NAVAL ENGINEERING

BY

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On the 28th January the Engineer-in-Chief of the Fleet, in his capacity as a Member of the Council of the Institution of Mechanical Engineers, delivered a lecture to the Graduate and Student Sections of the Institution. Much of the lecture was devoted to organization, training and other matters which are integral parts of the profession of the naval officer. The following extracts, though they may be well known to some, may be of interest to others in showing trends in the development of the modern Navy.

THE ENGINEER OFFICER

Engineer officers are primarily naval officers dealing with a large body of men, and, although their engineering ability is vital to the future of the nation's defence, it is complementary to their primary function of leadership. This leadership cannot however be exercised without adequate technical knowledge and experience, because the Engineering Branch as a whole is a very tightly knit team.

Although the division of material responsibility between the various Admiralty departments and other appointments in which engineer officers may be called upon to serve is clearly drawn, the officers, as individuals, are not rigidly confined to one sphere. The object is to produce officers in the senior ranks who can administer any section of naval engineering. For instance, there is nothing to prevent an officer who has spent most of his career on ordnance equipment holding a senior post on the marine propulsion or the air engineering side. This versatility, which is very necessary if the Navy is to make the best use of its officers and to attain a proper cohesion of the different specializations, is achieved primarily by a thorough basic training in engineering.

Marine engineering experience is normally brought up to date before officers are promoted to higher ranks. As an example, an air specialist will probably have two periods, of about two years each, as a marine engineer before he reaches the rank of captain. This is the ideal for all three specializations, but it cannot always be achieved.

The Advanced Engineering Course at Greenwich should equip those officers, who are specially selected to undergo it, with post graduate qualifications which will enable them, with their sea experience, to give guidance to industry in the development of naval machinery.

THE NAVAL PROBLEM

Probably the greatest need in modern development is good engineering. The scientist, presented with a problem, produces a possible solution. The task of making that solution a workable reality depends upon understanding, not only the original problem and the basic solution, but all the intricate details of daily use to which the equipment will be put. In fact, I do not believe that it is possible to design the best equipment for a ship, or any other purpose, without the guidance of the man who uses and maintains it, provided of course he has the experience and training to qualify him to give it constructively.

The particular problem which faces the designer of naval machinery is to reduce to a minimum the weight and space occupied by the machinery and its fuel, while keeping it as simple as possible for ease of operation and maintenance. The problems are different from, and more difficult than, those met in the design of power station or merchant ship machinery. Not only is a reasonable efficiency necessary at full power in order to reduce the size of boilers, pumps, pipes and valves, but a very high efficiency is required below one-fifth power to give the ship maximum endurance for a minimum of fuel at the normal cruising speed. The machinery and fuel weight adds up to a considerable percentage of the ship's total displacement. In general, anything that is saved can be added to the fighting equipment of the ship.

RESEARCH AND DEVELOPMENT

Since the war, a great deal of money has been spent on research and development. The work is done mainly under contract by those firms best fitted for it, and our aim has always been to make the fullest use of the knowledge and ability of the country's industry.

At the outset it was realized that, if worthwhile advances were to be made, a major departure from previous practice in the Navy would have to be faced. Until the end of the war, the materials used in the machinery of H.M. ships were limited to those which could be worked on board by ship's artificers with the machine tools and equipment normally provided in larger ships, backed by depot ships and dockyards for the heavier tasks. This policy imposed a big handicap on designers who could not, in consequence, take advantage of advances in technique. It was decided that a much greater latitude should be allowed in the use of alloys and other special materials, and it was accepted that machinery would have to be built to greater accuracy and run at higher speeds. This decision meant that many parts, and even complete engines, which formerly could be kept serviceable by jobbing repairs, must be replaced by new ones on the completion of their stipulated life. It followed that standardization had to be introduced wherever possible, with a greatly improved system for the world-wide supply of spare parts and units. The Navy is getting nearer the aircraft conception of repair by replacement, but it is unlikely that it will ever approach the completeness with which this system is applied to the aeroplane, except perhaps in small and very specialized craft to which it is akin.

