen to help one another, to share experiences, offer advice, and share knowledge. There was a genuine effort to help and encourage the young and to advance technology. In Hong Kong particularly, where the Institute now has a strong Joint Branch with the Royal Institution of Naval Architects, these feelings and concepts are still in evidence. The Royal Navy is involved with the merchant navies and during my time in Hong Kong there were many reciprocal visits to ships and I understand that the Base Engineer in H.M.S. *Tamar* is still a member of the Institutes' Joint Branch Council.

After Hong Kong, a job in Bath with the Director General Ships gave me an insight into some aspects of the commercial side of marine machinery. This used to be an area of knowledge in which service personnel were lacking but, more and more, we are now aware of the need to be cost-conscious. We need to appreciate how, where, and why the taxpayer's money is being spent. We are getting better at such things; most of us accept the need willingly and are involved in making best use of limited funds and encouraging joint venture and development with industry.

From Bath I went to a frigate squadron and the operation and maintenance of ships, and I believe that my career has provided me with a good overview of the Royal Navy today.

I now wish to turn to the way in which the Royal Navy has developed its ships, the way they are maintained and the way that the people have had to change during the last 30 years.

The Changing Scene

Over this period there have been several developments which appear to me to have had major influences on the shape and size of the surface fleet in the 1980s. These developments have also had far-reaching effects on the training and working conditions of officers and ratings in the engine-room department.

In the 1950s there was some concern over the time taken to prepare a steamship for sea. In general it took some four hours to raise steam from cold and to be ready to provide full power. There was a need to be able to leave harbour or an anchorage at shorter notice—a feeling which stemmed from consideration of a 'Pearl Harbor' type surprise attack and which was amplified by the possible use of nuclear weapons. The use of internal combustion engines would enable ships to be under way much more quickly. The concept of propulsion by diesel engines, particularly for small ships, had always been attractive from a ship endurance point of view but, for reasons discussed later, diesel propulsion was only fitted in eight frigates and destroyers. Now that the gas turbine, another internal combustion engine, with high power available at very short notice, was gaining prominence in the world, the concept of using it for marine propulsion was examined.

As with most changes, there was an interim phase when a combination of steam and gas turbines (COSAG) was used to propel ships. These were the TRIBAL and COUNTY Classes, using steam turbines for cruising and gas turbines for boosting up to high power. Each plant could be used separately and the gas turbine gave the ability to get to sea quickly.

In the late 1960s the Royal Navy took the bold and brave decision to phase out steam turbines for major surface warships and to go instead for all-gas-turbine propulsion plant using aero-derived marinized gas turbines. This decision was made without the benefit of full sea evaluation of the engines to be used but with definite indications of the suitability of gas turbines for ship propulsion emanating from the COSAG ships. There was also considerable experience of operating an aero-derived gas turbine from the BRAVE Class patrol boats, which used the Proteus engine. This installation provided vital confirmation of the aero-gas turbine's ability to accept the marine atmosphere and spray without severe adverse effects in the engine. The design and development of engine ducting and salt/spray eliminators, together with methods of engine cleaning, had advanced considerably from experience of the Proteus at sea. There was also a considerable amount of testing and development being undertaken ashore to investigate the effects of a marine environment on various gas turbines, particularly at the National Gas Turbine Establishment within the Admiralty Test House.

The route to the decision to change to all-gas-turbine propulsion was opened up by the changes in defence thinking in the mid 1960s. This altered the envisaged role of the Royal Navy and required closer involvement with our NATO allies as well as action to combat the potentially massive submarine threat to our seaways.

The submarine threat called for smaller ships with anti-submarine (A/S) and anti-aircraft (A/A) weapon capabilities for self-defence. Air cover was to be provided by the Royal Air Force and the new fixed-wing aircraft carrier replacement was cancelled. The need for the new Type 82 Class (H.M.S. *Bristol*) in support of a carrier was therefore gone and in its place there was an urgent need for a destroyer class for area defence and a frigate class for anti-submarine patrol. Two existing smaller carriers, H.M.S. *Bulwark* and H.M.S. *Hermes,* were to convert to helicopter carriers and a new class of 'through-deck cruisers'—the INVINCIBLE Class—was planned to replace them. Gas turbines appeared to be eminently suitable for the propulsion of the next generation of ships.

At this time, gas turbines were being used extensively in the world, primarily for aircraft propulsion but also in other land-based applications in generating and pumping stations. Their high power-to-weight ratio made them additionally attractive for use in ships. Gas turbines were 'fuel-thirsty' engines but, at the time they were introduced for propulsion, fuel was relatively cheap and there were no fuel supply problems within the foreseeable future.

There were of course big savings available by using existing aero-gas turbines, thereby avoiding initial development costs.

So, the decision was made and there is no doubt that the introduction of the all-gas-turbine ship has been a successful venture. It has also improved the environmental working and living conditions in those ships. Although the artificer derived great satisfaction from a personal involvement with 'labour intensive' steam machinery, and possessed the ability to 'keep it running', the junior ratings often worked and lived in a rather depressing environment. There has been therefore a shift in job satisfaction and a change in the balance, giving the mechanic a much more fulfilling task with key responsibilities and altering the artificer's task into one of machinery health monitoring and problem diagnosis.

The man in the middle, the traditional Petty Officer Stoker Mechanic, has lost his boiler room and power in his own domain and has now to accept the challenge of finding his place in gas-turbine ships. He is a valuable asset to any ship and must be encouraged to equip himself to fit into the new type of propulsion. It needs a process of adjustment and a change in training which is evolving as the number of ships increases. Already there is a Gas Watchkeeping Certificate in being and many Petty Officer Marine Engineering Mechanics are watchkeeping in gas-turbine control rooms.

