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Patron : His Majesty The King. President : Sir William Crawford Currie.

The Operation of Water-Tube Boilers at Sea.

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On Tuesday, September 11th, 1945, at 5.30 p.m. at 85, Minories, E.C.3.

Chairman : W. Lynn Nelson, O.B.E. (Chairman of Council).

Synopsis.

The paper deals firstly with the reasons why there has been a big increase in the percentage of steam propelled merchant tonnage fitted with watertube boilers operating under the Red Ensign during the war years. This is followed by a study of the fundamental rules for operating this class of boiler successfully in service—covering in particular the means to be adopted for keeping the tubes clean on both sides of the heating surface. This includes methods of keeping feed and boiler water scale-free and properly conditioned.

In addition to the boiler proper, air preheaters and economisers are considered in like manner.

The last portion of the paper deals with the operation of the firing equipment—particularly oil firing gear—together with questions of furnace maintenance.

One of the many effects of this war on the British Merchant Service has been the large increase in the number of ships fitted with watertube boilers. By 1939 this type of boiler was already firmly established in ships of the passenger liner and cross-channel classes, but with comparatively few exceptions—such as certain cargo liners, tankers and special duty vessels—the rest of our tonnage adhered to Scotch boilers if they were steam-propelled.

There are four reasons for the big increase in British-owned or managed watertube boilered steamers since 1939—(*a*) the large number of American-built ships transferred to the Red Ensign, (*b*) the general increase in ship speeds, calling for more powerful machinery without undue loss of carrying capacity, (*c*) the saving in steel for fabricating watertube boilers compared with heavy cylindrical units, and (*d*) the desire for more advanced steam conditions to effect economy in fuel consumption.

The watertube boiler has been established in U.S.A. merchant tonnage for many years; this is largely due to the fact that the large cylindrical type of boiler has never been an attractive manufacturing proposition in the States and the watertube boiler is used in land practice to the almost complete exclusion of shell-type boilers as used so extensively in this country. Furthermore, the fact that the majority of U.S.A. shipyards are concerned with purely ship building and not with building marine machinery makes the question of transport of large shell-type boilers from their place of manufacture to the shipyards a very determining factor in favour of the watertube boiler. The result is that the present generation of American marine engineer is essentially watertube boiler minded as all his background has been built up on this type of steam generator.

In our case, the introduction of such boilers into our ships has come as a distinct innovation to a considerable percentage of our marine engineering personnel, and the author is of the opinion that war time at sea is not the best setting in which to become acquainted with entirely new types of machinery; so if we have been accused of receiving new designs in war time with a degree of suspicion, perhaps we have some good reason.

However, time and experience have shown that with reasonable handling the watertube boiler is a most attractive element in the make-up of a marine steam propelling unit, and the object of this short paper is to summarise the points which need attention in order to effect good and trouble-free service.

Practically all watertube boilers fitted in merchant ships fall into two generic types—(*a*) the header type (Babcock & Wilcox) and (*b*) the two and three drum boilers of Yarrow, Foster-Wheeler, Johnson, Babcock & Wilcox, etc., designs, where all tubes are expanded direct into the steam and water drums. It is not within the province of this paper to deal with the merits or demerits of any of these designs, nor to study design and constructional details; it can be accepted that all such boilers have established themselves in service as practical operative entities, being based on sound principles for fulfilling the dual functions of burning the fuel and absorbing the heat generated thereby. To be a practical proposition each of these designs must therefore embody proper facilities for access for inspection and cleaning.

The watertube boiler is a more compact assembly than a Scotch boiler of equivalent output and therefore contains much less water. It is inherently a very flexible boiler owing to its positive circulatory system, hence steam raising is a very much quicker operation than obtains with a cylindrical boiler. The time required for steam raising is determined not by the pressure parts of the boiler—this portion being free to expand readily without setting up stresses—but by the furnace refractories. With a dead cold boiler it is essential to allow the brickwork to adjust itself correctly to the rising furnace temperature, hence up to two hours is a good figure to work to. With warm brickwork this time can be greatly reduced.

The relatively small amount of water in the boiler means that care must be taken in working to the correct level; a good rule is (*a*) quarter-glass when cold, (*b*) three-quarter glass when shutting down (these figures allow for expansion and contraction respectively), and (*c*) half-glass during operation. All watertube boilers of British build and design are fitted with automatic feedwater regulators and these should be set to maintain (*c*) in service. Conditions (*a*) and (*b*) are obtained by hand control. While on the subject of water level, it will be appreciated that if at any time during service the level falls below the bottom nuts of the gauges it is essential to shut off the oil burners (or damp down the fires in the case of coal) immediately, *i.e.* before endeavouring to locate the cause of the water shortage; it is always good practice at sea to have the stand-by feed pump on the auxiliary feed main ready for action. By doing this the watch-keeper always feels safe—and it is a very simple precaution to take.

The outstanding factor which makes (or mars, as the case may be) successful watertube boiler operation is keeping the heating surface clean on both sides of the tube surface. Dealing firstly with the water side: here, the requisite degree of purity for safe working conditions varies with pressure (and corresponding saturated steam temperature) and low pressure jobs can stand a lesser degree of feed purity than is called for by higher pressure installations. The effect of scale is more and more marked as steam temperatures increase, as the temperature of the metal of the tube wall closely follows saturated steam temperature *provided* it is in contact with the water. Scale causes this tube-wall temperature to rise—hence, owing to the higher basic temperature of the tube metal in a high-pressure installation, a given thickness and texture of scale is much more dangerous under such conditions than with a low pressure boiler.

This question of boiler water has been given a good deal of publicity in recent years in the appropriate engineering institutions, and the British Standards Institution set up a Committee in the early days of the war to consider the whole subject, this Committee being a fully representative body. A sub-committee thereof handled the marine side of the problem, and B.S.I. Specification No. 1170 has now been issued giving their recommendations. The author strongly recommends that all marine engineers should study this publication, and in view of this wealth of pre-published material all he needs do here is to summarise his personal interpretations of good practice and reasonable precautions.

