NAVAL ENGINEERING DESIGN INVESTIGATION TEAM (ROYAL CANADIAN NAVY)

BY

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INTRODUCTION

The Royal Canadian Navy has been operating the Naval Engineering Design Investigation Team since January, 1954, and this paper is an account of the formation and function of that team.

The recent activity in the building of warships to form the nucleus of the post-war Canadian Fleet has been described by Commander E. B. Good, R.N., in his article 'Canadian Y.100' published in Vol. 9, No. 2 of the *Journal of Naval Engineering*.

REQUIREMENT

In the past, it was normally the practice of the Royal Canadian Navy either to obtain its major warships from Britain, or to build British designs in Canada. The improved Tribal Class destroyers are an example of this policy, some of the class being built in Britain and some in Canada.

The *St. Laurent* Class destroyer escorts was the first step in the production of Canadian warships ; the hull is an entirely Canadian design and the fittings and equipment of the ship are mostly of Canadian manufacture to fill Canadian needs, which differ in many important points from those either of the Royal Navy or the United States Navy, in conjunction with which the Royal Canadian Navy normally operates.

Although some Canadian shipyards manufacture propulsion machinery and its associated auxiliaries, the trend, as in other countries, is increasingly to purchase this type of machinery from specialist contractors. The scale of requirements at the present time does not make it worthwhile for the specialist contractors to maintain large design staffs solely for marine work on a permanent basis, bearing in mind the overall pattern of Canadian industry and the acute shortage of designers. Owing to the predominance of water for electric power generation (96 per cent in 1954), there is no large section of Canadian industry principally engaged in the design and manufacture of steam power units for generating stations on which the United States and Royal Navies very largely rely for their main machinery designs. There is, therefore, no body of well-equipped firms to which the Canadian Government can apply for Canadian machinery designs for new or projected warships and it is necessary to obtain designs from abroad, although manufacture is normally carried out in Canada. The Canadian Y.100 is a very good example of this policy where the British Y.100 design was, except for the first ship's set of machinery, manufactured in Canada.

With the policy of manufacture in Canada successfully established, it became necessary to ensure that the selected machinery would be that most suited to the needs of the Royal Canadian Navy. The Staff Requirements of the modern warship are so stringent and the machinery to meet them so

involved, compared even with the immediate pre-1939 era, that it is beyond the capacity of the staff of the Department of the Engineer-in-Chief to study all the competing claims in the necessary detail, as well as to conduct the day-to-day administration of the Department. This became quite clear during 1953, when the Royal Canadian Navy was considering the ships to be built to follow the destroyer escort programme, and it became essential to form a separate projects organization to digest the available information and to advise the Canadian Engineer-in-Chief concerning the selection of machinery designs to meet the Staff Requirements.

FORMATION

When it was decided to form a Canadian projects organization, advice was sought from both the United States and Royal Navies, where similar organizations have existed for some time. The United States Coast Guard and Messrs. Yarrow & Company, Limited, were also consulted, the former as a Service of roughly the same size as the Royal Canadian Navy and therefore having much the same requirements, and the latter as the operators of the Yarrow-Admiralty Research Department. All these gave freely much useful advice.

Canadian Organization

As the result of much study, it was decided to form a team which would consist of civilian engineers who would be employees of a commercial firm, but that the head of the team should take his orders direct from the Engineer-in-Chief and be directly responsible to that officer without passing through the management of the firm. This was acceptable to the contractor, Peacock Brothers, Limited, who, being themselves commercial competitors for the supply of auxiliary machinery, agreed to keep the research team entirely separate from their commercial operations and to house it in a location separate from the main plant.

Team Leader

It was originally hoped to secure the services of a civilian as leader but at the time when the team was formed, no suitable man was available. The Admiralty therefore agreed to the appointment of an engineering specialist of the Royal Navy as Officer-in-Charge to set up the team, to supervise its functions for the first year and to supply a relief for him until a permanent appointment could be made.