The types of machinery which have emerged as the result of this policy cover all classes of ship. In aircraft carriers, which have to be capable of frequent bursts of high power for flying operations and use the greatest power per shaft, geared steam turbine machinery still reigns supreme ; in cruisers and destroyers, again, it is primarily steam turbine installations that are used, but considerable research is being made into the possibility of using gas turbines, geared to the same shafts, for boosting the full power of the steam installations. Since these classes of ship spend a comparatively small proportion of their life at high power, fuel consumption at high power is not so important as at lower speeds and it is possible, by using the simple gas turbine cycles, to produce a great deal of power in a small space. There are many problems, such as the size of the air ducts required, which are particularly important in larger ships where they have to be taken up through several decks. Even in smaller ships there is considerable difficulty in fitting the fighting and navigating equipment into the space on the upper deck, and large funnels and intakes are therefore unpopular. However, as gas turbines are developed to use higher temperatures, and efficiencies improve, these difficulties will progressively diminish.

In smaller ships, where the power on each shaft is below about 8,000 h.p., Diesel engines offer advantages. The normal merchant ship Diesels are far too large and heavy for naval purposes and we have therefore developed small, high-speed light-weight engines. The provision of spare parts for these, all over the world, presents a major consideration and we therefore try to use engines with a standard design of cylinder unit for a large range of powers. For small high-speed craft, gas turbines are already proving their worth and we have three boats at present under trial where gas turbines are being pitted against the latest light-weight Diesel engines.

In submarines, Diesel machinery has reigned supreme for many years and the improvement of this type of machinery continues. We are also experimenting with submarines whose high underwater speeds are produced by engines using hydrogen peroxide. This gas produces the oxygen required to burn Diesel fuel, as well as giving out intense heat as it decomposes. By its use, the modern high-speed submarine can be freed from dependence on atmospheric air.

SOME RESULTS

In steam installations, development mainly at the A.F.E.S., has enabled more than double the amount of fuel to be burnt in a furnace of a given volume. This reduces the boiler size, but at the cost of higher air pressure, requiring more power from the fans or blowers.

In wartime boilers, the temperature of the steam dropped as the power was reduced, with consequent loss of efficiency. In the new boilers, the superheat temperature can be controlled at all powers, so that full advantage is gained from the higher temperature for which the machinery is designed. This arrangement also allows the temperature to be reduced before manœuvring, thereby protecting the machinery from severe thermal stresses.

The use of double reduction gears and the introduction of alloy steels for turbine rotors has enabled us to double the revolutions of the turbines, with a very large saving in their size and weight. This, in turn, enhances the reliability of turbines under higher steam conditions, because the differences in temperature, and hence distortion, are much reduced.

Great effort has been spent on improving gearing production methods so that the loading on teeth can be increased and the size of the whole gearbox consequently reduced. With the introduction of hardened and ground gears, the tooth loading has been much increased and although bearing problems have arisen, their investigation is showing that gains in gearing efficiency are possible by reducing bearing length.

In auxiliary pumps, the development of a high speed turbine, running at over 20,000 r.p.m. and driving the impeller through epicyclic gearing, has raised the turbine efficiency and reduced simultaneously the bulk of the complete unit.

These and similar developments in the components of steam machinery have given an overall reduction of 30 per cent or more in the weight of machinery per horse-power. An important factor, which has greatly contributed to these achievements, is the creation of teams of engineers, under development contracts, to study each overall problem away from the day-to-day administration, in which people inevitably live from one crisis to another. These studies are followed by a diligent search for the best that the country can offer for the development of each component, with the final object of fitting them all together to produce a balanced installation. The process involves a large amount of heat balance and other calculations and drawing, but without the technical assessment which results from this work the whole development effort could be misdirected. It has been applied to various fields of propulsion engineering.

Under Admiralty development work two Diesel engines have recently emerged. One is the Admiralty Standard Range I for normal applications of high speed engines where ease of maintenance in place is required. A high proportion of the parts are standard for the whole range, and maintenance problems have received detailed study. The other, developed particularly for naval purposes, is the Deltic engine. This is probably the lightest Diesel for its power in the world. It is designed for applications where the engine can be lifted out and replaced, instead of being refitted in place. It is particularly suitable for high-speed coastal craft, minesweepers and indeed anything requiring a very light-weight machine of about 2,500 h.p. with a life between refits of 1,000 hours. It can also be used at a lower rating of 1,900 h.p. with a 5,000 hours' life.