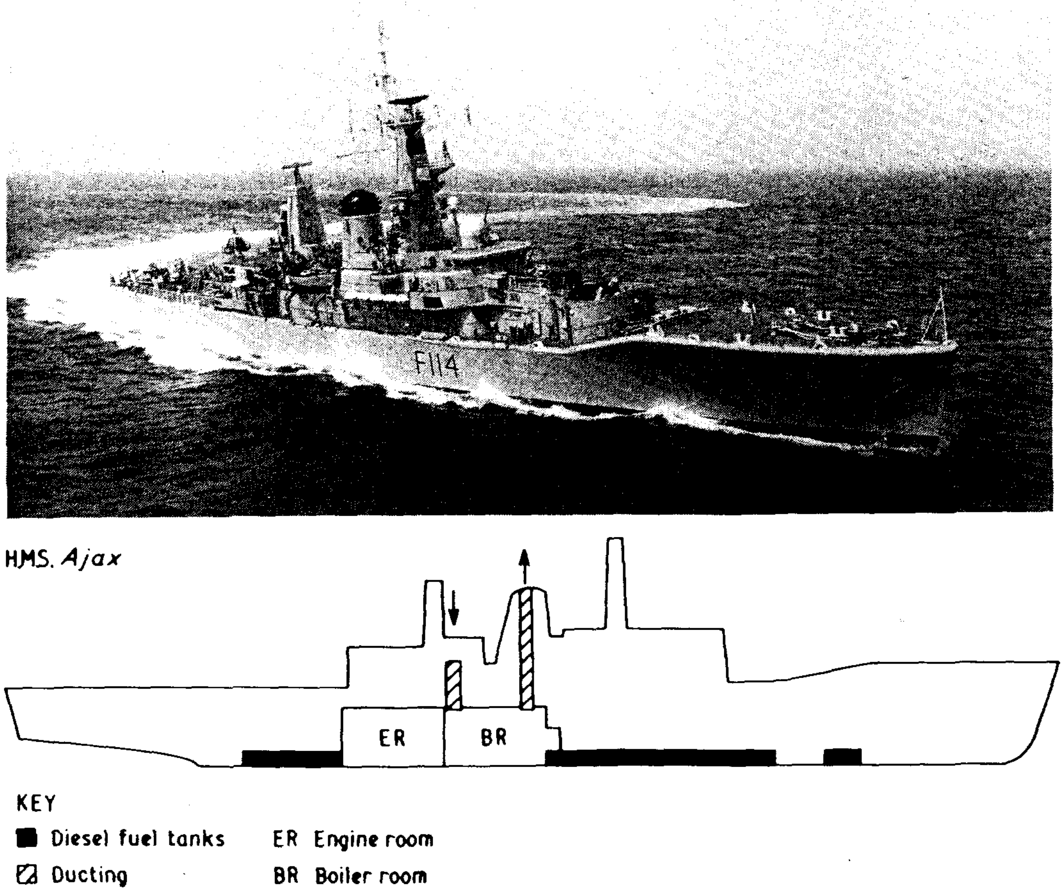


FIG. 1—LEANDER CLASS STEAM FRIGATES

Propulsion Machinery: 2 boilers; 2 double-reduction geared turbines; 30 000 shp; 2 shafts.
Speed: 30 knots
Displacement: 2450 tons standard
Complement: 263 (17 officers; 246 ratings)

This sort of change in personnel training and in the way people need to think is part of a healthy, forward-looking Navy. There were difficulties in artificer recruitment in the mid 1960s because of a reluctance in people to accept formal apprentice-type training at a time when technology was taking on a more academic flavour. Young men were encouraged by their teachers to stay on at school to obtain 'A' levels and to go on to University. The Royal Navy had to adjust its sights in order to attract the right sort of man to join the service—at all levels. To this end the RNE College was geared up to provide formal degree standard training, artificers were encouraged to obtain HNC and ONC during their naval training, and many schemes were introduced to enable men with ability to get on.

It is vital to have such flexibility built into a disciplined service which is manned on a volunteer basis and which in peacetime has to compete with attractive and often more lucrative careers ashore. There is little doubt that the decision to change to gas turbines helped the progression of technology and provided proof that the Royal Navy meant to keep itself up in the technology hunt and as modern as possible. The new ships were cleaner and more comfortable to live and work in. There were also advantages in operating such ships in a world increasingly influenced by the need to reduce pollution.

It should also be remembered that the Royal Navy's senior engineer officers in the 1960s had served a lifetime with steam. They had suffered and tolerated the hot, oily, smelly, dirty, and generally unpleasant conditions below, to keep their machinery in good order. As with the change from coal- to oil-fired boilers and from reciprocating engines to steam turbines, they were aware of the existence of attractive, practical alternatives for propulsion. As engineers, they were keen to exploit them and to be first.

As we move into the 1980s another factor has emerged to modify our thinking—the limited availability of high-specification distillate fuel and its cost. It now seems likely that the next generation of frigates will utilize the economy of diesel engine propulsion in conjunction with a gas turbine for high-speed boost. Such a machinery fit would appear to give the best of both worlds. The Type 23 frigate is mentioned in some detail later in this Address.

The Evolution of Surface Propulsion Plant

Steam Propulsion

The progression of steam propulsion machinery for Royal Navy frigates reached a 'milestone' with the LEANDER design. This was a three-stage development of Y100 machinery into Y136 and, finally, Y160 for LEANDER Class frigates. A total of 26 of these frigates were built, the last (H.M.S. *Apollo*) being completed in 1972. The Y160 was a sophisticated, remote-controlled steam plant which took account of all the improvements and economies which were available at the time. They were, and indeed still are, reliable and effective ships with an impressive track record. Some details of the Class are shown in FIG. 1.

Originally the Y100 steam plant was designed to propel the Types 12 and 14 frigates and it was in these ships that many of the teething troubles were dealt with. The real changes from earlier steam plant were the boiler change, from a three-drum to a 'D' type boiler; and from separate HP and LP turbines to a single-rotor impulse turbine. These principal element changes to smaller, more compact units afforded good savings in weight, gave improved efficiency, and facilitated the progression to higher steam conditions and modern controls. Two examples of the improvements are the sequential cam-operated nozzle control of the turbines, giving increased efficiency, and the enclosing of the boiler front, allowing better combustion.

Naval boilers have always required considerable maintenance effort. Three-drum boilers burning Navy furnace fuel oil were a constant drain on labour at sea and required frequent external cleaning to remain efficient. The D-type boiler, with its higher efficiency, particularly after the change to high-quality distillate fuel, made less demands but still required a great deal of care and maintenance.

It was, however, in the auxiliary machinery areas that the weakest points of reliability and maintenance loading were apparent. As with all steam plant, the main units relied on effective auxiliary feed, extraction, circulating and lubricating pumps and distilling plant. The type of auxiliary machinery currently at sea in surface ship steam plant is turbo-driven and requires careful and regular attention by highly skilled personnel. The equipment was designed to be maintained and repaired mostly onboard by the ship's staff.

