BOILERS

BY

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The following paper is the substance of a lecture on the work carried out by the Boiler Section of the Marine Engineering Division of the Ship Department, presented by the Author who was from August, 1959, until December, 1963, the Inspector of that Section.

Introduction

The purpose of this paper is to give some indication of the work of the Boiler Section during the past four years. FIG. 1, although somewhat rudimentary, gives an immediate picture and also indicates quite clearly how

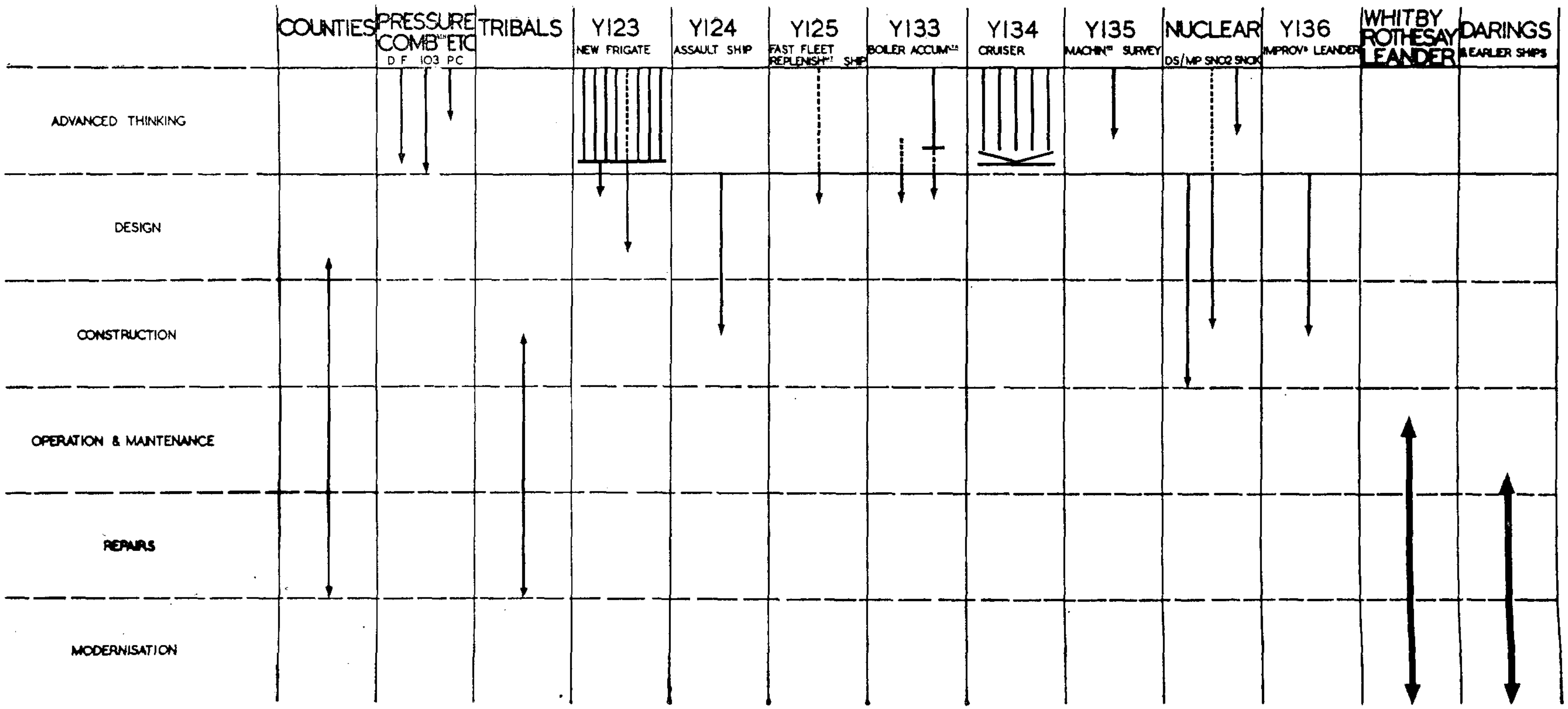

FIG. 1—BOILER SECTION WORK, MID-1959 TO MID-1963

TABLE I—**Advanced Thinking**

Associates:
Admiralty Fuel Experimental Station
Universities
Research Associations (Private)
Research Establishments (National)
Industry

diverse in subject and in character the work has been. The side-headings give some idea of how a project progresses. It will be noted that none of the arrows in the project brackets goes all the way from the beginning to the end. That is not at all surprising because this period, even as far as getting a ship from the advanced thought about it into operation, is of the order of ten years. The thickness of the arrows is an attempt to indicate for any one project the amount of work that has been put in, and where there are a number of lines, these are representative of the number of times that we have had to cross the same ground with slightly different sets of requirements to be met.

The TABLES indicate who the people and organizations are with whom the Section collaborates on any given aspect of work. These will be referred to in some detail.

Advanced Thinking

The initial stage of any project is the advanced thinking—the thinking ahead on a long term basis. This immediately involves us in the sponsoring of basic research. There are many uncertainties about the parameters of boiler design so that progress depends very much on research and development. We in the Navy tend to accentuate the problems by asking for something different each time. We have the basic research carried out by universities, obviously better suited to this work than our own R. and D. establishments and also making it, where appropriate, available to the widest possible number of interests. We have had work going on at Sheffield University on various aspects of combustion, ranging from the very basic to the very applied. At one time they investigated the pulsation problem, which a number of readers will no doubt have experienced quite directly and found to be one that is well worth investigation. An interim solution, at least, has been found to this problem.

We also have work going on at Imperial College and we are in touch fairly continuously with other research associations, such as the British Ship Research Association. We also work with the National research establishments, such as the N.G.T.E., where they do combustion research not necessarily benefiting the boilers but setting a background.

The Admiralty Fuel Experimental Station is the first on the list of our actual collaborators, because it is so much a part of the Boiler Section that we consider the A.F.E.S. and the Boiler Section D.M.E.'s two hands, and we do believe that in this case one does know what the other is doing. Industry comes in rather more specifically, e.g., for research into special materials.

When we have got the basic research covered we come to the projects which are, although beyond the laboratory stage, some way off. For example, the most prominent one that has occupied our time has been pressure firing.

