STEAM INSTALLATIONS

BY

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Spectacular technical advances were made in the equipment of the fighting services during the Second World War, and Research Teams proved to be vital links between the operational staff and industry in ensuring that developments provided the best possible answers to staff requirements. It was a prudent decision to continue the use of the Research Teams after the war, although to a lesser degree, because these specialists provide the most effective means of carrying out thorough design investigations, having the most up-to-date theoretical and practical knowledge at their command.

The Problem

The Engineer-in-Chief's problem is to provide the lightest, smallest and most economical machinery and equipment to meet Fleet requirements. Only by reducing the weight of machinery plus fuel for a given endurance can more armament be carried and the best design of warship produced. The development of diesel engines and gas turbines is simplified because these machines are self-contained units, and therefore contracts can be placed with particular specialist firms for complete engines. The steam problem however is far more complex as it entails the use of boilers, turbines, condensers and associated auxiliaries which, apart from being the products of many specialist firms, must be designed to work as a unit so that the plant as a whole can be operated easily and economically at the required powers.

The Team

In an effort to provide the most suitable steam installations to meet staff requirements for H.M. ships, a team of technologists has been set up under the auspices of Messrs Yarrow & Co., a firm of long standing associations with the construction of machinery and ships for the Royal Navy. Officers from the Engineer-in-Chief's Department feed the team with operational data and work in close collaboration to ensure that the machinery provided is suitable for H.M. ships. It is entirely a Yarrow organization, known as the Yarrow–Admiralty Research Department and its function is to co-ordinate but not design. Through its contacts with industrial and research organizations it is in a position to integrate the components designed by the various specialist sections of industry into a balanced machinery installation.

The object of this article is to give the reader some idea of the work carried out by this team, and to bring into focus the thought and design effort which is going into the steam installations of new construction ships.

The first work undertaken by this Research Department was a comprehensive world survey of present land, merchant marine and naval practice, with the object of deriving future lines of advance in the design of naval propelling steam machinery. This led to the detailed investigation of promising cycles and indicated certain specific problems of practical research, reference to which will be made later.

Special Requirements

Consideration of the naval problems brought out clearly certain points of paramount importance in the design of machinery for H.M. ships. Although it would be impossible to satisfy all the requirements, at least the best compromise can be worked out once they have been clarified. These special requirements, which are taken into consideration in all designs of main machinery, systems and ancillary equipment are :—

(*a*) Efficiency of performance, including economy in consumption,

(*b*) Economy of weight and space,

(*c*) Reliability, including ability to withstand shock, a degree of immersion and heel,

(*d*) Ease of operation by inexperienced personnel,

(*e*) Ease of maintenance, including durability and interchangeability,

(*f*) Ease of production, including avoidance of scarce materials.

So far as (*a*) is concerned, there is one very important factor which is not easily apparent. The Engineer-in-Chief must know the powers at which prolonged steaming may be expected, so that the plant can be designed to give maximum efficiencies at these powers with consequent increase in endurance. In this respect a careful analysis of war-time records was made of the hours steamed at various powers by a number of ships of each class, and this realistic data is now available to assist staff divisions in determining their requirements for endurance at stated speeds in new construction ships.

Gaps

As a result of the survey of current steam practice, certain gaps in the knowledge available to specialist firms became apparent, and some research work has been, and is being carried out on these problems. Three specific cases are :—

Heat Transfer in Condensers. Examination of technical literature revealed that the results of the various theoretical and experimental investigations made in recent years were not consistent. The most important gap in the knowledge of heat transfer is the effect of scaling of the tubes. The mechanism of heat transfer in surface condensers is of a complex nature and the factors to be considered are :—

(*a*) The coefficient of heat transfer from steam to tube, (*b*) The resistance of heat transfer through the tube metal,

(*c*) The coefficient of heat transfer from tube to water,

(*d*) The effect of tube deposits on heat transfer on the steam and water side of the tubes.

The research into this problem clearly indicated the necessity for further experiments to determine the most efficient combination of tube diameters, water speeds, tube materials and the effects of scaling, air leakage and baffles on steam and/or water sides.