It seems appropriate to recall one of the most appealing advertisements for Royal Navy technical men: 'You can't send for the AA in mid-Atlantic!'. It was necessary to carry a large inventory of spare gear and the fitting of spares required deep specialist equipment knowledge, high skill and much experience to guarantee reliability and confidence in a repair. As well as this support it was necessary to hold major assemblies and whole equipments in depots ashore for fitting when urgently required to replace failed units and, on a planned basis, during refit and overhaul periods.

Diesel Propulsion

During the late 1950s two classes of frigates with all-diesel propulsion were built. These were the Type 41 anti-aircraft frigates (four ships) and the Type 61 aircraft-direction frigates (four ships). With a displacement of just over 2000 tons they had a good performance, with a top speed of 25 knots and a range of some 4000 miles at economical cruising speed. Two of the ships were fitted with variable-pitch propellers and the Type 41 had stabilizers. For essential stability a fully water-compensated fuel tank system was necessary.

The propulsion diesel engines were 8 × 16VTS ASR1—four on each of two shafts, giving a total shaft horsepower of 14 500. The engines were very similar to those used in conventional 'O' and 'P' Class submarines and some details of these ships are given in FIG. 2. The main engines and the diesel generators, with their 160 cylinders, caused a heavy maintenance load for both ships' staff and the Royal Dockyards. The main difference in engine operation between the diesel frigate and the submarine was that the frigate used direct drive whilst the submarine used electric drive for propulsion. This meant that the frigate's engines were often operating at low powers or, even worse, idling. In consequence, the lubricating oil suffered from fuel dilution and some contamination. The ships had difficulty in changing the large quantities of lubricating oil involved. There were also difficulties in the supply, stowage, and handling of the oil.

Against these problems, the diesel frigates had the real advantages of long range and no feed water problems.

These ships also had exceptional engine flexibility and at sea were often operated with a shift engineer on call instead of conventional watchkeepers, which released staff for maintenance work.

There were attractive advantages in diesel frigates but this particular design never really gained popularity. There were those who knew and liked the ships, there were others who knew them and disliked them, and there were many who never had an opportunity to get acquainted with them. There were so few diesel frigates and other exciting ideas were developing in marine propulsion, including another type of internal combustion engine—the gas turbine.

It should be said, however, that, although the Royal Navy has not pursued diesel frigates during the last 20 years, several successful small frigates and patrol craft have been built for overseas customers to British designs in British yards. It is worth commenting that a smallish ship with medium-sized diesel propulsion is suitable for a calm water area, such as the Persian Gulf, but for operations in the North Sea and the Atlantic a larger hull, higher speed and more powerful machinery are necessary.

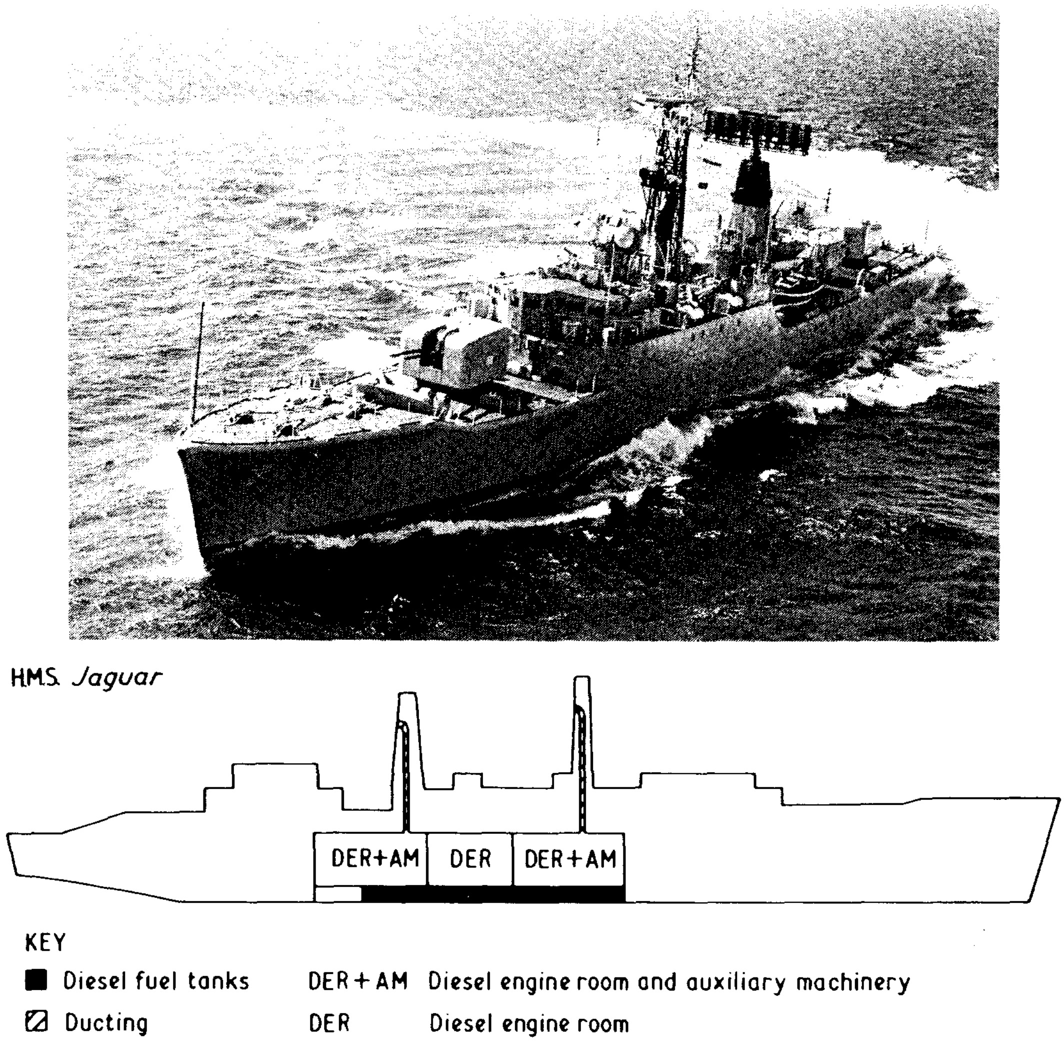


FIG. 2—TYPE 41 DIESEL FRIGATES
Propulsion Machinery: 8 ASR1 diesels (3 engine rooms); 12 300 bhp; 2 shafts; 4 engines geared to each shaft
Speed: 25 knots
Displacement: 2300 tons standard
Complement: 205 (10 officers; 195 ratings)

Combined Steam and Gas-turbine Propulsion (COSAG)

In the early 1960s ships with a combination propulsion plant—steam and gas—were designed and built. These were the COSAG ships of the TRIBAL and COUNTY Classes. The TRIBAL Class, at 2500 tons, had a single shaft using a Metropolitan-Vickers G6 gas turbine to boost the steam turbine. The COUNTY Class had a steam turbine and two G6 gas turbines on each of two shafts and were large cruiser-like ships of some 6000 tons displacement.