As the result of a change in Canadian Government policy, it has been decided that all organizations such as the Naval Engineering Design Investigation Team must in future be staffed by Civil Servants and this change is being carried out between 1st April, 1957, and 31st March, 1958. This will mean that the team will be part of the Department of the Engineer-in-Chief, although neither its function nor its location will be changed.

FUNCTION

Title

The title, 'Naval Engineering Design Investigation Team', was chosen with great care as most nearly describing the function of the group.

Terms of Reference

The terms of reference of the team are :—

(*a*) To draft, in part, the machinery specifications for which the Engineer-in-Chief is responsible.

(*b*) To prepare guidance drawings of acceptable machinery layouts for incorporation in machinery specifications.

(*c*) To calculate weight, space and fuel requirements to meet the speed and endurance figures prescribed by the Naval Staff for new construction ships.

(*d*) To prepare machinery layout designs for appraisal by the Engineer-in-Chief, incorporating and employing to best advantage the types of machinery and equipment procurable by the Royal Canadian Navy.

(*e*) To serve in a consultant capacity on questions arising from the specifications in shipyards and machinery manufacturing plants.

(*f*) To assist the Engineer-in-Chief, as required, in appraising machinery designs submitted to him by manufacturers in response to specifications.

(*g*) To prepare production drawings, except for detailing, in special cases where the required degree of design proficiency is beyond the capacity of the drawing offices of shipyards which receive only intermittent warship contracts.

(*h*) To keep abreast of the work of research and development organizations in allied countries with a view to benefiting from the advances in ship propulsion methods of other navies and without necessarily duplicating their investigations.

Location

It would have been possible to have located the team in the Ottawa area, but not inside the National Defence Headquarters, where office space was not available. This possibility was rejected, because it would have meant that the team would inevitably have been drawn into the day-to-day business of the Department of the Engineer-in-Chief, whereas one of the major requirements for its correct functioning is that it should be free from distraction to pursue its investigations in an untroubled atmosphere.

It was found convenient to locate the team at Montreal in the same building as the Naval Engineering Test Establishment, which is also operated by Peacock Brothers, Limited, on behalf of the Canadian Government, where economy of administration could be secured by sharing services. The team is, however, completely separate, technically, from the test establishment.

Allocation of Work

Projects are allocated to the team at the discretion of the Engineer-in-Chief, usually after preliminary discussions with the Officer-in-Charge to ascertain how a new project can be fitted in with those already occupying the team. No contract formalities are required, which is a great advantage in that it enables investigations to be carried out quickly and in accordance with an easily agreed priority. With the change in organization incorporating the team into the Civil Service, it will receive instructions from the Engineer-in-Chief in the same way as any other outstation of his Department.

TECHNICAL FACTORS

Accuracy

In naval engineering, where there are many conflicting factors that must be given due consideration but where any one of them cannot usually be allowed to assume a dominating position, accuracy is of extreme importance because a comparatively small change in emphasis of one factor can completely alter

the appearance of the whole project. In order to ensure accuracy, it is necessary to make paper investigations both of the manufacturers' claims for individual machines and of the project as a whole, in considerable detail. It is also essential to examine the assumptions that must be made in any engineering investigation and to ensure that they are justified in relation to the project as a whole and individually in themselves. This process often results in the alteration of long-held beliefs.

There are few things more dangerous, when considering the machinery for, say, a new class of ship, than ill-digested information. This, except by a lucky chance, inevitably leads to wrong conclusions and may well result in the ships, when built, failing in some important particular to fulfil the Staff Requirements or to be substantially less efficient than would have been possible. Unfortunately, accuracy entails the checking and re-checking of calculations and information supplied from outside and these processes take time, with the result that the answer to what often appears on the surface to be a simple problem may seem to be unreasonably delayed.