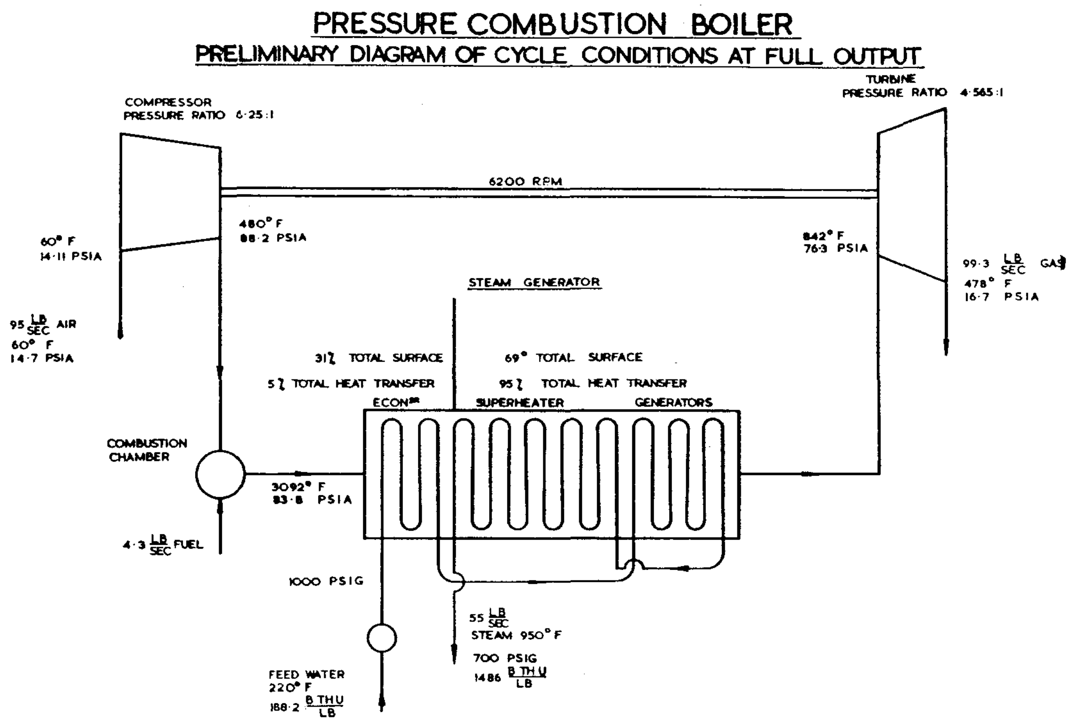

FIG. 2—PROJECT CYCLE FOR A MAIN PROPULSION STEAM PLANT USING PRESSURE COMBUSTION

Pressure firing can mean a lot of things. One idea is shown in FIG. 2. This is a pressure firing cycle which is based on an existing gas generator, namely the H.P. turbine and the pressure part of, actually, the G6,—but this is slightly irrelevant. The cycle is that the air comes into the compressor and is brought up to about six atmospheres as a maximum pressure. It then goes to a combustion chamber—ill defined because not yet known, but which we have been approaching via gas turbine work, rocket work and that sort of application, appropriate in scale but not yet accepted as normal in marine practice. From the combustion chamber at about 2,000 degrees F. the gases leave and first of all go through a heat exchanger. The economizer element comes first, then the superheater element and then the generator element. This is not vital but it gives a reasonable possibility of keeping the tubes cool enough to avoid fracture due to overheating. The steam then leaves at, in this instance, 700 lb/sq in., 950 degrees F., but this also is relatively immaterial. The gases, having lost the dangerous part of their heat as far as the driving turbine is concerned, then go along and do some mechanical work. The great advantage of this plant compared with a conventional one is that it is very, very much smaller. It is approximately one-third to a half of the bulk of a conventionally fired boiler for the same steam generation. By the same token, it has a number of other advantages compared with boilers: less weight, greater flexibility, smaller heat losses. Compared with gas turbines, the advantages are, firstly, the lower air requirement—about 16 times the weight of the fuel fired as compared with about 100 times in the gas turbine; air and gas ducting sizes come down enormously. Secondly, as previously mentioned, the peak temperature in the cycle occurs just before the heat exchanger so that there is no problem of looking after the turbine to prevent it getting into trouble because of dangerously high gas temperature. Furthermore, if there is any rubbish about it will collect in the heat exchanger rather than on the turbine blades.

As part of the approach to different steam generating cycles, we have also looked at Dieso firing. This is much more pedestrian—it uses ordinary pressures—and can also be used in perfectly ordinary boilers, as has recently been

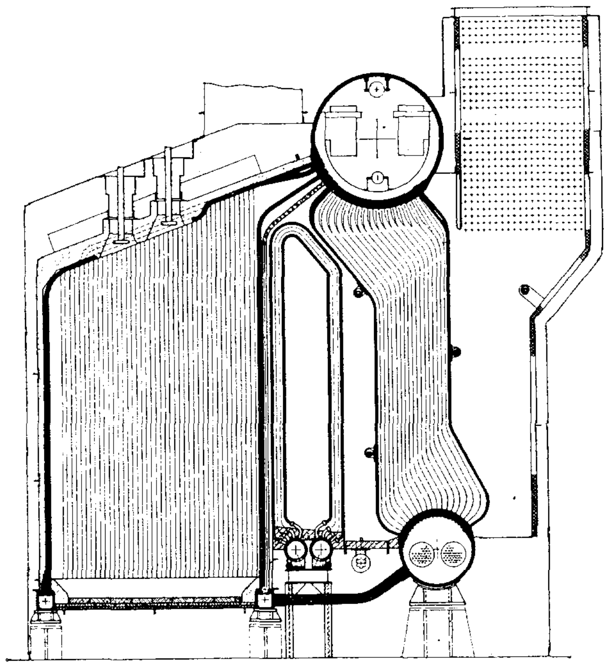

FIG. 3—SECTIONAL ELEVATION OF A BOILER WITH DOWNWARD FIRING REGISTER

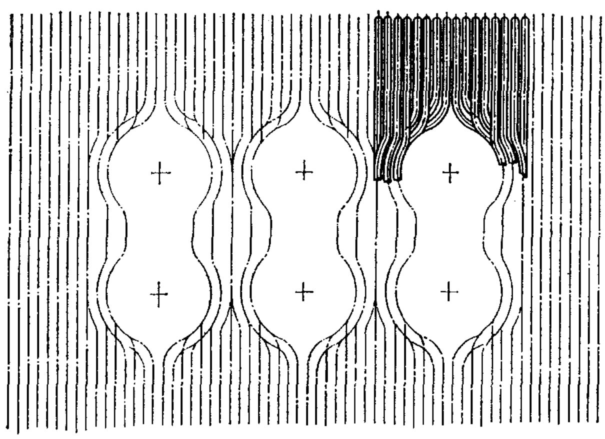

FIG. 4—DETAIL OF LAYOUT AROUND REGISTER IN A BOILER WITH DOWNWARD FIRING

proved very well in a number of Type 12 and Type 14 frigates. It can at the same time give quite significant benefits; something like 20 per cent saving on bulk—and there are circumstances where even 20 per cent is worth having. However, this question of burning Dieso in a steam generator, as distinct from a power generator like the Diesel engine where Dieso has always been accepted, is being treated with a great deal of caution by all concerned, and all concerned here range from D. of S. to the oil companies, so that this is a problem where the technical merits are really quite clear, but the rest of the picture is still remarkably confused.

Another possibility that we have looked at, this time with a specific design in mind, is downward firing. Downward firing, as can be seen straight away from FIG. 3, is exactly what it says. Instead of injecting the oil and air horizontally and then hoping that it will go up at an angle, when nature intends to make it go straight up all the time, it is fired downwards with reasonable velocity and the trend is for the products of combustion to peel off from the jet progressively and flow through the gas path, which makes for a more efficient usage of the steam generating surface, makes for a better and more even distribution of the heat as compared with ordinary firing and, furthermore, encourages solid matter, which will have a significantly different specific gravity from that of the gases, to fall out on to the floor where it will do no harm. This was actually investigated with the possibility of application in new designs, and is a realistic proposal. FIG. 4 shows a possible solution to some problems with downward firing which are not shown in FIG. 3, in particular the configuration of the orifice through which the fuel and air come, indicating that these are by no means insuperable.

This sort of tube layout may not impress marine engineers very much but it is apparently 'old hat' as far as power generating stations are concerned, and they certainly do not saddle themselves with anything that involves them in a substantial maintenance penalty. So with that background, it seems worthy of consideration as a 'reasonable runner'.

We have also been interesting ourselves in subsidiary equipment development—this obviously very much together with the A.F.E.S. The first thing that comes up in this connection is the possibility of some fuel atomizing scheme different from the one we are using at present. The one we are using now which involves high pressure and return flow, is satisfactory in itself but saddles us with a number of penalties which we would like to avoid. Other means of trying to achieve the same thing are reasonably well known in themselves but have not really been explored in the naval context before, so we got down to doing this. The most promising one at present is to use steam to assist atomization. This means that with the oil at a reasonably high pressure, about 500 lb/sq in. instead of nearly 1,000 we are using now, the atomizer is operated as a simple variable pressure jet down to the output where the pressure is only just good enough to give proper atomization. For outputs below that value, a steam jet is brought in which helps to keep up the quality of atomization even when the oil flow is reduced still further. The steam consumption is not frightening in terms of modern evaporating equipment. Even in small ships it would be acceptable observing that, if really pushed, you could dispense with that aid and simply stick to that part of the atomizer performance curve which does not need the steam. This steam-assisted atomization has got a lot of interest in commercial circles at present, but we are not yet by any means entirely clear about its benefits, so the investigation continues. It is certainly an interesting possibility. Another alternative—a very long standing one—is to use a cup rotating at high speed into the centre of which the oil is injected. The oil then runs along to the edge and sprays off. This has got a very reasonable characteristic—the less the flow the finer the spray—but in this case we land ourselves, as we have found, with a fairly hefty device on the boiler front, together with the air metering equipment, approximately three times the weight of what we are using at the moment. We also land ourselves with a mechanical drive which has not 100 per cent reliability. As far as we have got, it rather looks as if what we are using at present, for all its cons, has as many pros as any of the other things have.