The COSAG plant reached a design peak in the early 1970s with H.M.S. *Bristol* which was, because of changing naval requirements, the first and the last of a class—the Type 82. H.M.S. *Bristol* was fitted with a highly-developed

TABLE 1—*Destroyers and frigates 1956—82*

Ship Type	Commissioning Date	Construction Cost		Displacement (Standard) (tons)	Speed (knots)	Propulsive Power and Range (shp/bhp)	Deck area taken up by main engine air inlet and exhaust gas trunking (m^2)	Electrical Generating Capacity (kW)	Type of Propulsion Machinery
		Actual (£M)	Adjusted for 1982 prices (£M)						
LEANDER Class frigates	1963–70	4.7 to 7	30.0	2450	28	30 000	43	1900 to 2500	2 × Boilers 2 × Y160 steam turbines and double-reduction gearing
Type 21 frigates	1974–77	14.0 to 28.0	43.0	2750	30/18	56 000 or 8500	166	3000	COGOG 2 × Olympus GTs or 2 × Tyne GTs
Type 42 destroyer	1975–78	23.0 to 120.0	135	3500	29/18	56 000 or 8500	218	4000	COGOG 2 × Olympus GTs or 2 × Tyne GTs
Type 22 destroyer	1979–82	68.0 to 120.0	135	3500	30/18	56 000 or 85000	308	4000	COGOG 2 × Olympus GTs or 2 × Tyne GTs
New Type 23 general-purpose frigate	1988	90 at 1981 prices		NA	NA	17 000 bhp per engine	NA	NA	CODLAG (Combined diesel/electric and gas) 2 × Spey GTs (Diesel engines not yet known)

GTs = Gas turbines.
NA = Information not yet available.

steam plant and Olympus gas turbines. In 1974 the ship suffered a major fire in the steam plant engine room but was able to complete vital sea trials of the Seadart weapons system, using only the Olympus gas turbines—a forcible demonstration of the confidence in, and the flexibility of, the propulsion plant. Soon afterwards the ship was refitted and restored to full propulsion capacity but the focal point of future ships had shifted to smaller ships with anit-submarine and anti-aircraft weapons.

Gas-turbine Propulsion

All the ship types described so far in this Address have demanded considerable effort on the part of engineer officers and artificers/mechanicians to keep them operational. There is nothing wrong in that concept but the machinery also required extensive skill and craft training of the ratings and this was at a time when big efforts were being made by designers and manufacturers to reduce the skills necessary on board to maintain machinery. There were pressures to reduce craft and skill training time and to spend the time saved on equipping men to appreciate modern technology and other important aspects of machinery and man management. Many improvements had been made in the quality and in the provisioning of spares and the trend towards 'upkeep by exchange' was well advanced.

The Royal Navy was ready for a change; a change into classes of ships which could be designed to accommodate all these factors. The aim was for ships which would run reliably, without massive onboard efforts in maintenance, and for equipment which would be modern and designed for upkeep by exchange by less skilled personnel when the need arose. Fast, powerful, and manoeuvrable ships were required which could leave harbour quickly and which were cleaner and more pleasant to live and work in.

The propulsion change came to meet the early 1970s. Steam propulsion had reached a high state of development and at that time there seemed little scope for significant improvements. There will always be engineers who (thankfully) will work to apply new technology, new ideas and methods to improve performance and efficiency in a total sense encompassing the machinery and the people who operate and maintain it.

These changes in policy coupled with the rapid escalation in new construction costs paved the way for smaller, less manpower-intensive warships.

Gas-turbine propulsion was to provide the answer to many of these problems and, inevitably, to create some of its own. Marine gas turbines also required the development of power turbines and gearbox transmission systems to the propeller. One of the main concerns was ingestion of salt and its effect on compressor blades, combustion chambers, and compressor and power turbines.

A feature of the gas-turbine ship is the large volume of space taken up for the provision of air to, and exhaust from, the main engines, which are normally situated low down in the ship. To minimize contamination from salt spray, the air intakes are fitted high up in the superstructure, resulting in long runs of ducting. The air inlet ducting must also be designed and installed with great care to eliminate air flow disturbances and turbulence and to maximize efficiency. Similarly, the hot gases must be exhausted high up to clear the superstructure. The engines require large volumes of air which is exhausted at a higher temperature than in diesels or boilers. The utilization of the heat energy in the high-temperature exhaust has not yet been possible because of the excessive topweight penalty, the back-pressure effect, and the engineering problems of a sizeable heat exchanger.

To give some comparison, the main engine ducting for steam, diesel, and gas turbine ships is represented by the hatched areas of the ship profiles shown in FIGS. 1, 2, 4, and 5 and an estimate of the deck area taken up by the ducting is given in column 8 of TABLE 1.

H.M.S. *Exmouth*, a single-shaft steam turbine (Type 14) was converted to all-gas-turbine propulsion for trials by Chatham Dockyard during 1966–68. The engines used were two Proteus for cruising and an Olympus for boost—in a COGOG arrangement. The power transmission was via a reduction gearbox and a controllable-pitch propeller.

The primary trial objective of H.M.S. *Exmouth* was the sea evaluation of the Olympus engine with numerous supporting trials of associated systems. The Olympus was to be fitted into H.M.S. *Bristol*, the last COSAG ship, which has been previously mentioned. Originally, there was sufficient time to undertake a sea evaluation over a long term but, because of the change in policy resulting in the introduction of all-gas-turbine ships and the cancellation of the Type 82 BRISTOL programme, an acceleration became necessary. These changes heralded and expedited the introduction of the all-gas-turbine warship.