With low pressure boilers there is no objection to initial filling-up with raw shore water provided it does not contain much by way of scale-forming matter, but for make-up evaporated water should always be used in order to prevent an accumulation of scale-forming solids. For boilers of 300lb./sq. in. upwards nothing but distilled water should be used at any time, and provided the evaporator is functioning correctly (*i.e.* with no liquid carry over) there is no possibility of other than a pure-water circuit so far as potential contamination from make-up is concerned. With high pressure boilers it is usual to ease the work of the evaporator by distilling all make-up from fresh water carried in appropriate tanks, only using sea water in cases of emergency or on long runs (where the extra weight of fresh water cannot be carried), and in such cases, using the evaporator with special care.

For low pressure watertube boilers make-up from evaporated sea water is quite sound practice. Salt can enter the boilers not only as the result of priming evaporators but also from condenser leakages, but fortunately modern condenser construction and tube materials have practically eliminated trouble from the latter source. If it *does* get into the boiler, salt not only acts in the same way as scale if concentration occurs, but also disassociates and releases free acid, which causes thinning away of metal unless neutralised by and with a slight excess of free alkali. Oil is the most fruitful cause of tube failures, as even small quantities in the higher rated (*i.e.* furnace row) tubes cause local overheating followed by blistering with consequent distortion and failure. Turbines give a non-contaminated exhaust, but when associated with reciprocating auxiliaries running on superheated steam and therefore calling for cylinder lubrication it is essential that the filtering devices be kept in good operational condition.

In the case of low powered ships where the main engines are reciprocating the importance of the filter becomes yet more marked. Regular servicing is *essential;* coke must be of the right consistency and of even grading to avoid the formation of channels and the towelling must be regularly cleaned. The author feels also that a certain amount of experimental work with other types of oil-absorbing media might quite properly be carried out by the makers of such filters; the Americans have, he believes, already done work of this nature, and in the case of the Uniflow type of engine operating on superheated steam and requiring a good deal of cylinder lubrication very special filtering apparatus has been successfully applied. As an alternative to cylinder lubrication by oil, graphite—introduced in colloidal form—appears to give very satisfactory results; graphite is non-injurious to boilers and condensers. In addition to the avoidance of scale-forming matter, salt, and oil there is a further aspect of this particular subject to be considered, *i.e.* what is usually termed water "conditioning". To avoid possibilities of corrosion by way of pitting or bleeding it is essential that boiler water should have an alkaline reaction.

Regarding re-agents: lime has been used in the past, but, as it eventually forms scale, it is only practicable for low pressure boilers and even then it is much better to use soda—either as carbonate, caustic soda, or better still, as trisodium phosphate. The carbonate possesses the disadvantage of liberating CO_2, and caustic soda if associated with a leaking seam can result in caustic embrittlement—although the absence of riveted seams in a modern high pressure welded boiler drum now discounts this objection. The actual permissible limits of alkalinity are within the range of 4 to 20 grains (phenol) per gallon and all the well-known firms of marine watertube boiler makers and the feed treatment specialist firms supply suitable portable testing sets to keep a check on this figure. To avoid having to mix chemicals aboard ship certain feed specialists supply ready-mixed compounds for feed treatment and conditioning, containing one or more of the soda compounds with either tannin, starch, or other organic compound to give colloidal and protective action.

The final safeguard in the feed system is proper de-aeration; with high pressure installations and even with lower pressure jobs of recent years, a closed feed system is adopted but even here ingress of air *is* possible, so every care must be taken to ensure that entrained air is taken off before the feed enters the boilers which must be after the feed pump, *i.e.* on the pressure side of the feed circuit by appropriate venting of the heater or heaters.

The permissible density of boiler water varies not only with rating but also with the inherent characteristics of each design referred to circulation and steam/water separation. Fair figures for the ratings which apply to merchant service work are:—

Up to 300lb. pressure ...	400 grains per gallon
300lb.-500lb.	300 " " "
Above 500lb.	100 " " "

So far the water side of the heating surface only has been mentioned; now we come to the gas side, where deposits are due to soot and ash. Normally such deposits do no mechanical damage, but they *do* cause heavy drops in operational efficiency. Cases have occurred, however, where excessive local overheating has developed from the ignition of such deposits—on tubes where the depth of deposit has militated against normal heat transfer impeding ignition, and again by deposits held up by baffles, etc. becoming ignited. All modern watertube boilers are fitted with a complete system of mechanically-operated soot blowers, and these used daily in accordance with routine instructions keep the gas swept surfaces in good condition at sea. When these blowers are steam operated, care must be taken that they are properly drained of water, and it is always an advantage to speed up the fan during the blowing cycle to assist in the removal and ejection of dislodged deposits.

In port, when routine boiler cleaning takes place, all the appropriate doors in the casings should be opened to enable corners, ledges, etc. to be brushed clear.

Air preheaters are normally fitted with soot blowers similar to those in the boilers proper; with the vertical tube heater (gases inside the tubes) there is little chance of soot, etc., collecting in spaces where it cannot be dealt with by the blowers, but in boilers fitted with the compact horizontal tube (air inside the tubes) design of heater, soot can gather in the corners of the casing enclosing the gas stream. If this is allowed to accumulate there is always the possibility of a fire starting, there being no water on the other side of the heating surface (as maintains in the boiler/economiser sections of the installation) to restrict metal temperatures automatically, and a very complete disablement can occur if such fires take place; when such heaters are installed, the regular cleaning operation is more important than ever, including opening up in port to get at the corners, etc. of the gas casing. It is essential that such heaters be designed to give easy access for cleaning on the gas side.

At the low gas temperature end of a highly efficient steam generator, i.e. air preheater or economiser as the case may be, very active corrosion can take place owing to sulphuric acid formation, especially at low loads, unless proper precautions are taken. An air heater by-pass on the fan discharge circuit is a very desirable feature, as this enables the heater to be by-passed on the air side; this by-pass should be used both when starting up and when operating at very low power in order to avoid excessively low gas exit temperatures. Where economisers are fitted in the unit, care should be taken to keep the feed to economiser at the highest possible temperature to avoid "sweating".

The author has not mentioned the superheater as distinct from the evaporative section of the boiler, as provided the superheater is properly designed and located relative to its duty requirements it calls for no additional attention for cleaning, etc., other than applies to the boiler tubes. Prevention of carry-over by control of boiler water conditions is of the greatest importance.

In spite of all running precautions it is still necessary to effect a certain amount of mechanical cleaning on the water side of the tubes, and this, except in certain multiple-boilered vessels where one boiler can be out of service at sea at certain periods, is normally looked after when the ship is in port. Hand, together with electrically or compressed air operated cleaning gear, are normally supplied with all marine watertube boiler installations, and whereas soft deposits and sludge can quite easily be removed by hand brushes, any trace of scale demands mechanical methods. If by some means heavy scaling has occurred, the air-operated type of gear has the advantage of blowing the dislodged scale and resultant dust clear of the cutting area, thereby speeding up the cleaning process.