Heat Balances

The basis of all recommendations concerning the selection of machinery to be fitted in a new ship is the heat balance. This consists of the analysis and summary of the performance of each individual machine at a series of power levels, starting with the main engines and boilers and going right through each auxiliary machine to estimate the power consumption and output so that, at the end of the calculation, it is possible to estimate with fair accuracy the fuel consumption. From this series of calculations, it is possible to state the amount of fuel that is required to give the range specified by the Naval Staff at the specified speed and to assess the price to be paid in weight of fuel, or range, for the addition of special machines or the substitution of, say, an auxiliary of a different type.

After preparation of the heat balance, the first estimate of the total weight of machinery plus fuel can be made. Steps can then be taken, before the design is frozen for production, to point out the effect on the machinery of the ship of difficult features of the Staff Requirements, which may result in reconsideration by the Naval Staff.

The preliminary heat balance of a completely new set of machinery is necessarily imprecise because it must be based on the manufacturers' performance estimates for machines that do not exist, and because a large number of assumptions have to be made, some of which may prove considerably in error at a later stage. As the machinery becomes available for test, it is possible to revise the heat balance with increasing accuracy, until the final stage is reached where the calculations can be compared with the actual performance of the ship at sea.

Where a machinery design is being prepared that is a development of existing machinery, there is usually sufficiently accurate data for the heat balance to be fairly precise but, in a completely new design, prediction of the fuel consumption is unlikely to be closer than plus or minus 10 per cent of the actual figures. Errors are least likely at full power where the steam consumption of the main engines dominates the heat balance, but at very low power, which is the power for endurance of several new designs, the total steam consumption is composed very largely of that of the auxiliaries, which is both less easily predictable and more subject to random alteration and error than that of the main engines.

Performance Margins

Owing to the imprecise nature of the performance calculations of non-existent machinery, and for other reasons, it is necessary to allow margins but these must be selected with the greatest care because, otherwise, the machinery weight will be unnecessarily increased or, less likely, will fail to meet the requirements under a combination of adverse circumstances. When selecting margins, it is vital to ensure that they are consistent, otherwise a margin may be built into a major component that can never be used owing to the lack of an equivalent margin in a comparatively insignificant auxiliary.

Control of margins is an important function of any projects team, because only an organization that is responsible for assessing the project as a whole can hold the balance between the natural desire of everyone to make certain that the machinery works satisfactorily and the inexorable demands of the Staff Requirements. Unless control is very tightly held, the final effect may be that the ship can exceed its designed full power and that the machinery may be substantially heavier in weight than necessary for the specified full speed. At the same time, due to the built-in excess performance, it may prove less economical at low speeds than was estimated and therefore fail to meet the Staff Requirements in this important particular.

Weight and Space

The factors of weight and space are very largely tied to reliability and ease of maintenance, reliability having been given first place in the list of requirements for naval machinery by Admiral Sir Frank Mason in his Parsons Memorial Lecture to the North East Coast Institution of Shipbuilders and Engineers (*Journal*, Vol. 10, No. 2). At one end of the scale is aircraft practice, where life without overhaul is deliberately sacrificed to compactness and light weight and, at the other, shore power practice, where additional weight is quite acceptable if it increases the periods between routine overhauls ; obviously we must attempt to strike a balance between these two extremes, basing the designs on past experience and engineering judgment.

The factor of space is particularly difficult for the projects engineer, chiefly because he is always working to a very small scale, and because it is never possible to show on drawings the host of what Admiral Mason has called ' unconsidered trifles ', that tend to dominate the individual items of machinery in a ship. This is really outside the scope of a projects organization, being essentially the business of the detail designer, but it is always necessary to remember that any machine is always larger than it appears from the small scale outline drawing, by virtue of the miscellaneous small systems that connect to it. Models can be a great help, so can full scale mock-ups, though neither of these are likely to be available in the preliminary stages, when the total space must be decided.