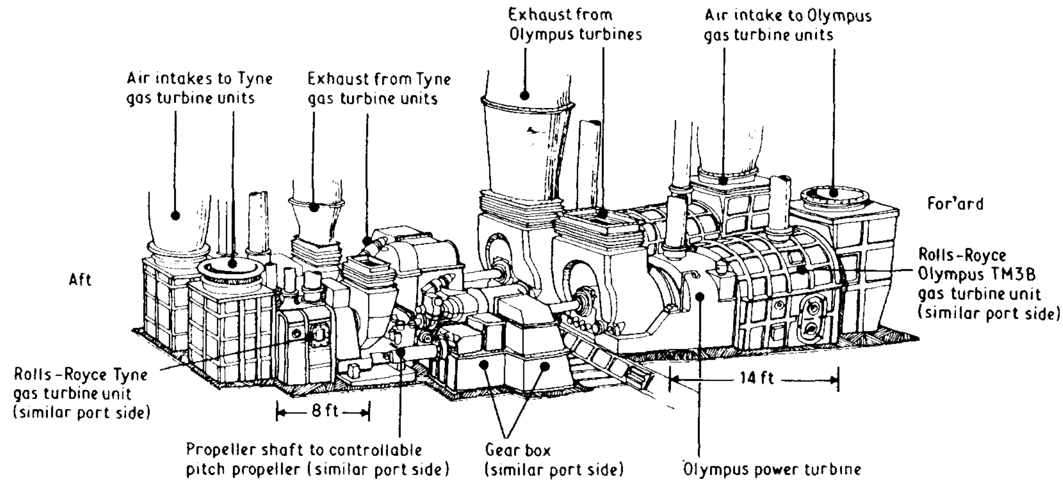


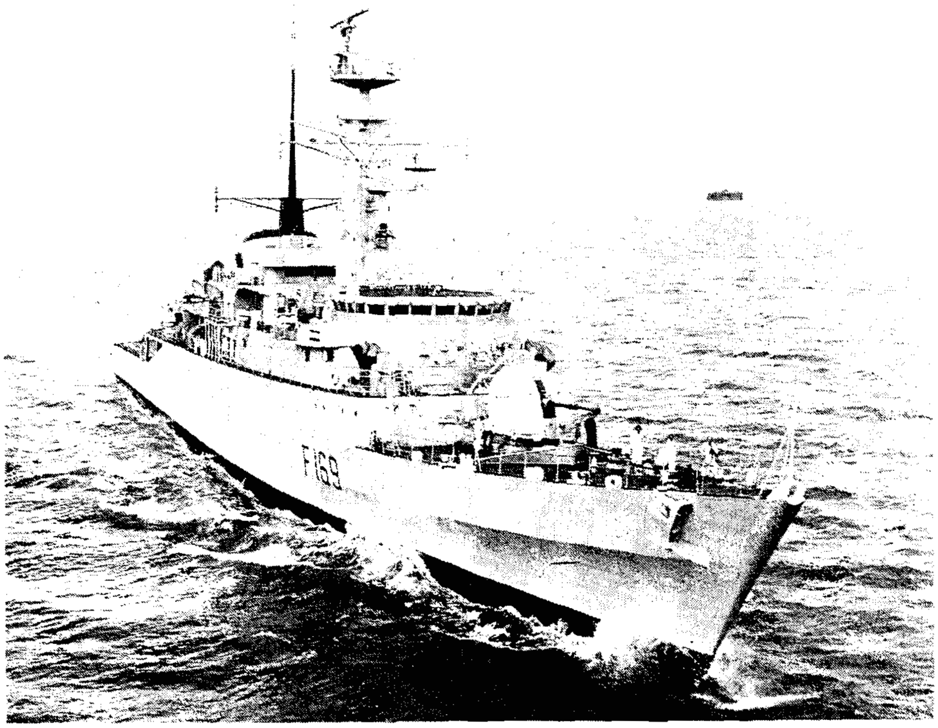
FIG. 3—TYPICAL COGOG ARRANGEMENT

The Tyne (cruising) and the Olympus (boost) engines were selected for the new ships and were to operate in an 'OR' configuration (COGOG). The ships envisaged were to have two shafts with a Tyne and an Olympus on each shaft, which provided an impressive variety of engine and shaft operating modes and some main engine redundancy capability when necessary. With these developments in mind, there was an urgent need to accelerate the *Exmouth* evaluation but, even without the reassurance of successful sea trials, it was necessary to proceed with the new building programme. It is sometimes necessary to accept calculated risks and, with the delay period between conception and commissioning, such risks counter obsolescence.

Several other navies have followed the Royal Navy's example, e.g. the Russian KASHIN and KRIVAK Classes and the US Navy's SPRUANCE Class. In particular, the Tyne and Olympus package (see FIG. 3) has been adopted by the Netherlands and there are involvements with the Belgians and the French. A memorandum of understanding (MOU) has been established with these countries for some years: this involves the sharing of a pool of spare engines, operating experience, and maintenance information and provides an obvious saving in costs.

The first COGOG order was for a Type 42 destroyer and went to Vickers Ltd., Barrow. The machinery fit was designed by YARD Ltd. in conjunction with DG Ships. The first ship was laid down in 1970 and underwent sea trials in mid 1974.

Almost simultaneously, another all-gas-turbine ship, a patrol frigate, was ordered. Because of the Type 42 and other commitments in DG Ships, this