Circulating Water Flow. As there was scanty knowledge of the circulating water flow and associated resistance head in H.M. ships under operating conditions at sea, trials have been carried out on certain destroyers to obtain the practical answers for comparison with design estimates and results of model tests.

These trials clearly indicated that the scooping heads at the various ship speeds fell far short of those forecast by model tests, and those calculated from design data available in technical publications.

The necessity for further investigation into the design of inlet scoops and outlet pipes was established, bearing in mind that the more cooling water which can be obtained from this source the less steam required by the circulators. On the other hand the drag caused by the scoop may require more horse power via the turbines and propellers than that required to drive the circulators. Probably the best compromise is to use the scooping effect at cruising powers and boost the water flow by means of a pump at higher powers.

Floorplates, Gratings, Ladders, Handrails and Stanchions. Hitherto, in H.M. ships, these items have been constructed in mild steel. As a matter of interest, the German Navy used aluminium alloy floor plates and ladders, though steel was used for the remainder of the items.

The report covers the study and appreciation of various lightweight designs submitted by firms specializing in these products and to give some idea of the saving in weight, it is estimated that in a typical destroyer there would be a reduction from 9·5 tons in steel to 3 tons in aluminium. It is evident that the availability of materials at any particular time will influence the selection of this equipment.

Design Studies

Turbines, Condensers and Gearing. Some indication of the design studies concerning these items has already been given in previous articles in the *Journal.* Perhaps one of the most interesting points is the fact that for H.M. ships it may well be advantageous in the interest of weight saving, to design for a reduced vacuum at full power thus sacrificing efficiency at that power, because at cruising powers the vacuum is almost as good as though the plant had been designed for a high vacuum at full power. The arguments influencing the optimum vacuum which the designer must bear in mind are clearly brought out under the heading of ‘ Full-Power Exhaust Pressure ’ on page 58 of the April 1951 issue of the *Journal.*

Boilers. Commencing with the article on ‘ Boiler Operation ’ in the July 1951 issue of the *Journal*, and the further remarks on design and efficiency in subsequent *Journals*, some idea will be gained of the field for investigation in this sphere.

Optimum Pressures and Temperatures. A very thorough investigation has been carried out into the effect of increases in pressures and temperatures on efficiency and endurance, taking into account the operation of the plant, production and the burden of maintenance. Some of the interesting points which came out of this investigation concerning a typical modern naval installation are :—

Pressures

(*a*) The gains actually achieved in practice from increases in the initial pressure of the cycle are far less than would be expected from purely theoretical thermo-dynamic considerations. This is due to the fact that higher pressures result in increased leakage losses at the high pressure end of the turbine both within the blading and at the glands. Practical limitations in respect of turbine clearances and rotor lengths are determining factors influencing these losses. A stage is rapidly reached where the gain in efficiency resulting from increasing the pressure becomes negligible.

(*b*) On the basis of a constant weight of machinery plus fuel in a given installation, it has been shown that the increase in machinery weight resulting from increased pressure will eventually so reduce the fuel carried as to result in a reduction of the ship's endurance.

(*c*) Pressing facilities in this country to deal with required plate thicknesses for very high pressures would not be available.

Temperatures

(*a*) Unlike the case of pressure, increasing the initial temperature of the cycle has the most beneficial effect. In practice, for the installation under investigation, each 100°F increase in initial temperature resulted in an overall gain in efficiency of about 4 per cent.

(*b*) The extent of superheat is largely governed by the availability of materials with suitable physical qualities. Creep considerations must be taken into account.

Taking all these factors into consideration, optimum pressure and temperature conditions have been established which no doubt will remain for many years to come.

Systems

As with the main and auxiliary machinery, all the systems have been subject to critical design studies to satisfy the special requirements referred to previously. These systems include feed, lubricating oil, steam and exhaust, drain, sea water, fire and bilge, forced draught and fuel. The following typical case will give some idea of the detailed consideration given to these problems.

Steam and Exhaust Systems—Design Considerations

(*a*) Steam at the required conditions to be supplied to the main and auxiliary machinery.