When boxing up a boiler after cleaning, it is always good practice to smear studs, gaskets, etc. with graphite to facilitate removal the next time.

Before leaving the subject of the heating surface, it should be emphasised that as and when a tube has to be replaced for some cause or other (and regrettable though it is, in spite of all operating precautions tubes *do* sometimes need renewal) it is essential that the maker's instructions both for cutting out the old tube and refitting and expanding the new one should be carried out. The proper tools provided therefor should be used, the whole idea being to avoid damage to the tube seats.

Leaving the boiler and its ancillary heat-absorbing surfaces, we now come to the other section of our study, i.e. the combustion side. The furnace proper and the combustion appliance—the latter varying from the plain hand coal fired grate to mechanical coal firing equipment, or (as is most general) oil-firing gear are so closely interrelated in their functions that they are best considered as one entity. (In fact, when designing a steam generator one starts with the fuel and determines the dimensional functions required for the combustion of the same, the other problem, i.e. efficiently absorbing the heat so generated, then following on). The number of hand fired watertube boilers in operation is now quite small; owing to their comparatively low rating (limited by maximum fuel rate per unit of grate area) they do not present much by way of operational problems in the furnace zone.

Firing a watertube boiler grate is easier than dealing with the equivalent grate area in a Scotch boiler as the grate is all at one level, but it means dealing with a very wide fire, hence it is particularly important than an even fire be kept over the whole grate; light fires are always advisable to obtain complete combustion in the furnace as there is no secondary combustion chamber for re-ignition of gas as occurs in the case of a Scotch boiler. Fortunately cleaning fires on the simple grate of a watertube boiler is a quicker operation than obtains with Scotch boilers (with their grates at different levels) as it will be appreciated that the whole of the boiler is affected when the watertube boiler grate is cleaned, the grate being not sectionalised as obtains by the subdivision of the total grate over the separate furnaces in the Scotch type of boiler.

Recent examples of coal fired watertube boilers have largely been fitted with mechanical grates, which apart from allowing higher ratings give much steadier steaming conditions and simple facilities for ashing. The operation of such grates presents no difficulties (otherwise they would never have been adopted for sea service), and maintenance at sea is a straightforward business, but as the present coal situation has meant such an overwhelming switch over to oil for marine propulsion, for the purpose of this short paper the author feels that he can concentrate on what is now the most general method of firing marine watertube boilers, i.e. by oil fuel.

The burning of oil fuel admits such simple control over all the factors which determine correct combustion that appreciation of the co-ordination of these functions at different loads is all that is necessary. On the other hand, operating oil burning gear without the application of such knowledge can result in much trouble and in fact lead to serious boiler failures. All the well known proprietary types of oil burning gear are fundamentally akin—they only differ in detail of design and assembly of the pumping and heating units, and of the burner and air controls associated therewith; the operational instructions which are issued by the various makers are concise and comprehensive.

Correct oil burning is determined by the appropriate combination of oil temperature and pressure associated with the atomising apparatus, followed by proper aeration of the resultant spray and control of the geometric shape of the flame envelope. Too low an oil temperature causes bad atomisation and a streaky flame, but too high a temperature results in pulsation and tends to disassociation of the oil in the tubes of the oil heaters with resultant carbonisation and much trouble in servicing and cleaning; in this latter connection it is necessary always to shut off the steam to the oil heaters when no oil is in circulation, or alteratively fit a thermostatic control. Round about 190° F. seems to be a suitable temperature for burning present day fuel oil supplies.

Oil pressures vary somewhat with the different systems according to the atomiser assembly, but a figure of 180lb./sq. in. represents a fair average, this being subject to control up and down to meet the actual boiler steam requirements within the ranges of the various burner tip combinations. Too low an oil pressure results in bad burning, and when manœuvring it is always better to shut off burners and not depend on excessive drop in the line pressure.

When selecting burner tip combinations for various steam outputs it is always preferable to select the smaller of two sets of tips with a higher oil pressure rather than the reverse, as this gives better flame control. When reciprocating oil pumps are fitted the air vessel should be kept well charged to reduce line fluctuations. When a burner is shut off the associated air control must also be shut to avoid a rush of air impinging locally on to boiler heating surface, and if a burner is out of operation for some time it should be withdrawn from its setting in order to avoid carbonisation of any oil which may be left in the barrel or tips.

Correct settings of air and burner control give optimum operational conditions at varying loads, and the result should never be less than 12½% CO_2 with a slight haze at the funnel. It is common practice to fit a multi-point CO_2 recorder and this type of apparatus must be kept in a cleanly condition with all its joints and connections tight if it is to be of service to the operating personnel. A simple portable set to give spot readings of CO_2 is a useful asset, but the author's experience is that observation of the smoke mirrors gives a very accurate, immediate and reliable computation of burning correctness or otherwise.

The flame envelope is determined by the combination of burner characteristics and air entry, and a cast iron rule to remember is that actual flame must not impinge on either tubes or side or rear walls. Impingement on tubes causes local overheating and if associated with even slight internal deposits causes tube failures; impingement on walls causes spalling and grooving and if neglected eventually leads to brickwork collapse.

Care is always taken when boilers are first erected that furnace brickwork is fitted with proper allowances for expansion, and it is essential to remember this when repairs are effected. Furthermore, only best quality fire bricks should be used and repairs should be effected by bricks similar to those already fitted, otherwise differential expansion sets up. The joints between bricks should be of the thinnest possible character; the author has seen much furnace wall trouble caused by neglect of this precaution.

It is very important that before a boiler is lit up the whole of the gas passages and the combustion chamber should be properly purged by fresh air obtained by running the fan for some minutes. It is dangerous to attempt to re-ignite burners by depending on incandescent brickwork, in case a build-up of oil vapour occurs with resultant gas explosion; a torch should always be used.

Finally the author wishes to thank three senior members of his staff—Messrs. W. R. Harvey, E. R. Stephens and A. W. Clark (all members of the Institute)—as it is their unremitting attention to the subject matter of this Paper that has enabled him to have available the essential factors governing the whole subject.

Discussion.