We have concerned ourselves with the development of improved heat resisting alloys of one sort or another. These have presented problems in the uncooled parts of not only modern boilers but in boilers right back to about the first world war. This development also is still going on, but substantial progress has been made, not so much because of what we have done as because of what other people in the rocket field have been doing on the same sort of materials. Refractories are in the same category, but here we have played a more positive part. In fact, industry, which uses a large amount of refractories, is really quite happy to accept our lead by way of quality control and so on. This is quite a high recommendation because very often industry argues that its requirements are very different from ours and what we do is of no interest to them. They have not said that in the field of refractories.

In the field of instruments, again we find that very often we want to know something more accurately, or we want to know something that nobody else is interested in, so we have to carry out development. Once again A.F.E.S. have done the work but we have provided some of the ideas and encouragement.

A specific piece of equipment with which we are very much concerned is the soot-blower. Soot-blowers have for a very long time been fitted to naval boilers and for a very long time they have been broadly unsatisfactory. In the latest selectable superheat boilers the situation has been improved somewhat, but we still feel that there is room for improvement. In particular, the problem has been to find a soot-blower which can be inserted into the really hot part of the boiler only during that time when it is working, when it is steam-cooled, and can be withdrawn at all other times. This is not easy because first of all there is usually insufficient room to withdraw it and, secondly, people's confidence in its continued ability to be withdrawn is small in the light of

TABLE II—Design

Associates with Questions:
Projects Group (Engineering)
Ship Sections
Specialist Sections
Associates with Answers:
Admiralty Fuel Experimental Station
Yarrow-Admiralty Research Department
Boiler Designers
Specialist Sections

general soot-blower experience. However, we have recently got one of the best firms in this field to put up a blower for trials at the A.F.E.S. which is proving more satisfactory than any of the earlier ones and it has got a better chance of survival. It is planned to fit this in the Assault Ship.

We also keep up a liaison with the various standardization organizations and to try to take part in the formulation of new standards. This produces some rather interesting situations. For example, we have just had a proposal from one firm of boiler designers that we should drop the old British standard and accept the new, as yet draft only, international standard for boilers. We have also had a proposal from an other equally qualified firm that we should pay no attention to the new standard because the old one is very much better. This does not help us much in deciding that we should do but it does give us a pretty plain hint that we need to think.

Design

Now to come to the 'design' part of the work. TABLE II gives an idea of who co-operates with us on this subject, but to give a picture of our task the various requirements that we have to try to meet will be discussed. The first one is to ensure a design which is not cramped so that we guarantee proper access for maintenance. On the other hand, of course, we must see to it that we take up a minimum space and, for a given design of ship, accept specified dimensions. FIGS. 5 and 6 show a progressive situation in this respect. The first design which really aimed very conscientiously to meet all these requirements was the *Whitby* Y.100, or Type 12 frigate. It certainly met the criterion of compactness—it is the most compact boiler in existence. The superheater headers touch one another, so there is no access to the tubes between them. On each side of the headers there are more obstacles not indicated—there are rather a lot of downcomers. What with one thing and another, those who have operated these ships will agree that they are extremely difficult to maintain, to say the least. Furthermore, there is a point of weakness in the design of the superheater support which is an uncooled plate integrated with the tubes in such a manner that you can only renew the plate if you renew all the tubes. The Canadians have had some bitter experience here. They found that for all the tubes might last eight or ten years, the plates last a great deal less. This is obviously a most unsatisfactory state of affairs.

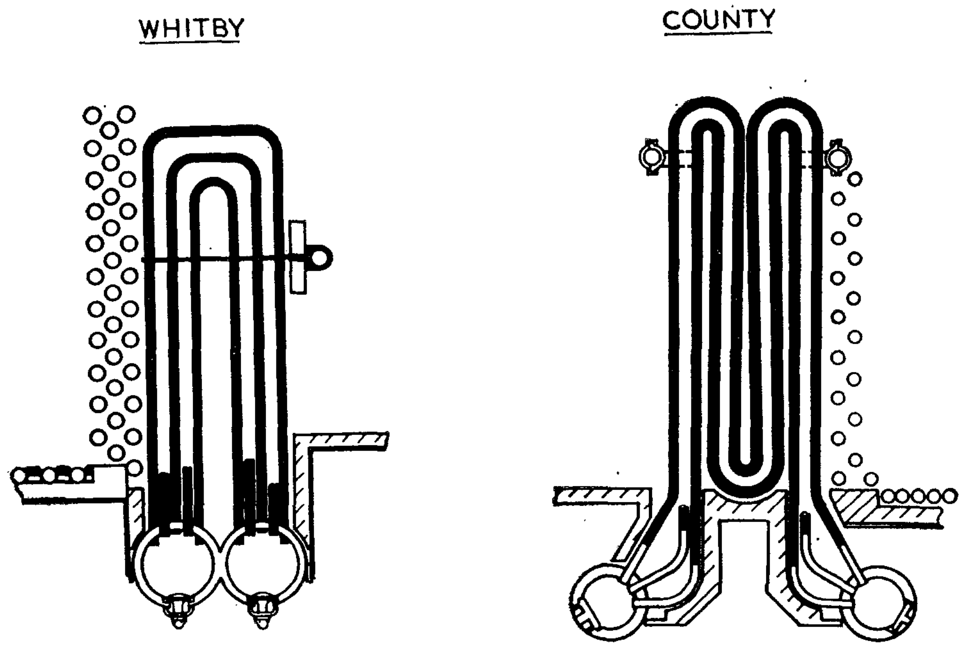

FIG. 5—'WHITBY' AND 'COUNTY' CLASS SUPERHEATERS SHOWING DEVELOPMENT OF DESIGN FOR IMPROVED ACCESS (STAGES I AND II)

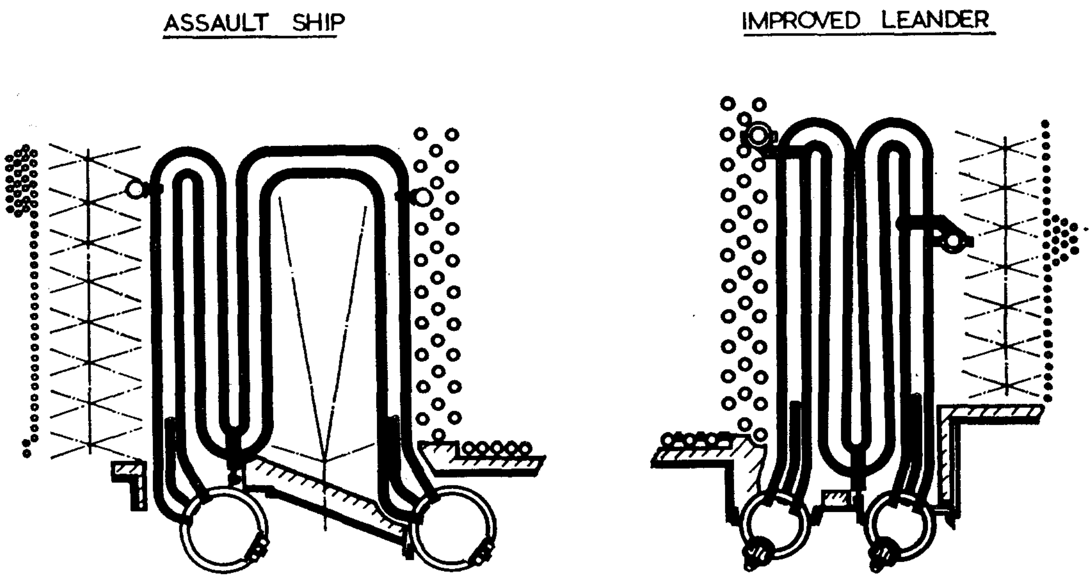

FIG. 6—IMPROVED 'LEANDER' AND 'FEARLESS' CLASS SUPERHEATERS SHOWING DEVELOPMENT OF DESIGN FOR IMPROVED ACCESS (STAGES III AND IV)

Some of the lessons learned from the Y.100 were applied in the next design shown in FIG. 5, that of the *County* Class. This has a different type of support, further out of the way, the headers set apart, access in between, even if somewhat cumbersome, but the tubes still very closely nested, making it difficult to get in there effectively.