A commercial Diesel, after development, has also been adopted as the Admiralty Standard Range II engine. Others, of lower power, are continually under test at the Admiralty Experimental Laboratory, West Drayton, to find their weaknesses and help the makers to improve them, before and after adoption by the Navy.

Developments in gas turbines for the Navy have received fairly wide publicity already. The Motor Gunboat 2009 was driven by the first seagoing propulsion gas turbine in the world. The *Bold Pioneer* and *Bold Pathfinder* are fitted with Diesels for cruising and gas turbines for high power. The *Grey Goose* is at sea with an advanced type of gas turbine giving a high efficiency over a wide range of power, and no separate cruising engine is therefore necessary.

From these sea trials we have learnt a great deal which gives us encouragement in the application of gas turbines for higher powers. One of the major lessons has been that the difference between the requirements for aircraft and naval gas turbines is such that they are seldom interchangeable. External vibration and salt spray problems, the wider range of speed and the need for a longer life than is normal in aircraft practice, make it essential to test engines afloat before any estimate can be made of their reliability under naval conditions. It is therefore preferable, although expensive, to have engines designed from the beginning for the duty they are to perform at sea. Where gas turbines developed for aircraft can be used for naval purposes, however, we shall use them.

Probably the development which has gained the greatest recognition recently is the steam catapult. This has been adopted by the United States, French, Dutch and Commonwealth Navies. Nations, like individuals, learn, if they are wise, from the experience and techniques of other nations and it is well that we can repay, in major kind, some of the inspiration we have gained, particularly from the United States.

There are, of course, other developments of which I cannot speak. Enough has been said, however, to demonstrate some trends of advance which are being made.

Automatic control is already being applied to machinery to meet the needs of future methods of warfare. As machinery becomes more complex, and more highly forced to reduce weight and space, a higher degree of automaticity will be needed to ensure that it is operated in the way the designer intended.

TOWARDS THE FUTURE

We are competing with the law of diminishing returns in raising steam conditions ; they will undoubtedly continue to rise in the future, but this will probably be a slow process. Our best line may therefore be to use gas turbines in combination with steam machinery for high powers. For low powers we have a choice of light-weight Diesels where economy of fuel is particularly important, and simple gas turbines where weight is the predominating factor. There are also possibilities in free-piston gas generators in combination with gas turbines. In any one field, one is inevitably up against the law of diminishing returns. The introduction of some new form of prime mover such as the steam turbine, for instance, or a new fuel, such as oil, brings about an immediate improvement in the engineering criteria of weight, space and performance. Further design and development effort produces further advances, but at an ever decreasing rate until, in the end, it may well be uneconomical to press on further in that particular field of endeavour.

Another great revolutionary change seems to be due, and I suggest that this is most likely to come about with the introduction of nuclear power. Nuclear reactor design is only in its infancy, but investigations so far indicate that power from this source has enormous possibilities and may ultimately displace, in most applications, other types of heat producer. From a naval point of view the main, and perhaps only, advantage of nuclear power is that fuel and fuel stowage would no longer be a ship design problem and the nature of the logistic problem would be radically altered. Endurance would be practically unlimited by our present standards, and the speed at which fleets could move would no longer be restricted by the necessity to conserve fuel. We can therefore expect the whole tempo of naval movements to speed up, and the ship designer will be set a problem to design hulls to withstand high speeds in rough seas continually. So, through oars to sail, sail to steam, coal to oil, we seem to be at the beginning of another era using yet another source of power, even if in the early stages that power is likely to be applied by conventional means.

Throughout, I have refrained from mentioning any firm by name. The reason is that they are so numerous, and their activities so varied, that to do so would have been impossible. I am none the less grateful to all the firms, great and small, all over Britain, which have helped the Navy so much, and are indeed continuing to do so, often at great trouble to themselves.