Mr. W. Lynn Nelson, O.B.E. (Chairman of Council), said that he felt sure that he was echoing the sentiments of all present when he said that they were indebted to Major Gregson for a very informative paper dealing principally, as he has done so ably, with the paramount features governing good and efficient operation in order to avoid trouble with this type of boiler; he would avail himself of the privilege to open the discussion with a few remarks.

The fact that due care must be taken when raising steam to allow the combustion chamber refractories to adjust themselves was interesting; this meant that, when burning oil, careful control of each specific burner was essential to ensure that one section of furnace did not become relatively overheated.

The superintendent engineer when specifying for water tube boilers was generally desirous of knowing the ratio of heat released in terms of B.T.U's. per cu. ft. per hour in order that he might be assured of moderate rating and not experience local overheating; he would have liked to have seen some approximate figures in this connection for guidance which were seldom given, as in his opinion it was sometimes the cause of tube trouble.

Dealing with feed water, he would say that their aim should be to evaporate and distil from raw fresh water stored in d.b. tanks; a duplicate evaporator/distiller unit should be installed to evaporate/distil from the sea into d.b. f.w. tanks.

Referring to the author's remarks on oil as being the most fruitful cause of tube failures, should they not endeavour to eliminate all reciprocating auxiliaries from the clean steam circuit, despite the alleged claims for colloidal graphite, by introducing a contaminated steam range to serve this type of auxiliary.

Mr. Nelson could not agree with the author that air must be removed from the feed after it leaves the feed pumps. He had evidence of most excellent results of adequate de-aeration on the suction side of the pumps, de-aerators being of ample dimensions and placed high in the engine room; in other words, an advanced development of Weir's closed feed system incorporating their direct contact feed heater which was popular many years ago with steam reciprocating machinery. Our American friends had adopted this system in many of their h.p. turbine driven vessels.

With regard to feed regulators, he had experienced trouble with these units when fitted inside the drum, and it was his firm opinion that they should be fitted outside.

With regard to accumulation of soot and ash, this was often caused by the wrong positioning of soot blowers, the nozzle being subject to impingement of flame and thus becoming burnt to a greater or lesser degree, thus affecting the direction and kinetic energy of the steam jet.

Referring to the burning of oil he thought Major Gregson would agree that the conditions for burning fuel were truly related to—

(1) viscosity,
(2) firing point,

so that it was dangerous to specify a temperature and/or pressure at which any fuel should be burnt without having the characteristics of the oil available.

Mr. W. Sampson (Member of Council) said that it was to be expected that Major Gregson's paper would be read and acted upon mainly by sea-going engineers, coming as it did from such an authoritative source. The opportunity of discussing certain parts of the paper and amplifying others was welcome.

A careful watch and check on a large number of war-time installations had shown that the importance of pure de-aerated feed was well understood, and the great majority of existing installations showed remarkable cleanliness and freedom from corrosion on the water side.

It was suggested, however, that to a large extent this followed from the continual efforts made to work to what might be termed a "standard of perfection", and he thought that the author, after recommending operators to be guided by the B.S.I. Specification 1170, should not have given a different standard of permissible densities varying from 100 grains per gallon at 500lb. to 400 grains up to 300lb.

Of course, it was true that boilers had been safely operated at these densities, but as the author said, permissible densities were tied up with the rating of a boiler in terms of steam release per sq. ft. of water surface in the drum, the height of water level and the volume of the drum—all these factors having a bearing on the possibilities of priming, so to obtain a long life of superheater, quite apart from a short term, safe operation policy, the aim should be to produce dry steam, for however small the wetness, the conditions in the superheater were cumulative and obviously the solid concentrations should be kept as low as was possible; that was why, after detailed consideration and the gathering of experience, the B.S.I. suggested much lower permissible densities than those given by the author. Perhaps the author would, in his reply, differentiate between what could be done in emergency as distinct from constant and normal operation.

Experience had shown that most boiler troubles had been due to bad combustion of the fuel, and a plea was entered here for more thorough training and more detailed instructions to be given to operating engineers on combustion principles, the design and operation of oil burners and mechanical stokers. There was definitely room for improvement in oil burner designs. They should be made less subject to mal-adjustment.

To illustrate what could happen with bad combustion, there was a case recently in a tanker with Foster Wheeler boilers where a burner tip had been left out and combustion conditions were extremely bad with flames of excessive length. This meant low furnace temperatures and high back-end temperatures, resulting in excessive heating of the downcomer section of the tube bank and too small a difference between the heat transfer rates on the fire tubes and the back-end tubes, which in turn, resulted in a slowing down of the circulation and in consequence, failure of the fire tubes. Of course there was, in this case, an excessive amount of after burning in the last passage of the boiler.

In another case with Foster Wheeler boilers, also in a tanker, there were fire tube failures. Opinions were given that it was due to excessive flame impingement on the tubes, but although hard to prove by an inquiry, it was obviously due to loss of water, caused either by faulty feed regulators or by failure in circulation as in the above case, but an analysis of the metal of the burst tube showed that it had been heated to at least 2,500° F., and other tubes which did not burst had been up to 1,650° F. No amount of flame impingement could raise the metal temperature so high in a scale-free tube with an adequate water flow. Poor combustion meant dirty boilers, excessive steam blowing, loss of fresh water with low boiler efficiency, and the fetish of trying to burn to-day's fuels at low pressure should be given up and proper instructions given regarding the correct pressure for satisfactory atomisation. There had been exhaustive trials on naval vessels and great improvements in atomisation had been made by the use of higher pressure, but there were still many engineers who saw a presumed virtue in low pressure atomisation.

Throughout the paper the author had attempted to set forth standards differing between high and low pressure boilers.

It was suggested that this was a mistake as it left one in doubt as to where was the dividing line. It would appear that the author had taken from 300lb. and upwards as high, and below this, low, but surely what was good practice for high pressure boilers was good practice for low pressure, and they should aim for a simple standard.

The next step in pressures would be a jump from 500lb. to 800lb. with re-heat, or even to 1,200lb. on large powered installations; would it not be better to set operating standards high now, and by good design, with attention to every possible detail, make the operating engineer's job even simpler?

The author had given recommendations regarding water levels for cold, shutting down, and operating conditions, but to save misunderstanding, should he not mention that these did not apply to boilers with regulators having rate of flow characteristics? Perhaps he would draw attention in his reply to the recent paper by Mr. Hillier before the Institute. This was mentioned because the regulator should take care of the "no-load" and "swell" conditions when adjusted and fixed for full load level.