The 'Improved *Leanders*' have gone a bit further again, but we were limited in that we had to maintain substantially the dimensions of the original. As can be seen in FIG. 6, this is a somewhat intriguing header layout, but it does keep the headers apart. There is a comparatively light closing section in between the headers with a support there, and the other supports are attuned to modern requirements. There is still no space in between. Finally, given a little more room in the Assault Ship, we have really 'gone to town' (FIG. 6).

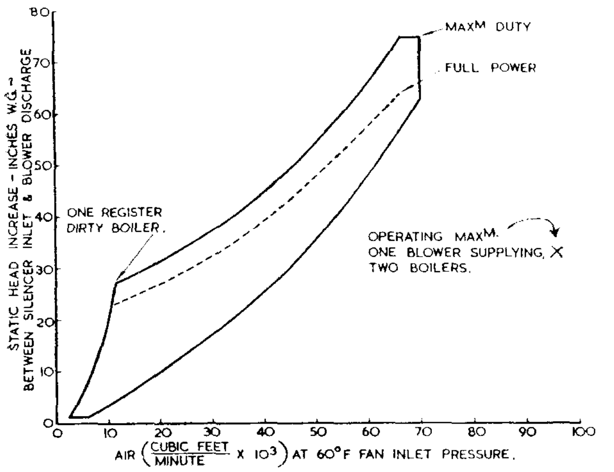

FIG.7—BOILER BLOWER CHARACTERISTIC CURVE

This is what the Americans would call a walk-in superheater. There is certainly room for manœuvre, and the headers are farther apart. There is a gap between the first and second rows of tubes, allowing a short retractable soot-blower to be fitted. This is in a good position to attack the deposits in the first row of tubes which we know to be those which are the most dangerous, and, of course, will also keep the second row clean. Superheater supports are pracically absent. They consist actually of ferrules round the tubes and a support tube which simply ensures that there is no relative movement of the elements. The ferrule is shown only on the one tube, but it is on each of these tubes. The ferrules continue to provide internal rigidity and keep the right spacing. At the top and bottom, there are strong brackets to keep the whole superheater steady against, say, underwater shock.

Another requirement is to get the highest possible combustion rating but, at the same time, to use the minimum fan power for combustion. This is illustrated in FIG. 7. Once upon a time, we used to specify our requirements for a fan simply by designating maximum head and flow, worked out from maximum firing rate. Now we have a different situation created by the introduction of automatically controlled combustion systems. We must allow the control some latitude without involving the blower and thence the air supply in danger of instability. The working area of the fan must therefore be some distance inside the blower stability boundary. Again, we have to consider full power plus a quantity margin for leaks which develop, plus a head margin for increasing resistance through the boiler when it is dirty. We then have to arrange a situation where stable operation throughout the whole of the burner output range, which should be also the air flow range, is possible right down to that air flow characteristic which ties up with one register only and a dirty boiler. The whole operating requirement for the fan is not only a more tricky one than it used to be, but also as compared with the old full power, we land the fan designers with something like a ten per cent penalty on head. No wonder with a top value for head somewhere near 80 inches W.G., that the fan designers tell us to keep it down.

Further requirements are (*a*) to provide all modern refinements, yet at the same time to keep the design simple, and (*b*) to meet any peculiar requirements from the A.B.C.D. point of view like shock resistance and blast resistance and yet to accept standard industrial techniques and materials.

An example is shown in FIG. 8 of how we have interpreted all this in the latest version, so to speak. As the caption indicates, these are basic design drawings of possible boilers for a new aircraft carrier. Here we have two designs from the two strongest contenders for the honour of building these boilers, which gives an idea of what we are aiming at. This concept of one header at one end and one at the other is not one of which we are terribly fond but, on the other hand, it does make the allocation of space for the headers rather easier. Again, the downcomers that get in the way here if all the headers are at one side are not shown. Supports are kept to a reasonable minimum. Actually, if this design were to go forward, these bends could be taken out through, or

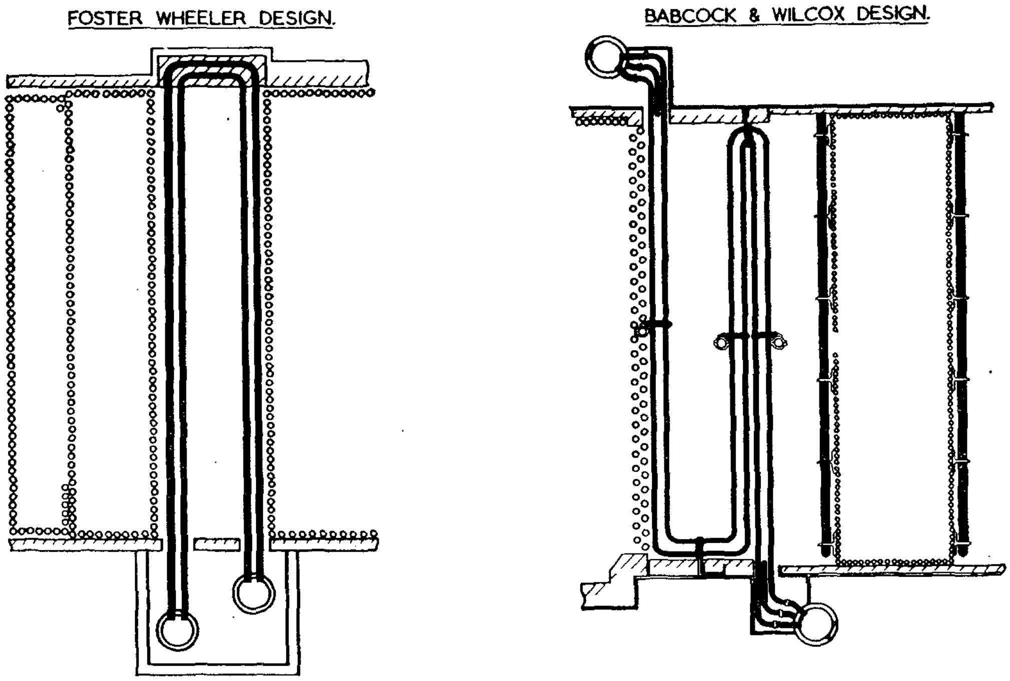

FIG. 8—PARTS OF (SKETCH) DESIGN FOR BOILERS FOR A NEW CARRIER

at least into, the refractory walls. The length of unsupported tube frightens people slightly but, in fact, it is quite easy to point to various designs in the United States which are using that sort of unsupported length and running quite happily, and our steel makers are no worse than the Americans. In the one design, the tubes are welded to stubs, the stubs being welded into the header. This is a very good method of construction and has the additional merit that, if a tube should need repairing, only a relatively simple stub-to-tube weld is involved. In the other design, the tubes are expanded, but this also could be reviewed.