Project Layouts

Together with the calculations of the main features of new machinery, a project layout of the machinery is prepared. The space available is laid down by the ship designer who usually provides a preliminary guidance drawing of the machinery spaces which fixes such parameters as length, beam, height and cross-section shape, into which the machinery must somehow be fitted. It is here that past experience is of vital importance, particularly the operating experience with the latest ships. It is nearly always necessary to fix finally the size of machinery spaces at a very early stage, together with the location and

areas of holes in the deck-head for uptakes, blower suctions, etc., and, by the nature of things, the Engineer-in-Chief is always under pressure to accept the absolute minimum of space.

The project layouts are developed in stages, starting with block diagrams and proceeding through the period when more exact and detailed information becomes available, to the eventual preparation of a guidance drawing that is acceptable to all concerned. It is, in fact, necessary to draw parts of the general arrangement of machinery in some detail in order to resolve the problem of the conflicting needs for space of such items as steam pipes, wireways and ventilation trunking. In certain particularly difficult locations, it is necessary to prepare perhaps six different views in great detail before an acceptable compromise is reached.

It is sometimes difficult, when serving in a ship, to reconcile the arrangement of the machinery in practice, with the designer's intentions, because there are always one or two bad examples of inaccessibility. Having seen the problem from the other side of the fence, the writer is convinced that cramping is, to a certain extent, inevitable in warship machinery spaces and that the machinery designer is fully alive to the problem and does his utmost to alleviate it. Quite apart from the details of the arrangement of machinery, which are usually the features that obtrude most noticeably in the completed ship, the project layouts enable the Engineer-in-Chief to be satisfied that the major items can be fitted in the space available or, if not, give him information on which to base his case for more space. Such factors as the ability of pumps to take suction under conditions of heel and trim are studied at the same time.

Consultation

Obviously the Engineer-in-Chief cannot work in a vacuum, and it is the usual practice in the Royal Canadian Navy to set up a Development Committee very early in a new project, on which sit representatives of the Naval Constructor-in-Chief, the Engineer-in-Chief and the Electrical Engineer-in-Chief. Here the problems of the machinery arrangement can be discussed as they arise and the best compromise can be made at an early stage. This committee is doubly useful, as the minutes of its meetings form a history of the development and give the reasons why certain decisions were arrived at, for guidance at a later date or when considering alterations.

SELECTION OF MACHINERY

It is the policy of the Engineer-in-Chief of the Royal Canadian Navy to obtain the highest quality machinery that is available and that is suitable. It is therefore one of the major tasks of the Naval Engineering Design Investigation Team to assess not only the fundamental suitability of machinery but the relative merits of individual machines in a competition.

Design Competitions

It is often found, when selecting machinery for warships, that there is only one reputable supplier for a particular item, or only one that is interested in supplying the Royal Canadian Navy, which has very small requirements compared with larger navies. However, where there is a number of possible suppliers, it is normally the practice to conduct design competitions.

A statement of requirements is made out and circulated to interested suppliers, who prepare sketch designs to meet them, in sufficient detail to enable a just comparison to be made. The response varies from a pencil sketch in outline to a super-salesman complete with photographs and advertisement pamphlets

in full colour, with the former predominating. As the analysis proceeds, it is usually necessary to contact the individual firms to clear up obscure points or to confirm figures that appear to be unlikely. After the proposals have been analysed, they are rated in estimated order of suitability and a report is prepared for the Engineer-in-Chief where the products are compared on their technical merits alone and a recommendation made. Although it is usual for the Engineer-in-Chief to accept the recommendation, it in no way binds him to do so and he is free to select any, or none, of the other competitors, according to his own judgement.

Despite their theoretical excellence, design competitions are not always the best methods of obtaining machinery. There are several reasons for this :—

(*a*) The process is necessarily fairly lengthy and decisions concerning selection may have to be made quickly, thus not allowing time for a competition.