As the author's recommendations covered all types of boilers, his advice regarding having a stand-by feed pump ready to work through the auxiliary check should be modified according to special circumstances, for there were many ships with various types of boilers fitted with economisers, and the Classification Societies, in view of the fact that economisers had only recently been fitted in marine boilers, had asked for means to by-pass the feed past the economiser in emergency. (One might mention at this time that this was not the practice in H.M. Ships). The by-passing was usually by means of the auxiliary check valve. The economiser should never be by-passed because of any derangement of the main feed line or boiler regulators, but only if the economiser itself had failed. Therefore it was considered important that the advice given should not be read too literally, and he was sure the author would be able to clarify this recommendation for boilers to suit boilers with economisers which could be by-passed. .

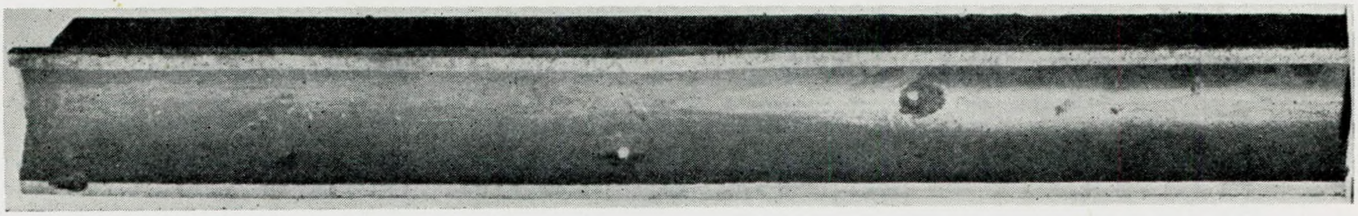
Finally, Mr. Sampson said he would stress the good advice given at the close of the paper, namely, that the furnace and gas passages should be properly purged by the fans before lighting the burners, for there had been at least two serious cases of gas explosions on boilers during the war—luckily with material damage only.

Mr. H. J. Wheadon (Member of Council) said that it was fitting that Major Gregson's paper should be the first of the post-war papers to be read before the Institute, for he doubted whether watertube boilers would have gained the confidence which they now enjoyed for ship propulsion had it not been for the war. Many shipowners who, until 1939, regarded them as too delicate and sensitive for cargo vessels had now had several years of experience with such vessels under their management. They had found them, when in combination with geared turbines, to be completely reliable and, moreover, less dependent upon a regular supply of skilled labour for inter-voyage repairs than some other types of machinery, and for that reason they would now, he believed, be much more inclined to employ watertube boilers in new cargo tonnage than they would have done had not this war-time experience fallen upon them.

Major Gregson referred to B.S.I. Specification No. 1170 and strongly recommended marine engineers to study its contents. It appeared, however, that on one important point he considered the recommendations too conservative—the speaker referred to permissible density. Prevention of carry-over, the author warned them, was of the greatest importance, but even so, he was prepared to permit a much higher concentration of dissolved solids than many marine engineers would regard as comfortable, and which in point of fact was at least double the limits recommended in the B.S. Specification. It would be of interest to learn if the author's firm had carried out tests of a marine watertube boiler evaporating at normal Merchant Service rating with a view to determining the variation of carry-over with density, and if so whether he would publish the results with his reply to the discussion for the guidance of operating engineers. Would he also state what he considered to be the maximum amount of carry-over which could be continuously permitted in a boiler fitted with superheaters designed to provide steam at say 500lb. pressure and 800° F. temperature, having regard, of course, to the maximum permissible density he recommended?

The author referred to the use of chemical re-agents and said that soda was much better than lime, which, as it formed scale, should only be used in low pressure boilers. Would it not have been better if he had said that lime should not be used under any circumstances in watertube boilers—it would be a good thing if sea-going engineers could be given clear advice on this—and perhaps the chemists present would express their opinions on this point.

Major Gregson had pointed out that carbonate of soda under the effect of high temperature and pressure was converted to caustic soda, and at the same time, liberated CO_2. The deadly effect of CO_2 in boilers, particularly on those surfaces which could not be effectively protected, was not generally known among sea-going engineers and so, for their benefit, he would like to give an account from his own experience of a very serious case of this type of corrosion which completely ruined the superheater elements of the boilers of two large vessels—the working pressure being 450lb./sq. in. After four years of service a few pinhole leaks were discovered, all of them in the inlet or saturated section of the elements. To ascertain the general condition, a number were sectioned and it was found that internal corrosion had taken place in the dangerous form of localised corrosive pitting, as would be seen from the photograph. Corrosive pitting of this type might, of course, be due to defects in the chemical or physical structure of the steel, but microscopical examination and sulphur prints proved that the steel was of excellent quality. Investigations next turned to the method of water conditioning. So far as the water in the drums and boiler tubes was concerned, the voyage logs showed it to have been maintained at a proper degree of alkalinity, the condition of drums and boiler tubes being very good. Samples of condensed steam drawn from the superheater elements, however, on being tested were found to be acid with a p.h. value of only 5·5 whereas water taken from the drum was of the order 10-11 p.h. From this it was concluded that the cause of the trouble was the presence of carbon dioxide in the steam due to the use of soda ash as a conditioning agent, the sodium carbonate breaking down to liberate CO_2 which passed into the superheater elements with the results seen in the photograph. The superheaters were renewed and caustic soda substituted for soda ash, and six years had passed with no further signs of pitting.



Major Gregson had no objection to the initial filling of low pressure boilers with raw shore water, provided it did not contain much in the way of scale-forming matter. In the speaker's view, distilled water should be used for this purpose irrespective of working pressure or rating, except of course under exceptional circumstances. Incidentally, would the author explain what he meant by a low-pressure boiler? Where evaporated sea water was resorted to for make up feed it should preferably be re-evaporated before use. This procedure was essential in the case of high pressure and highly rated boilers.

He had found from experience that the use of a fixed compound was more simple and satisfactory than the application of the reagents individually. The fixed compound method of boiler water conditioning was controlled by three very simple routine tests (for alkalinity, chloride and hardness) and the treatment together with the routine tests could be carried out in 15-20 minutes daily. In addition to eliminating the tedious operation of weighing each separate reagent, the phosphate test, which under sea-going conditions was difficult to perform, was unnecessary.