At this stage, a decision has to be taken whether or not a design embodies sufficient new thought to necessitate having a prototype. We start off from the principle that a prototype for shore testing should be built whenever possible, but this gets watered down almost at once by other requirements. Again we have to consider how we are going to treat the water in this boiler. We know that this is a tricky problem and one that must be solved thoroughly if trouble is to be avoided. We start off there by proposing deaerators in all cases, as a matter of principle, and the first thing that happens is that someone comes along and says, 'You won't want to fit a deaerator in this, will you old boy'. That is where the argument starts; where it ends depends on many factors, not by any means all of them technical.

Incidentally, one assessment of the Assault Ship, which was referred to as being a reasonably satisfactory design from our point of view is: 'I think this is a typical example of condensing a high pressure boiler into the smallest space possible and then wrapping it up in a minimum size box. The arrangement of the boiler itself, uptakes, economizers, etc., is neat, but there is no disguising the fact that space is at a premium and this will bring in its train the inevitable and unenviable problems of maintenance, on which many man-hours will have to be spent'. That is a review of the best we have been able to do; it is not very good but there it is.

TABLE III—**Construction**

Associates:
Ship Sections
Production Group
Boiler/Machinery Builders
Standardization Organizations

Construction

One might think that the Boiler Section would not have a great deal to do in the field of actual construction of new boilers, but that is not entirely true. We do have to check all the drawings that are produced. The boiler designers, of course, draw these out and check them before submission, but it is quite disconcerting how often we have found not only that some of our perhaps peculiar requirements have been misunderstood, but that some perfectly plain piece of engineering design has gone wrong. This takes a great deal of time which is most difficult to allow for in advance. We also have to try to advise on constructional problems, particularly where we have embodied some new feature which nobody previously has had to convert into cold steel. This can quite often, with a conservative main machinery contractor or boiler builder, create quite a serious problem.

In the nuclear field, H.M.S. *Valiant* has steam generators which owe at least something in their design to the Boiler Section, even if much more to Foster Wheelers. We all have had to proceed on completely new ground. It will be interesting to see how that new ground is covered.

At this stage in any project the use of mock-ups is of the greatest value. We are happy to note the extent to which they are being used, but even so they could still be used much more. We have all learned a lot from mock-ups, both for new constructions and for modernizations. In the nuclear field, where nobody knew just how things were going to work out, the mock-ups have been of even greater importance.

An unenviable task we have had much too often is to approve dispensations for things that have gone wrong in the process of construction of boilers. This sort of thing does make a lot of unnecessary work. Then again, at this stage, we quite often find that we want to make some minor improvements, as a result of developments which have taken place since the design work was done. For example, in the *Whitby* Class, header doors generally in economizers, water walls and superheaters were on the principle shown on the left of FIG. 9. They were not entirely satisfactory. This was found out after the original design for the *County* and *Tribal* Classes had been put up, but we asked the designers to cover the ground again and it can be seen from the right hand side of FIG. 9 that they came up with a very much neater arrangement. For the economizer, where we cannot find much benefit in having doors, these are eliminated entirely. You can look into the ends of the headers but nothing else. If it is really necessary to do anything more than that, then the best thing is to cut out an element, and put in a new one, which a really competent welder can do because it is only a tube-to-tube weld. The old one can then be thoroughly inspected and, if necessary, cut up for complete examination.

In the water wall we have kept to the square shape of the header because of the tube insertion problem, but we have come to a very much smaller, neater

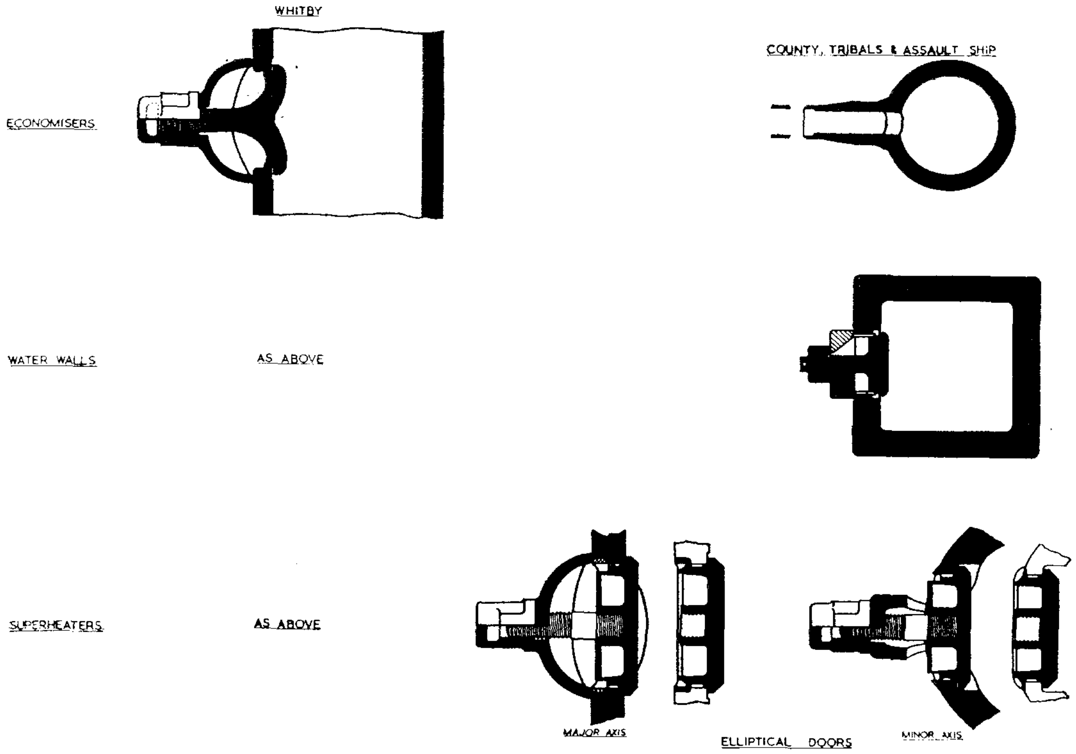

FIG. 9—HEADER DOORS—ADVANCE IN DESIGN BETWEEN 'WHITBY' AND LATEST CLASSES

door which seals on to a mild steel ring, as distinct from the double dipped, double dyed, double wired strips of jointing in the earlier design. It is true that on odd occasions this type of door also has not behaved with perfect propriety and has dribbled, but generally it does very well and it is certainly much less unreliable than the other. Once you have tightened one of these you can reckon that it will stay tight. The same could not be said of the older type.

In superheaters we have gone even further and in the really high temperature superheaters (950 degrees F.) we have yet another type of door. Once the superheater header has been examined internally, which is part of the acceptance drill, this type of door is secured in with a weld. Should any further internal examination be necessary, then this weld can be cut. To remake the joint a strong-back is put across as in past practice. You are no worse off than you were; but in ships in service so far we have not had anybody having to carry out this evolution. We do think that these solutions are a great improvement from the Fleet's point of view, where there have been bitter and very justified complaints about the amount of nausea created by leaking doors of one sort or another.

Obviously the Production Group comes into the picture of our work in this field. We have, generally speaking, very good relations with them and we try whenever we can to keep them informed when something changes or goes wrong. If it is a major matter this is of course proper policy; even on minor matters we try to do this because we find that for overseeing we must rely entirely on D.G. Ships staff at the manufacturers, M.M.C.s or wherever the work is being done. We cannot afford even to pretend that we can supervise work that is going on in a number of places, all of them several hundred miles away. So it is most important from our point of view that the Production Group and through them the overseers on the spot are kept fully up to date.

Our liaison with the standardization orgnizations again comes into the picture to a certain extent. Sometimes a main machinery contractor suggests that we alter something to fall in line with what he says is standard practice.

We have then got to be in a position to check not only whether it really is, but also whether the standard is high enough.