HMS. *Amazon*

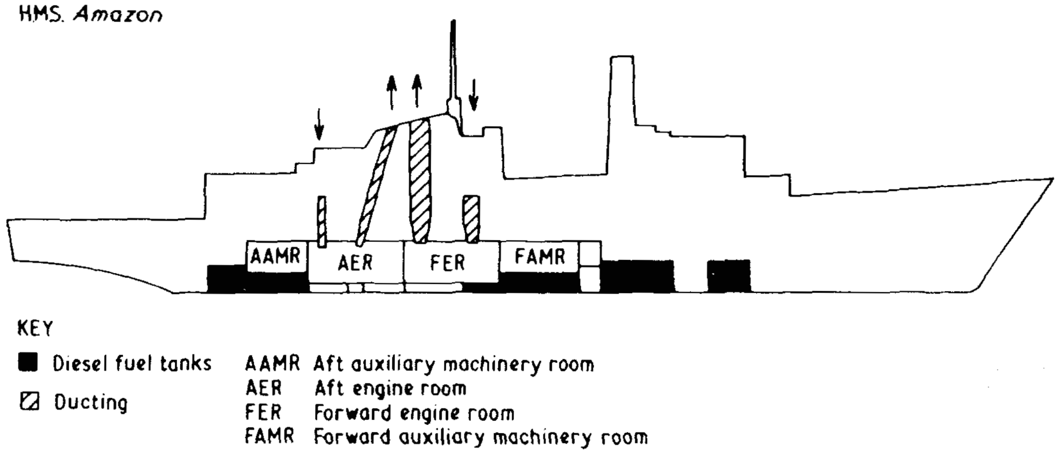


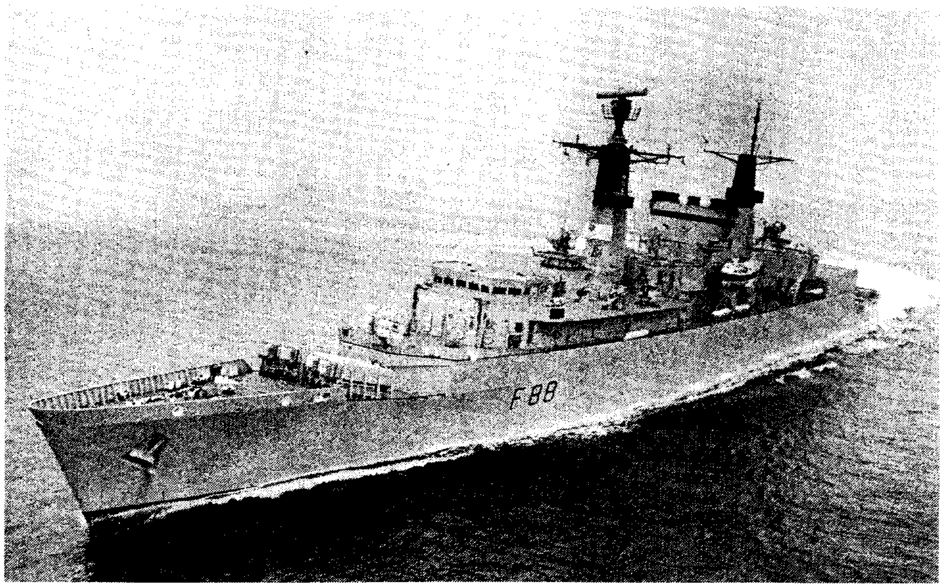
FIG. 4—TYPE 21 COGOG FRIGATES

Propulsion Machinery: 2 Olympus GTs, 56 000 bhp; 2 Tyne GTs, 8500 bhp; 2 shafts; 5-bladed CP propellers
Speed: 30 knots maximum; 18 knots cruising
Displacement: 2750 tons standard
Complement: 175 (13 officers; 162 ratings)

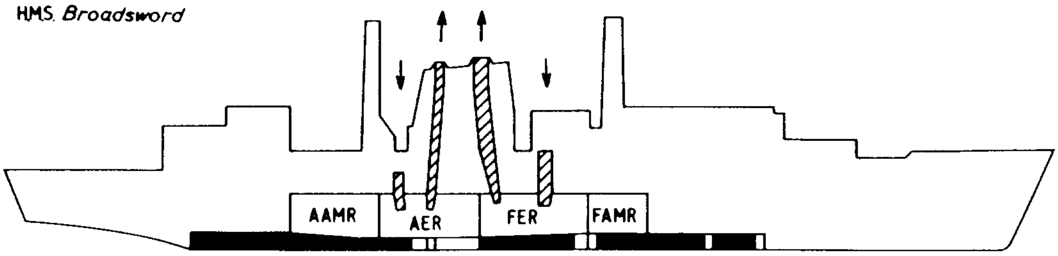
patrol frigate was contracted on a 'design-and-build' basis from commercial sources. This was the Type 21, designed by Vosper Thornycroft Ltd. with limited MOD involvement (FIG. 4). The project was in conjunction with Yarrows Ltd. who built some of the later Type 21s. The first Type 21 was laid down in late 1969 and started sea trials in mid 1973. The *Exmouth* trials greatly assisted the successful development of marinized gas turbines.

A third class of ship, the Type 22—an A/S point defence frigate using the same COGOG machinery fit—commenced building in 1976 and several are now in service (FIG. 5). All three classes have controllable-pitch propellers.

It should also be mentioned that a class of through-deck cruisers is now in service using only Olympus engines (two on each of two shafts) with fixed-pitch propellers and reversing gearboxes.



HMS. *Broadsword*



KEY

■ Diesel fuel tanks
▨ Ducting

AAMR Aft auxiliary machinery room
AER Aft engine room
FER Forward engine room
FAMR Forward auxiliary machinery room

FIG.5—TYPE 22 COGOG FRIGATE

Propulsion Machinery: 2 Olympus GTs, 56 000 bhp; 2 Tyne GTs, 8500 bhp; 2 shafts; CP propellers.
Speed: 30 knots maximum; 18 knots cruising
Displacement: 3500 tons standard
Complement: 223 (18 officers; 205 ratings)

These new ships are very different from the earlier ones described in this paper. The ships were designed and built to extremely high standards of configuration definition and control. They incorporate all the concepts of upkeep-by-exchange and the reduced onboard maintenance enabled a reduction in the engineering complement from that of previous similar ships. Any reductions in the high-cost area of manpower are worthwhile and savings of over 30 per cent. are possible. The propulsion plants have been equipped with sophisticated engine health monitoring using all available modern techniques and engine life is gradually being extended.

The main features of gas-turbine ships have been fully documented elsewhere as indeed has the operating experience. Suffice it to say that these ships have proved successful. The men who work in the ships like them and enjoy a far more agreeable environment. The ships are still a novelty for many.

Comparisons: Steam and Gas-turbine Propulsion

There is no doubt that a steam plant is easier to understand and that the operating and maintenance personnel have less difficulty in diagnosing problems than with gas turbines. Because there is less upkeep by exchange designed into a steam plant, there is a need for greater onboard skills. Of course, the ability to survive at sea and to be able to repair defects, or to improvise, must be a vital consideration and objective. Steam machinery lends itself to such self-contained remedial action more readily than the more sophisticated gas turbines and their associated equipment.

All ships depend to some degree on spare parts but the gas turbine ships have been purpose-built for upkeep by exchange and demand the provision of the right spares. Considerable progress has been made in this area to provide such spare parts and components. The definition of equipment terminal points (i.e. the points at which mechanical and electrical connections must be disconnected before any equipment is removed from the ship for repair or maintenance) and the quality of spares has required high expenditure but, provided it achieves the objective in keeping ships operational, it is justified. The skills traditionally associated with machinery maintenance have been allowed, quite deliberately, to diminish and, although some 'old hands' prevail, ships are becoming less self-reliant as the span of new technology increases.