He much preferred the use of starch to tannin as a coagulant, as tannin possessed the objectionable property of discolouring the boiler water, which made the results of the control tests difficult to determine.

Although his comments had been confined to the care of the water side of watertube boilers, he offered no apology on that account, for it was upon the chemical treatment of his boiler feed water that the marine engineer was in most need of unambiguous and straightforward advice, and if Major Gregson's paper, amplified by the discussion, fulfilled that need, it would have served a very useful purpose.

Eng. Rear-Admiral S. R. Dight, C.B.E. (Member of Council), congratulated the author on his enterprise in compressing within three pages what would normally occupy several volumes; it afforded subsequent speakers, he said, an opportunity of adding something in the discussion.

He wished first to refer to the lack of reservoir capacity in a watertube boiler as compared with a tank boiler, which meant that if a sudden change was made in the steam demand by a change of speed, and that was made in the engine room without at the same time increasing the output in the boiler room, it would result in the pressure in the boilers being reduced, causing a good deal of ebullition and even priming. His own experience of naval watertube boilers was that much trouble was caused in that way, by opening out on the engines quickly on manœuvring without warning the boiler room.

He wished to emphasise the necessity for proper control of boiler room operations and the need for handiness of the controls. He had visited a large number of merchant ships during the war in connection with the suppression of smoke in convoy, and he had found in very many cases that the handiness and accessibility of the arrangements for fan operation, control of pumps, heaters and oil sprayers, and the communications were not what they should be. Such arrangements were not so important, perhaps, in a merchant ship as in a warship, but arrangements should be made whereby the boiler room could first of all generate the increased output of steam before an attempt was made to use it in the engine-room; it was bad practice to operate as in the days of the cylindrical boiler, where with the vast reservoir of steam available the position was entirely different.

A great deal of trouble was due to deposits on the outside of boiler tubes and superheater tubes, due to bad combustion and smoke. In many ships it was the normal custom to black out the harbour with smoke when raising steam. Many Chiefs looked on it as a sort of act of God, and took the view "everything is cold; you must make plenty of smoke". That, however, was quite unnecessary; it was possible to raise steam in boilers without that smoke. It was only a question of supplying the air necessary and getting the oil temperature right, and using the correct sprayers, and then it was possible to burn the oil smokelessly in a cold furnace. In his view, a great deal of the trouble due to deposits on boiler tubes and superheater tubes was started by making smoke when raising steam.

In war-time in convoys where there were continual changes of speed, there had been in many cases no proper drill for the regulation of air when changing speed, with the result that when speed was changed there was a good deal of smoke, which also led to deposits on the tubes of the boiler and superheater. The effect was cumulative, for the deposits in turn led to more smoke. That was quite unnecessary for there was a simple tip for dealing with it which everybody should know. To burn oil, first of all there must be sufficient air in which the oil can burn completely, and so when increasing speed one should put the air there first and put on the oil afterwards, and not do it the wrong way round. The natural tendency when one wanted more steam was to put on another sprayer, but it was wrong to do that if there was not sufficient air for the oil to burn in. A great deal of trouble was caused by lack of attention to this simple routine.

He would like to refer to a point made by Mr. Wheadon about the filling of boilers. In the Navy, it was the practice of de-aerate the water as far as possible before filling the boiler. The feed water should be as hot as one could get it, and if it had gone through the de-aerator so much the better, to avoid the danger of any CO_2 in the water.

When cleaning the boiler special attention should be paid to the cleaning and adjustment of the feed regulators, which should never be neglected. The feed regulator governed the boiler. It was not a very delicate piece of apparatus, but it was often neglected; the float chamber became filled with muck and the feed regulator got out of adjustment. It did not take much time to attend to it, and neglect would lead to trouble on going to sea again.

Oil burning, unfortunately, was not quite as easy as the paper seemed to indicate, especially with the very low grades of fuel oil sometimes supplied, and the instructions supplied with oil-burning equipment often left a great deal to be desired, and gave the engineers of ships who had these as their only guide, a whole lot of wrong ideas. In many of those instructions one found such incorrect information given as that the burning temperature had some relation to the specific gravity of the oil or to the flash-point of the oil, but it had nothing to do with them at all; the burning temperature depended on the viscosity of the oil, the viscosity which was suitable for the type of sprayer which was used.

In that connection, he had endeavoured, with fair success, to produce a simple apparatus for ships in the form of a viscometer, which would indicate the viscosity on a gauge and show whether one was running at the right viscosity for burning or not. Whether that would be successful he did not know; there were all sorts of snags in its development, such as choking with dirt.

Another point which he wished to emphasise was the need for care of the oil fuel sprayers and regular attention to the cleanliness of the registers. With some of the dirty oils which were supplied nowadays carbon deposits were found on some of the registers, and unless they were removed in time one got burning of the register and trouble with the combustion. It was unusual in his experience to find that the oil fuel sprayers had been properly looked after, but everything depended on their being kept in perfect condition; otherwise the oil would not be broken up into a fine spray. It was an important job to see that they were kept in proper order. Often they were cleaned badly, and were mishandled with the result that smoke and bad combustion were produced. It was easy to prescribe a proper system of working, but he could quite understand the difficulty, with the usual stokehold staff, in having the necessary order and discipline to get them to do it in the right way. They would usually do it, however, if they were shown, and in many cases he had gone down himself and shown them how to clean the sprayer and set it and operate it, and he found that they took an intelligent interest in it, and that might have done some good. He thought it was possible to teach them to respect the sprayer and use it properly.

He was astonished that some of the old designs of oil-burning arrangements which were fitted to ships ever burned oil satisfactorily and it was surprising that they ever worked with the oils now supplied. He felt the greatest sympathy for many of the Chiefs who had been bullied by Captains and Commodores for making smoke when to his mind the marvel was that they were able to keep the ship going at all, in view of the state of some of the apparatus which they had to use.

The author suggested the use of CO_2 recorders in ships. His own experience of the CO_2 recorder in the ships which he had visited was that it was seldom reliable and seldom worked. Sometimes one found a second or third engineer who was an enthusiast and looked after it, but in most ships it did not work at all. A smoke mirror only told one when one was making smoke, but not why. The smoke might be due to one dirty sprayer, and if one put the air pressure up and did other things to avoid that smoke one might be running very inefficiently. In his view, a funnel thermometer was of much more value than a CO_2 recorder. Knowing the standard conditions of the boiler from the data obtained on trials, one would get a good idea of the conditions by seeing that the funnel temperature was normal, and that in conjunction with a smoke mirror would give the best idea of whether one was burning one's oil efficiently.