Operation and Maintenance

Operation and maintenance is the next stage of our work. Once again it is not immediately obvious why the Boiler Section should have a working part in this but, in fact, the problems of the operation of a boiler have to be thought about as soon as you start building it, and new ones continue to arise even after years in service. Obviously in this respect we work together with the Ship Sections. We hope also that in future there will be a contribution from the Ship Maintenance Authority and the centralized technical staff who are in an extremely good position to get a complete picture of machinery performance from the Fleet. This will enable them to discard unimportant reports and pass on only the important ones. That is what has been missing, quite frankly, in the 'S.2022' picture, where we have been swamped with a pile of reports, a lot of which patently was not relevant to the improvement of design. Of the rest, even if it was relevant, it usually got to us so late that we could not check on or really do anything effective about it. We hope the Home Fleet Central Staff will improve this situation.

We have to try and produce handbooks for new boiler designs, as mentioned previously, more or less as soon as we start building them. This is a big problem. The writing of the handbook in itself is a task which is not automatically included in the average draughtsman's training, nor in the training of the average marine engineer. Furthermore, outside concerns on whom we can call as experts for boiler building are, by their own evidence, far from being experts in writing handbooks. So this is frankly a difficult job. The organization for it has recently become very much better, but we have several times been in the situation of having to re-write some very basic offering in about 48 hours because the ship is then going to start steaming. This is not fun and again means a great deal of work which is very unrewarding.

At about this time, we also have to think about the provision of special tools, spare parts, and so on. If the boiler is perfectly standard there is not very much to this, but with almost each type, in spite of the aim to produce a copy of an earlier design, there is something different to be allowed for. Usually it is an improvement, but it is still something that is not the same as it was before, and this aspect of it has to be checked.

If prototype trials are going to take place, the necessary arrangements have also to be made at this stage. We are, to a certain extent, co-ordinators in this respect. We know, broadly speaking, what we want from the boiler. The special requirements tend to come from the designers, who have some aspect on which they want some more information, from the control people, who wish to know something about the behaviour of the boiler and its controls as an integrated concept, and of course from the makers of the auxiliary machinery, who have to prove that their auxiliary machinery and the boiler will get on well together.

Sometimes we also have to do some fairly extensive development of special ancillary equipment for the boiler. The most striking example of this arose in the case of the steam generator which gets its energy from a nuclear reactor, where obviously access is very tricky and limited. In fact, there are a couple of headers in this thing with half-inch bore tubes welded to the outside of the header by a most ingenious process which, incidentally, is one of the triumphs in that particular field of engineering which it is hoped will spread to the more conventional fields. Anyway, it is necessary to have a perfect weld between these tubes—about a thousand of them—and the outside of the header. It is impossible to get one's head inside the header—its outside diameter is about

TABLE IV—**Operation and Maintenance**

Associates:
Ship Sections—Ship Maintenance Authority—Fleet
Admiralty Fuel Experimental Station
Admiralty Laboratories
Industry
Consultative Committees

18 inches and the only means of access inside is a small door in one end. The question of plugging any specific tube, even when you have discovered which one it is that leaks, is quite a job. Well, a tool for this has been developed—it is a 'glass eye on a bent stick' type. To begin with, the leaky tube is located visually and then, all from a distance because it would not do to stand too close to this device, you feed in first of all a plug, which is gently pushed home, and then a special hammering device which rams it home. This equipment has been tried out on test rigs a large number of times, and once in earnest on a steam generator, so we know it works. However, as a maintenance tool it is pretty sophisticated and cost a lot of hours of work, although not all the work was the Boiler Section's. You will notice in TABLE IV that the consultative committees are placed under 'Operation and Maintenance'. The Navy Department Corrosion Committee and sub-committees, and the Navy Department Fuels and Lubricants Committee are probably the most prominent ones. They do come into the question of how we run things, water treatment, oil treatment, etc., and we do collaborate with them. The question of putting our problems in such a manner that the outsiders, who must be on these committees if they are to be of any real value, understand them in full is quite a task and we find that this is one of the trickiest parts of the job. Normally, inside the Division and even the Department, one is dealing with people who have some knowledge of how naval problems run; the more experience, the greater generally the knowledge. Outside, one comes up against people who, with vast experience in their own fields, just have not a clue of what goes on when there is salt water about. This can slow down progress very substantially.

Repair and Refit

The problem with boiler repairs, even more than in the case of most other machinery, is that it is extremely difficult to get an assessment of the size of the repairs needed until you actually start taking the boiler to pieces. This means that, although the dockyards with their experience manage to set aside a reasonable amount of labour, time, etc. for boiler work in a refit, just how this is to be deployed and just how that money is to be spent needs to be worked out at the last minute, and that is where we often have to come in. We frequently get faced with some brutal second best because, for some reason, the way the job should really be done is just not possible, In particular, in the case of the Y.100 boilers with their very poor access we try to advise and make things easier since we do realize the design shortcomings. At the same time we try to build in some improvements and usually all concerned are very keen to do anything that will help in the future.

The dockyards do come to us direct quite often on minor points. Major

TABLE V—**Repair—Refit**

Associates:
Ship Sections
Repair Authorities
Boiler Designers/Makers

TABLE VI—**Modernization**

Associates:
Ship Sections
Admiralty Fuel Experimental Station
Boiler Designers

points are handled through the Ship Sections. The boiler designers and manufacturers come in where we have found that some component, some device or other has proved quite unacceptable, and we have to try to get a new design replacement.

It will be appreciated that this repairing and refitting is a rather erratic sort of task. This does not make it any easier for us because we cannot afford to have one man consistently dealing just with that aspect of the work; it has to go with the ships jobs. The man who works on frigates, when one of them comes in for repair, has to try to turn from a thinker about new designs into an adviser on repair matters, and the same thing applies with the other classes of ships.