(*b*) Special designs are costly to prepare and busy firms find it difficult to apply the necessary effort, except in response to a firm requirement.

(*c*) Due to (*b*), many concerns, especially those who have not dealt much with the Navy, submit their nearest standard designs.

(*d*) Many projects are undertaken for each one that reaches fulfilment and the law of diminishing returns applies if design competitions are used too often. It is not reasonable to expect commercial concerns to provide even sketch designs at frequent intervals for projects that have little prospect of adoption.

Specifications

The machinery for a ship is, of course, manufactured to a detailed specification. The Naval Engineering Design Investigation Team prepares a statement of requirements in parallel with the recommendations for the selection of machinery, the heat balances and the project layouts. These statements of requirements can, when and if approved by the Engineer-in-Chief, be used as the basis of the detailed specifications.

LIMITATIONS

Machinery Design

It is recognized by the Engineer-in-Chief that the detailed design of machinery is the proper business of the manufacturer and that the functions of design and manufacture cannot, in fact, be separated. It is, therefore, no part of his policy to usurp the position of the manufacturer and the function of the Naval Engineering Design Investigation Team is to assess designs for suitability for naval use rather than to try to tell the manufacturer how to design his products, although, especially with the less experienced suppliers, it is sometimes necessary to suggest modifications to improve the potential performance in naval service.

A service which the team can render to any supplier is to advise on sea experience, particularly to those firms that have supplied large numbers of machines, so that the design can be modified for better performance and to avoid the repetition of mistakes. For this, it is essential for the team to be in fairly close touch with what is going on at sea and this factor is easily arranged by its structure, with a Naval Officer-in-Charge who can make it his business to keep himself informed through his opposite numbers inside the Department of the Engineer-in-Chief.

Ship Design

As with the design of machinery components, the detailed layout of machinery in the machinery spaces is the proper concern of the shipyard drawing office and no attempt is made by the Naval Engineering Design Investigation Team to usurp this function. As has been mentioned above, it is necessary for the team to satisfy itself that the machinery will in fact go into the space provided, but apart from small individual components where the fit is doubtful, all detail work is left alone, their interest ceasing with the preparation of guidance drawings. It so happens that at the present time the shipyard drawing office is centralized in the Naval Central Drawing Office, which is also in Montreal, so that liaison between the team and the drawing office is very close ; this feature is most desirable to avoid the grosser type of mistake in the earlier stages.

RESEARCH AND DEVELOPMENT

In the course of its job, the team inevitably finds features of machinery that could do with further development, or has proposals to make for machinery for which no commercial supplier can be found. The normal accepted procedure for dealing with these occurrences, both in Britain and the United States, is by means of development contracts. In Canada, control of Government-sponsored research is centralized in the National Research Council for civilian projects and in the Defence Research Board of the Department of National Defence for military, the two working very closely together. This slows down the process of getting a research item under way, but it does ensure that each scheme is subjected to expert scrutiny before large sums of money are spent, and that unnecessary duplication is avoided.

SUPPLY OF INFORMATION

Obviously a team such as the Naval Engineering Design Investigation Team needs a large amount of information on a wide variety of subjects, including design information that is the property of commercial concerns and which is not in the ordinary course of events released to customers. Much information can be obtained direct from potential suppliers, but there is a great deal of information in the possession of suppliers that is covered by the Official Secrets Act in Britain and is ' Classified Military Information ' in the United States, which is needed by the Royal Canadian Navy to enable the correct choice of machinery to be made. There is, therefore, a considerable exchange of information between the Royal Canadian Navy, the Admiralty and the Navy Department of the United States, but this still leaves a gap. This gap is to a large extent filled by a direct exchange of information between the Naval Engineering Design Investigation Team and the Yarrow-Admiralty Research Department, much to the advantage of the former.