The spalling of firebricks was often caused by bad operation. Spalling of firebricks would occur due to sudden change in temperature. It often happened that a burner was shut off and the operators did not bother to shut off the air to that air register, with the result that there was a blast of cold air over the hot bricks which would lead to bad spalling. Some years ago he carried out a number of experiments with a boiler and deliberately ran it badly and let the men delay in shutting the air off after the sprayer was shut down, and he shortened the life of the brickwork tremendously by so doing.

With regard to furnace brickwork, there was the question of the effect of rust in the furnace. After the boiler had been cleaned out, he would emphasise the necessity to clean out very carefully all flakes of rust inside the furnace; otherwise in the reducing atmosphere of the furnace that would melt and form a flux with the brickwork, which could cause a great deal of trouble.

He would like to say a word on the question of the training of engineer officers. In visiting large numbers of ships during the war, he had found that in many cases the junior engineers knew little about the operation of oil burners and oil-fired boilers, and very little about the operation of boilers at all. A young engineer was sent out to do boiler room watch-keeping and pick up his knowledge as best he could, and the men in the boiler room knew a great deal more than he did, but they knew a whole lot of wrong practices which they had picked up from other people. He most strongly advocated more and better training for engineer officers in boiler and machinery operation, and training as far as possible for the stokehold staff in operation of boilers. There was not a great amount of it needed, but it was essential that they should be taught the right way to do things, because many of them went to sea and picked up bad habits from their predecessors, with the result that they tended to ruin what would otherwise be quite good installations.

Mr. G. T. Adams (Member) said that the interesting paper under discussion was singularly appropriate at the present time, when many engineers were becoming interested in watertube boilers for the first time. He therefore wished to put a number of questions to the author, without, perhaps, contributing very much else. First of all he would like to know what was likely to be the extent of brickwork renewals in watertube boilers in commercial marine service, and whether the Classification Societies would insist on periodic brickwork removal in connection with their boiler surveys. Next, cases had occurred of failure of automatic feed regulators; was a satisfactory type of low water level indicator available? It had been suggested that where an installation was fitted with automatic feed regulators, the gauge glass did not receive from the operating personnel the attention which it required.

The author mentioned the danger of oil in watertube boilers. It would be interesting to know whether there were any means available for detecting the presence of small quantities of oil entering the boilers in a closed feed system. With regard to the danger of oxygen and CO_2 entering the boilers along with the feed, perhaps the author would say whether there was available a practical and reliable method whereby the ship's engineers could ascertain whether this was happening.

He would like to know which, in the author's opinion, was the most suitable type of CO_2 recording apparatus for use at sea by the ship's engineers. In his own experience, delicate scientific measuring apparatus in the hands of ships' engineers could always be relied on to produce the desired result rather than the correct result, that is provided the chief engineer knew what the answer ought to be! He recalled that, in the early days of the turbine ship, reading the torsionmeter was regarded as a good guessing competition, and if the water meter did not indicate a satisfactory figure it was promptly put down in the voyage repair list as being out of order. The author might regard the former as being outside the scope of the paper, but perhaps he would give members the benefit of his advice as to the most suitable type of water meter for marine use.

It was apparent that a certain amount of testing and measuring apparatus must be carried on a watertube boilered ship, and a small laboratory was almost as necessary in the engine room as the engineer's store. Perhaps the author would be kind enough to give a list of the essential requirements for such a laboratory.

He would like to know what, in the author's opinion, was the correct treatment for the water side of the heating surfaces of a watertube boiler, first of all prior to putting the boiler into service for the first time and secondly after cleaning and subsequent service. Distilled water for reserve feed must be kept in a tank somewhere in the ship; what was the best preservative to use for the steelwork of such tanks, in contact with the reserve feed water?

It was stated that watertube boilers should not be kept under steam or steamed at fractional ratings for long periods, yet in commercial service this was quite frequently unavoidable, as for example when a ship was lying at anchor in a river whilst loading, with the engine on stand-by for a number of days. What was the best method of safeguarding the boilers in such circumstances?

Mr. W. Nithsdale, B.Sc. (Member), congratulated the author on his brevity, and said that if all the papers read before institutes were no longer than the present one the proceedings would be much more interesting. Personally, he did not agree that to deal with the subject of operating watertube boilers required several volumes. It was, however, rather a pity that the author ruled as outside the province of the paper the merits or demerits of particular designs.

On the first page, it was stated that "war time at sea is not the best setting in which to become acquainted with entirely new types of machinery". During the war, however, the Royal Air Force had had to become acquainted and keep pace with new types of aircraft coming out almost every month, and the same applied to gunnery, tanks, radio location and indeed every branch of engineering. He did not accept the implication that marine engineers in any way were lacking in readiness to encourage developments in the national interest.

The position being discussed to-day seemed to him very like what it was after the last war, when people talked of the watertube boiler as something new. Twenty years had passed since then, and during the interval many watertube boilers had been installed in the Merchant Navy. This reference to lack of familiarity with the watertube boiler was now difficult to understand, because all power stations had watertube boilers and they were in all ships of the Royal Navy, so that the time for considering them an innovation anywhere had long passed.

Some excellent questions had been put to the author, for instance as to time required for raising steam, and brickwork upkeep. With regard to these, it all depended on how much brickwork there was in the furnace. Some furnaces had very little and there were designs with none at all, in which steam could be raised in a few minutes, so that two hours was rather a long time.

The question of water level and keeping water in a watertube boiler was a salient point. As long as there was water inside when there was a fire outside nothing much would go wrong. They put in gauge glasses to show water level, feed water regulations to keep it right, devices to shut off the oil fuel if the water level fell too low, and in addition now had distant-reading gauges in the engine room. In spite of all these safeguards it was not unknown when shutting down for someone to close the bottom gauge cocks, leaving a level showing and later to forget to re-open them on lighting up again when there might be little or no water in the boiler at all.