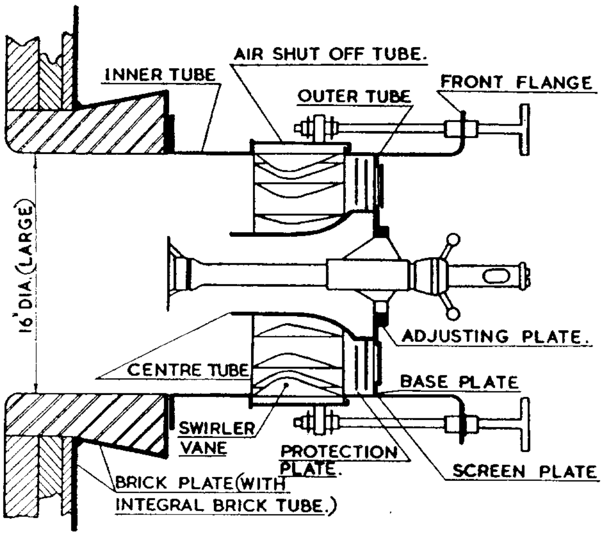

FIG. 10—H.M.S. 'EAGLE'—TYPE OF REGISTER ORIGINALLY FITTED

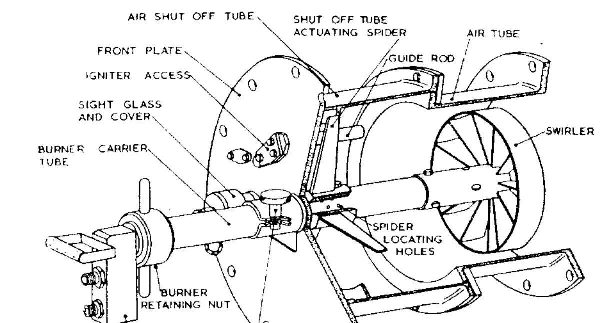

FIG. 11—H.M.S. 'EAGLE'—TYPE OF REGISTER FITTED DURING MODERNIZATION

Modernization

The last stage on our list is modernization. This again is a peculiar sort of job. When ships machinery is modernized, almost always an attempt is made to convert the boiler into something quite different from what it used to be. A feed pump remains a feed pump and a fan remains a fan but the boiler, or at least the boiler front, by the time it is finished tends to have a completely new look. FIGS. 10 and 11 show an example of this. These refer to H.M.S. *Eagle*. FIG. 10 shows the register and burner fitted to this ship originally, mounted on the brick plate, with no other mounting. The flame was stabilized on the brick throat. The old sprayer had a very simple oil lead into the back with one flexible hose, clamped in position. Operation of the air slide was by two separate movements. FIG. 11 shows what it looks like now. First there is an additional casing which has to be air tight, so the thing has got to line up and remain lined up under all conditions. Combustion, instead of being stabilized on the brickwork is stabilized on this swirler. That form of stabilization is now standard practice, but it is a big change nevertheless. The oil supply, instead of coming through one simple lead, comes in through two leads on the back, which have to have more curvature to keep them from being damaged and are secured by nuts instead of being clamped. An igniter had to be worked in, so we had to find room on the front for that as well. The only simplification is that instead of two operations to flash or shut off the register there is now only one, because the air slide is now allied to the sprayer carriage and the whole thing is pushed forward or pulled back in one movement. This is a pretty big change and a lot of work, of ours and of the A.F.E.S.'s, a lot of development and, one must admit, a lot of trial and error has gone into producing it. From our point of view it is nearly as much work to bring an old boiler up to date as to do our part in the design of a new one.

The list of *Darings* and earlier ships that have been modernized is a very long one. There is hardly one of them going now that has not been modernized in one way or another within the last ten years.

Conclusion

The things that have been mentioned so far are all direct problems. In conclusion, brief reference will be made to our work in the form of advice and liaison of various kinds. First of all, liaison of all kinds with the A.F.E.S. is fairly obvious as quite a big component of our work. We are their 'link with Head Office' and we try to keep them in the picture. They have good contacts with the Fleet, and they tell us what goes on there; we have contacts at Headquarters and we try to give the A.F.E.S. early warning of any new requirements that are arising, new suggestions from industry, etc. In addition, of course, we have always had strong liaison with the Commonwealth. More recently, that has developed also with the European countries in N.A.T.O. and even outside N.A.T.O. We also keep in touch with those countries who have bought ships from us, not all of which have been trouble-free in their subsequent life, and generally with various interested parties who have come along to talk to us about all sorts of problems. If one is at all that way inclined, this is a very pleasant task. One hopes that one is being helpful and certainly there is generally an appreciation of the advice that one gives, but it does mean additional time spent which cannot really be defined as being concerned with the boilers of Her Majesty's ships, which are our proper charge.

DISCUSSION

At the conclusion of the original lecture questions were invited from the audience. Some of the questions together with the author's replies are given below.

Q. Why has development been concentrated on wide range registers, instead of on the older simpler type, converted, or developed, to be operated by remote control?

A. When the A.B.C.D. requirements that led to this development arose, available designs of remotely controlled on/off registers were tested at the A.F.E.S. This indicated not only that wear and tear would probably make them unreliable but also that even when new they were liable to jam now and then. However, it is relevant to the question that a new design which appears to be a great improvement on the earlier ones is due to be tested at the A.F.E.S. as soon as the manufacturers supply it.

Q. Is there a general trend for pressures and temperatures to increase?

A. There is no general trend upwards. Pressure may increase somewhat above the 700 lb/sq in. which is our present maximum, but this really depends on the plant requirement. Temperatures will not go above 950 degrees F. with present fuels and 850 degrees F. is the most likely value.

Q. There was no mention of developments in water treatment, What about these?

A. There has not been any real development in the last four years. The old compound is proving perfectly satisfactory even in the *Counties* where we were prepared to find that it was not. For the carrier there is little doubt that a different treatment will be needed, and research in this connection is starting now.

Q. What is the Boiler Section's attitude to (internal) chemical cleaning of boilers?

A. We are all in favour of doing this to new boilers to condition them for service, and this has been done in a number of new ships. The only problem is to prevent the cleaned boiler from rusting before it is steamed and a protective layer of oxide is formed on the steel. We are sure that this problem can be beaten and in the meantime we are making a start with having chemical cleaning recognized as an alternative to mechanical at this stage in the boiler's life.

There is no thought, however, of introducing it as a routine measure, or to try it on boilers in service.

Q. The pressure combustion cycle looks as if it might be made inherently self-regulating. Has any work been done on this?

A. No. A great deal of work has been done by others, in connection with the automatic control of pressure combustion systems, of controlled circulation steam generators and of gas turbines. Should it be decided to design a pressure combustion plant for naval purposes, it is considered that this work would provide a good basis for the design of any controls; anything more specific would have to be defined from the characteristics of the plant. This is definitely an aspect of pressure combustion where development work will be required later.

Q. Can any figures be given for the water consumption of steam assisted atomizers?

A. These figures tend to vary a great deal, depending on who quotes them. They are also not easy to express clearly, because for a given atomizer they vary with, but not in the same way as, the oil flow. It is also relevant that the type of atomizer in which we are most interested requires steam assistance only when it is operating at less than 60 per cent of its design output. All in all, consumption should rarely be more than one ton per atomizer per day. This is about three times as much as the figure which the manufacturers quote from mercantile experience.

Q. Can something more be said about efforts to reduce the boiler fouling problem, particularly in the early ships of the Y.100 class?

A. Apart from the possibility that the long-term research will provide the basic answer to fireside fouling, the following ways out exist:—

(*a*) *To burn Dieso*. Extensive trials to establish the long term balance of advantages and disadvantages are proceeding. What has emerged so far is that external cleaning seems necessary no more often than every refit, and that the problem of keeping machinery spaces clean is greatly eased. The cost is considerably greater than that of F.F.O., but a proper cost balance must include differences in boiler repair work needed and can therefore not be drawn up yet.

(*b*) *To burn some distillate other than Dieso* (F.F.O. is a residual fuel). This possibility is being studied in various contexts: by the Navy Department from the point of view of reducing the number of different fuels required for the Fleet, by all the Ministry of Defence Services and by N.A.T.O. with a similar object but in a much wider sense, and by the oil companies as regards economics and the refining pattern. The only thing that can be said at this stage is that the evidence from the research work is, that the benefits should be much the same as those from burning Dieso.

(*c*) *To remove the offensive materials from F.F.O.* 'De-ashing' in the refinery is possible but the higher price the oil companies insist they would have to charge for de-ashed fuel has so far stifled interest in the process. It is also relevant that this would not eliminate foreign matter which gets into the fuel between the refinery and the boiler. This is thought to be not insignificant. Centrifuging plus washing is standard practice where F.F.O. is used in Diesel engines but has been unacceptable for boilers not only because it is traditional that boilers do not need clean fuel but also because it involves a considerable complication of the fuel system and its operation. Centrifuging alone has recently been shown to be worth while and has far fewer disadvantages from the naval point of view. A ship trial of this process is being considered.

(*d*) *To neutralize the offensive materials.* Although there is no case for spending money on any of the panacea type commercial additives, there is evidence that some alleviation of the fouling problem can be achieved by introducing into the combustion process certain elements which, although not reducing the quantity of the deposits, do make them less difficult to remove. If all else fails this would be better than nothing and a shore trial in a boiler of naval design is a possibility. The Central Electricity Generating Board are carrying out full-scale trials in some of their boilers, the results of which are being passed to us.

Q. Would a change to a distillate fuel mean that external cleaning of boilers could be dispensed with altogether?

A. Although routine cleaning would not disappear altogether, its frequency would be reduced to 'every refit', or even 'every alternate refit'. However, there is some risk of fouling as a result of something going wrong with the fuel system, or its operation. This would not be affected by a change to distillate.