Security

The provisions of the Official Secrets Act of Canada are, of course, applied fully both to the staff and the information in possession of the Naval Engineering Design Investigation Team. This is not all, however, because much information that is not strictly covered by the Official Secrets Act is supplied by contractors to the team on the understanding that it will not be divulged to a third party or used in a way which makes its origins and features obvious. This necessitates stringent measures to avoid accidental indiscretions and the position of the team will be made much clearer when it is fully integrated into the Department of the Engineer-in-Chief. At the present time, the firm holding the administration contract, being themselves competitors for the supply of auxiliary machinery, have no access to the work of the team or to the offices where the work is carried out.

IMPARTIALITY

Like the administration of justice, the operation of a projects organization must not only be impartial, but must manifestly appear so to be. A reputation for complete fairness in considering the proposals of manufacturers is essential, both to build up confidence of all concerned in the team and to ensure that even unsuccessful competitors are willing to continue to submit proposals as they are called for. A reputation for impartiality is very difficult to acquire, partly because everyone naturally thinks that his ideas or the products of his efforts are the best and partly because, in the limit, judgment has to be based on opinion and this is, to say the least, fallible.

In the Naval Engineering Design Investigation Team, the normal procedure is to obtain the opinion of as many people as possible and to discuss fully the significant factors of any proposal, before submitting it to the Engineer-in-Chief, to make it as nearly a composite opinion as is humanly possible. The aim in this direction is to build up a reputation similar to that enjoyed by the better known firms of consulting engineers.

COMMENT

Cost

It may seem that a projects organization is a luxury for the engineering branch of a comparatively small navy, particularly where well established designs can be obtained from allied countries. However, it is the opinion of the writer that any navy that is going to be responsible for its own machinery requirements must employ a projects group to ensure that it can meet the increasingly rigorous demands of the Naval Staff. The cost of an organization such as the Naval Engineering Design Investigation Team is not great when compared with that of building ships, and it is quite possible to save the expense of running the team many times over in the reduction in first, operating and maintenance costs of the ships for which the team is employed in the planning stage.

The Position of the Naval Officer

The position of a naval officer as head of a projects group working as employees of a firm outside the Government Service is somewhat anomalous, but has worked out satisfactorily in practice ; this is chiefly due to the terms of the contract under which the team has been run during its first three years, so that, from the technical point of view, it has been an extension of the Department of the Engineer-in-Chief.

With the integration of the team into the Civil Service, the position of the Officer-in-Charge will become identical with that of the head of any other outstation reporting to the Engineer-in-Chief.

A naval officer is, of course, at considerable disadvantage when he first arrives in a job in which his staff, having many years' experience in the fields of interest to be covered, knows a great deal more about the detail than he can ever hope to absorb in the comparatively short time at his disposal. On the other hand, this limitation has been accepted for many years by both the Royal Navy and the United States Navy and seems to be a reasonable compromise between the requirements of continuity of technical staff and of feeding back operating experience at sea into the very earliest stages of design.

CONCLUSION

The Naval Engineering Design Investigation Team has an essential function to fill in the Engineering Branch of the Royal Canadian Navy, a function that

is likely to become even more necessary with the increasing stringency of the Staff Requirements for propulsion machinery and the complexity of the machinery necessary to meet these requirements.

The organization has worked quite satisfactorily to date and time alone will show how it will fit in under the revised procedure where it will become an outstation of the Department of the Engineer-in-Chief.

It is hoped that the team will result in the Royal Canadian Navy's obtaining the machinery most suited to its needs. It is also a salutary and very pleasant experience for a naval officer to work closely with highly qualified civilian engineers.

It is appropriate here to express the thanks of the Royal Canadian Navy to Sir Harold Yarrow and to his Company for the advice and help so freely and altruistically given, both in the founding of the team, its staffing and in supplying so much of the information held by the Yarrow-Admiralty Research Department. Without this, it is doubtful whether the team could have got going so quickly, if at all. It would certainly not be nearly so useful an organization.