There is, inevitably, a long delay in the effects of fundamental changes in personnel training and it is difficult to introduce new technology whilst retaining the old skills. Today's artificers need to be equipped with a high degree of diagnostic intelligence to accept the responsibility of expensive plant with heavy reliance on instrumentation. It is no longer normal to make parts onboard and there is a natural deterioration in manual skills. There are penalties from this engineering progress. It is expensive to provision high-quality spares and an exchange policy requires more units to be purchased initially to keep a supply pipeline full.

Considerable expenditure has also been committed during the last ten years to incorporate concepts stemming from the past experience. Naval machinery is designed for reliability and is subjected to extensive testing and modified if necessary. In addition to this, manufacturers are encouraged to undertake a formal study into the reliability of their equipment to identify areas which could prejudice reliability of their product in service. Within the constraints of cost, we build in redundancy to minimize the effects of failure. It is necessary to reduce the noise from machinery to acceptable limits to help avoid detection by submarines and to improve sonar performance. Key items of machinery are built to be 'submersible' so that they can still operate in a flooded compartment. Key equipment is also designed or modified to accept underwater shock without failure. We have also attempted to build some classes of ships identical, one to the other, for ease of support. All these constraints cost money and there may well be a need to reconsider some specifications in the interest of economy, provided it is based on informed opinion and experience.

As with a pendulum, there is some movement back towards more repairs on board by ship's staff, which may require additional craft training. It is often much cheaper to repair a component in an equipment than it is to change the equipment. Well-trained engineering minds will always seek to investigate a 'black box' when it fails to function.

Maintenance Philosophy

When I joined the Royal Navy, maintenance was on a rather *ad hoc* basis. It was breakdown maintenance assisted by the personal opinions of those responsible for machinery. Maintenance was done on an opportunity basis and few maintenance activities were recorded. Of course, some ships had excellent records but, in the absence of formal standards and methods, much was missed.

The first formal maintenance system for the Fleet was introduced in 1953 when ships were allocated to 'Class' Authorities. The Authorities, in each of the home base ports, were responsible for establishing maintenance routines to fit in with the operating cycles of the classes of ships within their allocation. This was the real start of planned maintenance and the majority of routines were calendar-based with an inevitable built-in safety factor which resulted in considerable over-maintenance.

As machinery maintenance information was accumulated, and in cognizance of a trend to use similar equipments in various ships, it was possible to merge the several Class Authorities into a central Ship Maintenance Authority. This was done in 1963 and brought big advantages in standardizing routines for similar equipments and in gathering data, particularly in problem areas. Several maintenance systems were developed and in 1980 the latest and most comprehensive system was progressively introduced into the whole surface fleet. This is called the Machinery Maintenance System (MMS) and it includes details of each Maintenance Operation (Maintop) and, wherever necessary, Job Information Cards (JICs) to enable the maintainer to have all the required information at his fingertips together with any special tools and techniques for that particular task.

Although it is necessary for many upkeep tasks to be based on calendar time or running hours, there has been a change in philosophy to avoid wasteful over-maintenance. Machinery was often being opened up, stripped, and examined when in fact there was nothing wrong with it. This gave rise to a feeling that opening up machinery to see if it was still in good order was pointless work and could often be more damaging than leaving well alone. This was particularly the case with machinery of advanced design and the reduced skill levels on board. Calendar-based maintenance also meant that many items of machinery were changed at a planned interval, often irrespective of condition—again an extremely wasteful concept.

In parallel with the new MMS, a new type of maintenance package was developed based wherever possible on machinery condition. Such thinking was vital for the new COGOG ships but the scheme was also relevant for most other ships. Some forms of condition-based maintenance (CBM) have been used for many years—machinery trials before a ship's refit, performance tests of main engines and auxiliary plant, and the human senses of touch, sound, sight, and smell are well-established condition assessors. These methods have now been supplemented by many other techniques to help assess condition and to detect signs of distress in machinery. These techniques include: endoscopes, fibrescopes, magnifiers, TV optics, magnetic chip detectors, debris testers, ultrasonic leak detectors, flowmeters, acoustic monitors, vibration meters, and vibration analysers.

The new maintenance philosophy was introduced with MMS and is aimed at reducing the amount of maintenance done to the essential minimum. It gives the ship's engineer a much greater power of decision regarding what should be done and when it should be done, and should lead to more effective use of maintenance personnel. It should also aid accurate problem diagnosis and enable repair at the lowest unit or component level without adversely affecting the upkeep-by-exchange principles. Condition-monitoring techniques also need to be complemented by sound experience and engineering judgement. Some of the work of the Ship Maintenance Authority has recently been transferred to the engineering staff of the Commander-in-Chief Fleet and closer links between design, upkeep, operation, and maintenance should result.

The gas-turbine ships are particularly suited to condition monitoring but the techniques are also being used successfully in most ships. To accommodate the need to undertake large maintenance tasks to a more flexible timescale, from the previous calendar-based plan, assisted maintenance periods (AMPs) have been extended and made less frequent. The ability to change or maintain complex machinery in AMPs, often using shore-based uniformed personnel, should reduce the work package and hence the time spent in dockyard hands at refit periods. As a result, ships should have higher operational availability—an obviously attractive benefit.

The Falklands Scenario

It should be appreciated that most of the Royal Navy's thinking, in recent years, has been orientated towards operations in the North Sea/North Atlantic, where ships would be operating relatively close to the U.K. or other friendly bases. Operating in the Falklands area, some 8000 miles from the U.K. necessitated a completely different approach.

One of the major factors was, of course, the need to transport a mass of equipment, personnel, and stores to the area of operations and, whilst there, to maintain a line of communications with the nearest airhead (at Ascension Island). This could not be achieved using naval shipping alone and it was necessary to use ships of the Merchant Navy, which were chartered or, when this was not possible, were requisitioned. The response of these ships, their owners and, above all, their crews was magnificent. In all some 55 such ships were used, ranging from *Queen Elizabeth 2* and *Canberra* to trawlers and tugs.

In a number of cases it was necessary to modify the ships to enable them to undertake their new tasks. Such modifications included the fitting of flight decks to take helicopters, the fitting of a refuelling-at-sea capability, and the facilities required to enable them to carry extra personnel. The modification work was undertaken in naval dockyards and civilian shipyards and was completed in remarkable time. For example, 60 hours after arriving at Southampton with a full load of passengers S.S. *Canberra* sailed with 2100 marines on board, having fitted in that time two flight decks capable of operating Sea King helicopters, a refuelling-at-sea capability and a naval communications fit—a truly remarkable achievement.