Q. In a pressure combustion system, roughly what is the ratio of power-to-the-compressor : power-to-the-shaft?

A. In a system like the one which has been referred to, with the power turbine separate from the compressor turbine, two figures must really be given in answer to this question. The first is the maximum h.p. to be supplied to the blower, to make up for the total deficit at low power when the compressor is very inefficient. This is 500 h.p. at 6,000 s.h.p. The second is the full power balance, which is an internal ratio. This is a somewhat complex value, since a good deal of the energy fed to the blower is recovered later in the cycle, but anyway it works out at about 3 : 5—13,000 h.p. in a system producing 22,000 s.h.p.

Q. What is the current attitude to the use of electric resistance welded tubes in place of solid drawn?

A. For generator tubes, we are in the process of altering the regulations to permit the use of E.R.W. tubes as an alternative to S.D. We are convinced that this does not in any way lower existing standards, or increase risks.

Q. What would be the effect on the design discharge head of boiler fans of changing to a wide range atomizer other than the return flow pressure jet?

A. The primary purpose of both the steam assisted and the rotary cup atomizer, from the naval point of view, is to prevent the falling off in spray quality with reduction in output which is an inherent disadvantage of the pressure jet, even with return flow. Changing to one of these would therefore not necessarily mean any change at all in the 'full power head' required from the blower. However, since, as has already been mentioned, the low output requirements of the current design of combustion equipment do have some effect on blower design it is possible that there would be some second order benefits. Any increase in the head requirement would be considered a serious disadvantage.

Q. What would be the effect on the current problems of boiler auxiliaries design of changing to a W.R. atomizer other than R.F.P.J?

A. The effect on blower design is covered above. The effect on fuel pump design would be to lower the maximum pressure requirement—to about half its present value with steam assistance and to about one tenth with rotary cup. The fuel system would also be simplified, and in the field of controls we would get away from the awkwardness of working with a small difference between two large values—although control of flow over a range of 15 : 1 or so is not easy whichever way you do it! Boiler front design would probably be neater.

Q. What is the present attitude to superheat temperature control?

A. Although the maintenance of a reasonably constant steam temperature over the full operating range is desirable in a naval boiler because it operates so much of the time at a very reduced output, and a low steam temperature would lower the cycle efficiency, the primary requirement for being able to control the temperature came from the engine end. It was agreed that the steam temperature should be lowered when manœuvring to prevent the overheating of the turbine when going astern. In addition, the point has been made that the ability to lower the steam temperature is useful to prevent damage, from overloading, to the clean portions of a very dirty superheater. The requirement from the turbine designers is understood not to exist any more, and the other benefit is considered too marginal to justify by itself the additional space, weight and complication of the split gas path boiler. 'Selectable superheat' has therefore not been specified for any new design of boiler, although it will continue to be a feature of any design which is merely a further extension of the current series.

Q. What are the benefits of fitting a deaerator as distinct from designing the feed system to be deaerating?

A. Trials in *Ashanti* have shown that while a deaerating feed system can keep the oxygen down to acceptable limits under steady steaming conditions, it shoots up when manœuvring. There is quite striking disagreement among the experts about how significant these 'excursions' into the high oxygen field are, but all the same it is agreed that they should be avoided 'if possible', which a deaerator does. The deaerator has the other advantage that it is not dependent on main engine vacuum.

It should be mentioned here that the same effect can be achieved by using an oxygen scavenger—some British Railways Cross-Channel steamers, which operate in cycles more similar to those of naval ships than the bulk of the Merchant Marine, have used oxygen scavengers satisfactorily for some years now. However, the introduction of chemical deaerating into naval ships is not being viewed with any more favour than the physical variety!

COMMENTS BY D.M.E.

The following remarks by the Director of Marine Engineering, Rear-Admiral H. G. H. Tracy, D.S.C., were made as the closure to the lecture and the discussion.

Mention has been made about the boiler as being 'the heart' of steam machinery. I know what that means but, for myself, I have tended to look upon it rather as a kind of crouching beast—an animal which has to be fed on the right diet, given just the right amount of water—and in every other way accorded proper attention and kindness, or it will bite!

To look back, I remember that in my first ship—the old *Furious*—we had 18 rather crude three-drum boilers. My most prominent memory is of going round Devil's Point with full speed astern on two shafts with at least three automatic feed regulators going wrong in each boiler room. We had an E.R.A. who had served with an earlier type of boiler where the fire row tubes were secured in the drums with union nuts. When you had a leak you turned the sprayers off, wrapped a man up in asbestos cloth soaked in water, sent him in the furnace with a spanner to tighten the nuts and flashed up again when he came out. We have come a long way from that! The *Ashanti's* boxed boiler can hardly be seen and apparently performs magically, all by itself.

Looking at present boiler troubles, it seems to me that maloperation is our biggest single problem. Some figures sent out by this Department showed that, of some 20 boilers burnt out in only two years or so, the great majority were caused either by simple maloperation or by maloperation allied to some form of mal-maintenance. A sad record! The causes are usually simple—the simplest is that people forget that, to stop this animal biting, you must turn off the fire. Watchkeepers are too apt to try and re-establish some form of feed supply when the water is lost, whereas what they should do first is to turn off the heat. This emphasizes the need for ensuring that both design and installation simplify, as much as possible, for the difficult job of operating a boiler. It is also of the greatest importance that the training follow-up is right, because if there is one job in a ship which demands the same sort of attention as driving on our roads today, it is keeping a main boiler happy!

In some of the ships I have seen recently, including modern ones, I have been disturbed at the lack of attention given to layout—for example, in the *Whitbys* you have to turn your back on the boiler to operate the fans. I hope that we have now bowled out that sort of thing.

I believe that the expectation Commander Inches has of getting the Fleet machinery failure problems presented in a more co-ordinated manner by S.M.A. are going to be justified. I have recently seen a little collection for an L.P. compressor. Three and only three S.2022s had been sent in for this machine, on diverse troubles, with the result that we had not regarded them as serious. The information now collated, from maintenance returns, defect lists and other records, runs to about six pages and makes it perfectly clear that the Ship Service Machinery Section is going to have quite a lot to think about to get this compressor right. I expect the same kind of problem will be plaguing the Boiler Section in connection with boilers in due course! Still on somewhat the same line of thought—satisfying the customer—there have perhaps been some doubts about fitting COSAG plants for the propulsion of ships, especially because one is bound to increase the maintenance problem, since there is a full steam plant, plus. Yet the customer likes them enormously—C.O.s of these ships with combined plants have been most enthusiastic.

We must remember that, although we may have technical reservations, we must essentially provide that which the customer wants, and not get too engrossed in purely marine engineering considerations. This means among other things that auto controls for boilers are with us. They have already had a good reception in the Fleet and it is in fact our technical customers who think that auto controls are wonderful. The changes in working conditions which have been brought about by auto controls for boilers are most significant and important to the average engineering rating. This is obviously something we must continue to develop.

The only other comment I have to make about the present situation is that it amuses me to hear that people are still trying to sell additives—a racket that has been going on for years and years. They seem rather like those special bricks you can buy—if you are sufficiently credulous—to put in your gravity tank. The only universally recognized property they have is that they dissolve away and have to be renewed.

What about the future? There I think the Boiler Section is in a very interesting state, because things could go so many ways. They could become concerned with integrated reactors, where the steam generator is part of the reactor, when we might well have to bring the Section's special knowledge to bear on the very tricky problems involved. Nothing must ever go wrong inside an integrated reactor. Then again pressure combustion may change the picture—that is, if the whole principle is not altered by the acceptance of an 'all gas turbine' design very possibly using a waste heat boiler. There is considerable user interest in 'all gas turbine' plant and based on the principle of 'what the customer wants', we may go to that—if it is not overtaken by nuclear propulsion. Again, our old friend the Diesel is looking up. There are at present several promising Diesels, both at home and abroad, which might win one of Y.-A.R.D.'s competitions. So I cannot really present a very clear picture of where we go from here—except that I have a shrewd idea that in ten years time the Boiler Section will still be very busy!