(*b*) Exhaust steam from auxiliary units to be collected and supplied to the de-aerator for feed heating purposes and attemperment for use in the evaporating and distilling plant, or automatically rejected as required.

(*c*) When insufficient exhaust steam is available for feed heating and distilling, saturated steam from the boilers is to be automatically supplied to the auxiliary exhaust systems as required.

(*d*) Steam supply pipe diameters to be chosen to limit the pressure reduction from the superheater outlet to some predetermined figure at the machinery components when the main machinery is developing full power.

(*e*) The exhaust steam pressure drop between each auxiliary unit and the de-aerator to be reduced to the minimum consistent with weight and space limitations. In some cases it may be preferable to design for fairly large pressure drops at full power to save weight, although there will be a slight reduction in efficiency at that power.

(*f*) The risk and effect of damage to pipework to be assessed, and isolating valves and cross connections provided as far as weight considerations permit.

(*g*) The steam system to be arranged so that the engine rooms may be isolated and steam maintained by the boilers, without the risk of contamination of the feed water by sea-water when the engine room is partially flooded or otherwise out of action.

(*h*) Pipe flexibility and stresses to be calculated.

(*k*) Pipe lines to be arranged to facilitate drainage.

(*l*) The system to be designed to avoid as far as possible surplus exhaust throughout the power range over and above what is required for feed heating and evaporation.

Practical Aspects

So far as the ship's staff is concerned, some of the apparent differences of practical interest will be :—

Higher Operating Lubricating Oil Temperatures. There is a progressive increase in efficiency as the temperature of the lubricating oil supply rises. Experiments are proceeding to establish the optimum temperatures consistent with maximum reliability at which the gearing and bearings will run satisfactorily. In future installations the oil inlet temperatures to bearings and gearing are required to be 120°F as against present practice of approximately 90°F.

De-Aerators. In the past the de-aerators have been fitted for use on auxiliary, and on the assumption that the minimum plant will be working in harbour. In future the de-aerators will be designed into the feed systems for use under main and auxiliary conditions.

Turbine Auxiliary Glands. Carbon packing has been dispensed with in favour of labyrinth packing, with gland evacuation systems discharging to own glands-condenser.

Exhaust Systems. The range pressure will be of the order of 10 lb/sq. in. under main and auxiliary conditions with automatic valves to reject to the condenser or make up from the saturated steam range to maintain a constant pressure.

Auxiliary Steaming. As far as possible the boiler rooms will be designed as self-contained harbour steaming units to include turbo-generators, evaporators and feed pumps so that if steam is kept in harbour the maintenance problem will be eased.

Specifications

The detailed investigation into the designs for machinery and systems for particular ships (including models, which are essential if the best machinery arrangement is to be obtained) has logically led to the preparation of machinery specifications by the Research Department. These specifications are in far more detail than ever before and include guidance drawings and reasons why certain requirements have been specified which, in addition to providing a permanent record, materially assists the main contractors in the preparation of their submission drawings.

Shore Trials

Shore trials are an integral part of advance design to enable comparison to be made between the practical and theoretical answers. There will always be mechanical teething troubles associated with progress, but once these have been overcome there must be a re-assessment after the trials so that a Mark II design can incorporate the necessary modifications where practical results fall short of design estimates.

Production

The design having been proved on shore, the next essential is to study the large-scale production aspect and the team is required to co-ordinate suggestions by machinery contractors for modifications to details which, whilst in no way affecting the fundamental design, will speed up production. Consideration is given to this problem in the prototype set but only the production experience of one firm is available in the initial design.

Conclusion

A big step forward is now being made in the design of steam machinery for H.M. ships, which is reflected in great saving in weight and space of machinery plus fuel to meet specified endurances. Further advances will to a certain extent be controlled by the progress of the development of materials to stand up to the higher temperatures and pressures without heavy weight penalties. Meanwhile, there are still many problems, as this article indicates, which must be under continuous survey by the Yarrow-Admiralty Research Department to ensure that, within the limits of design knowledge and available materials, the most economical, reliable, and in all other respects suitable machinery is provided for the fleet.