Another factor was the need to be able to repair ships in the Falkland Islands area. To overcome this problem, two North Sea oil rig support vessels were chartered. The ships' normal repair capability was enhanced by fitting additional equipment and by augmenting the crews with a large party of naval engineers and technicians. The first ship, *Stena Seaspread*, was in the South Atlantic for virtually the whole period of operations. Most of the repair work was carried out on the high seas, sometimes in the worst conditions that the South Atlantic could provide.

Naturally, initial repairs were undertaken by the crews of the ships concerned but subsequent repairs of structural damage caused by explosions, bomb/missile impact, fire, and flood were undertaken with outside assistance. A considerable amount of resourcefulness was used: for example, an air inlet trunk for a gas turbine was constructed of wood and, on another occasion, parts of an electric toaster were used to repair a radar set.

Of the two types of propulsion system in use in the R.N. ships, gas turbines and steam each showed their individual advantages. The redundancy available in naval COGOG systems was demonstrated by the ships' ability to keep moving after damage or one or more failures, while the robustness of steam plant was reflected in its ability to withstand the appalling conditions and the shocks which it frequently received.

Of some significance is the heavy manpower requirement imposed when the control systems of COGOG ships are damaged. Manoeuvring in hand control consumes watchkeepers who may be desperately needed to repair other damage.

Overall, ships and men, faced with modern, highly lethal weapons, demonstrated the ability not only to survive but to continue in the fight and return to their base port for repair.

There can be no doubt that it was a wonderful achievement of the Royal Navy to land such a large body of troops on a hostile shore in appalling weather conditions at 8000 miles range with very little time for preparation. It will probably go down in history as one of the Royal Navy's greatest-ever feats. The landing could not have been achieved without the most superb inter-service co-operation and the wholehearted support of the Royal Air Force and Army. Their achievements were also outstanding and, of course, the action after the initial landing is another story of great accomplishment.

I have already said that the part played by the Merchant Navy was absolutely vital and quite marvellous. But to return to the warships, the hardware performed pretty well, as we would have expected. There were problems and great ingenuity was used in solving them—with much support from the RAF in flying out components.

But the reason that the hardware coped and allowed the Operational Commanders to win the battle was that the engineering personnel performed superbly. I believe that this is the greatest lesson on the engineering front that comes from the experience. Our people were loyal, dedicated, and well trained and we can be very proud of them. This Institute can also be very proud of its many members in both the warships and the merchant ships.

The Next Generation

The conflict in the Falkland Islands has raised many questions on warship design, machinery outfits, and weapons. Prior to the conflict a new frigate was well advanced on the drawing board and scheduled to be in service by 1988. It is now incumbent on the designers to incorporate the more obvious changes into that ship to take consideration of the Falkland experiences. Once again there is a compression of time and an urgent need to specify the ship in order to meet the intended time scale.

The ship is the Type 23 general-purpose frigate, an anti-submarine ship with a point defence capability. It has been decided that the ship will have a propulsion plant comprising a diesel-electric drive with a gas turbine boost (CODLAG). The electric drive will provide the quiet running mode which is desirable for anti-submarine towed array sonar and for the avoidance of detection. The high-speed boost will be provided by a new generation of marine gas turbine—the Spey engine. Such a propulsion package should enable reductions in the size of air and exhaust trunking from that of a COGOG plant.

There is, of course, a multitude of considerations which must be given to a new class of ship, many of which have been mentioned in this Address, but it is not possible to go into these details for the Type 23 at this time.

It is postulated, however, that maintenance will be undertaken at the lowest sensible unit level and that more maintenance operations will be within the capability of ships' staff. This is seen as a refinement of upkeep-by-exchange policy to enable more economic repair of some equipments. The ship's complement will be in the order of 150 as against 250 for a Type 22 and the build cost around £90 million compared with £135 million for a Type 22 (both at 1981 prices). The MOD is determined to keep the cost down to the minimum consistent with meeting the essential requirements in full.

There are always enforced deviations from the ideal ship from the viewpoints of the designers and operators. The Naval Staff requirements for a new ship have to be interpreted into a ship design and concessions often have to be made to enable the ship to be built to a particular time scale and to a budget cost. The vagaries of politics and the MOD expenditure patterns often clash with ideal engineering objectives. Unlike Merchant Navy practice, there is no feedback to a profit and loss account and no real measurement of effect except in time of conflict or emergency. Provided the Royal Navy acquits itself well at such times, it must be deemed successful; recent events, it is suggested, provide the proof of the pudding.

The time is now ripe for new thoughts and innovation to get the best solution to the staff requirements incorporated into a 'cheap' frigate. There may be more scope given to commercial sources for equipment specification. The Falkland activities have added an impetus to the continuous process of reviewing the policies and standards relating to shockproofing, vulnerability to fire and flooding, and habitability. Any enhancements are expensive in terms of money, space, and weight and must be judged in light of the fact that the ships will be operated in a 'bullseye' war. If missiles get through to a ship they have a high probability of hitting and causing massive damage.

These problems have to be addressed and resolved but every effort must be made to assure our future and to ensure that the Royal Navy's ships of tomorrow are properly built and equipped for their tasks.

If we make a real success of our designs and building there should be some financial return resulting from overseas sales. Although the sale of whole ships overseas has not been a successful venture recently, there have been large sales of machinery and equipments. Gas turbines are a good example of this and the new marinized Spey engine is stimulating a lot of interest.

We now, more than ever, need to make our points with forceful logic and professional integrity. We need to argue our case firmly and believe in our reasoning so that no one can deny us the fulfilment of a proper ship.

It is all very well for us to have CHEAP and NASTY ships—provided they are CHEAP to build and operate; and NASTY for the enemy.

Acknowledgements

I wish to end this Address by expressing my personal feelings as President of the Institute. I am deeply conscious of the great honour paid to me by the Members in electing me to be their President. As well as a personal compliment, I see it as an indication of the high esteem in which the Marine Engineering branch of the Royal Navy is held. I am very grateful, and indeed privileged, to have the opportunity to serve the Institute as both President and Chairman of Council.

I want to thank all of those people who have helped me during my career; those who have encouraged and supported me in my Institute activities, and especially those who have assisted me in the preparation of this Address. I am also indebted to the authors of many articles in the *Journal of Naval Engineering* over the years, to which I have referred.

The views expressed in this Address are those of the author and are not necessarily endorsed by the Ministry of Defence.