He would like to endorse the views expressed by other speakers as to the importance of seeing that all fittings worked properly and were given adequate attention. Under the Admiralty Merchant Shipping Dept., at Hartlepool his Company (Richardsons, Westgarth & Co., Ltd.) had had running for almost a year an exact duplicate of a Foster Wheeler boiler as fitted in the standard types of cargo liners and fast tankers, and every week a number of engineers attended courses and saw boilers under construction, operation features, methods of dealing with tubes, etc. They had never had a tube burst despite the number of different personnel who had handled the boiler. The principles taught applied to all boilers, and the courses were run independently by the Ministry of War Transport, so that he could not be accused of partisanship in the matter.

He wished to emphasise that when a ship went to sea engineers should bring home to the manufacturers that it was not good enough to issue one set of instruction booklets only for the Chief Engineer, who, with all respect, was apt to put them in the ship's library and not let anyone else see them. Full sets should be issued to all the officers who were likely to be near the boilers, and the same applied to the rest of the machinery. One could understand the Chief's view in wishing always to have a complete set at hand, but it was important to have other "working" sets.

There was another thing on which he would insist, if he were accepting a ship. It had been said that instruments such as CO_2 recorders, salinometers, etc., did not always function and were suspect, but they were all right in land practice, because land engineers insisted on makers' representatives coming and making them work. If he were taking over an engine room, he would make sure that all the instruments were registering satisfactorily, and once in order they would continue to do so, with reasonable care and, especially in the case of feed regulators, the necessary cleaning.

The author advocated for boilers of 300lb.. per sq. in. pressure and upwards nothing but distilled water. Personally, he agreed with that absolutely at sea, not for scientific reasons but because one had only about 5 per cent. make-up water, and it was a standard not difficult to attain. So far as land practice was concerned, however, if the author were talking about his land boilers before the Institution of Mechanical Engineers he would be given instances of their working at 800lb. per sq. in. with a very large percentage of raw make up subject only to chemical treatment. While agreeing that distilled water should be used at sea, one should not forget that on land plants were running—and the author's firm ran quite a number —without distilled water, or with only a very small percentage.

After advocating nothing but distilled water it was rather surprising that later in the paper the author seemed satisfied with filtering to keep out lubricating oil. He thought they should have the courage of their convictions and say frankly they would not recommend watertube boilers for a reciprocating engine having superheat or re-heat involving oil in the cylinders.

He agreed with Mr. Wheadon that if there was distilled water for the boiler there should be one form of treatment and one only necessary to preserve a degree of alkalinity. There was no need to have a variety of compounds but one standard for all distilled water which was the same, distilled properly, whether from sea water or varieties of shore water. There should be no necessity for marine engineers to study complicated reports on treatment or carry out elaborate tests on a standard water.

He did not want to say anything about hand firing for watertube boilers, because with the present price of coal it looked as though there would not be many watertube boilers at sea with coal firing for some time to come.

Any who were interested in engineers attending the course previously referred to should apply to the Ministry of War Transport, who would be very pleased to arrange matters. He was not familiar with all details, but ten or twelve went through each week.

The **Chairman** referred to the presence of Mr. Turner, who was Chairman of the British Standards Institution's Sub-Committee on Methods of Boiler Water Treatment, and said that a few words from him on the treatment of boiler water in high pressure watertube boilers would be helpful.

Mr. T. Henry Turner said he was glad to be able to be present, because the British Standards Committee wanted to keep in touch with what was being thought by practical engineers. It had been most striking that evening to listen to something entirely different from what was being said three years ago. The engineers who had spoken that evening seemed happy with watertube boilers and with the need for careful control of boiler water treatment. The idea of using lime seemed almost to have died out; yet three years ago the use of lime was stated to be the rule, in certain quarters. All that was to the good.

The series of Committees—it was not only one—seemed to him to go on interminably. He was a railwayman, yet he was Chairman of a British Standards Committee dealing with boiler water treatment for merchant ships. It was altogether wrong, and he hoped that soon the Research Association which the marine people were in process of setting up would be able to take over such Committees. However, the use of boilers on land had justified the present organisation in the past, for the sampling of boiler water and the analysis of boiler water was common to land boilers and boilers aboard ship.

So far as marine boiler water treatment was concerned, the Sub-Committee was about to hold its ninth meeting and was considering comments received from all over the world, and not from this country alone. It was well on with the revision and had finished the engineering section and the main part of the chemical treatment section and was now on the last lap home. He hoped that there would not be too much impatience with this delay, because while the Committee was going on a considerable number of people were keeping in touch with it and passing the information on to the others. In parallel with this work went that of an Admiralty Committee considering the same problems from a slightly different point of view. These two committees had a number of members in common.

One point which the author had not mentioned—perhaps, it did not come within the title of his paper—was whether there should be better control of evaporators than existed at present.

Whether shore water was used or not was relatively unimportant. The statement that on shore many large boilers used shore water and not distilled water was, in his view, misleading, unless it was added that it was the practice of all modern power houses to have complete water softening arrangements. Often they employed external lime/soda softening followed by base-exchange and completed by chemical conditioning in the boiler itself. That rather changed the picture.

In naval practice greater reliance was placed on evaporators; the Merchant Navy had relied less upon them. He thought that the Merchant Navy would be well advised to improve evaporators as far as possible. There then remained the problem of evaporator carry over, for there was no really good instrument for showing continuously the density of the brine concentrated in an evaporator. The help of the instrument makers would be welcome because carry over from the evaporator was a common cause of pitting and corrosion, or excessive use of chemicals, in marine boilers. If good evaporators and deaerators were used, modern high pressure watertube boilers would require the minimum of conditioning chemicals.

Eng. Rear-Admiral W. R. Parnall, C.B., C.B.E. (Member), remarked that after listening to what had been said that evening, and having at one time or another been Chief Engineer of several ships fitted with watertube boilers, he had come to the conclusion that he had run those ships very badly, and he wondered that they ever worked at all. They worked, however, with lower pressures than were in use to-day, and no doubt with higher pressures it was desirable, if not indeed necessary, that greater care should be taken with the condition of the water.

Personally, however, he took the view that if circumstances arose in which it was impossible, for a time, to be meticulously perfect in the control of the water conditions, there was no need to worry. He thought it was essential only to keep salt out of the water, and for that reason he had listened with interest to what Mr. Turner had to say; and he listened with particular interest to Mr. Turner's statement that there was no satisfactory means of ascertaining the density in the evaporator, because some years ago he devised a little instrument for that purpose which was made by Messrs. Dewrance and had been under trial; it would have been under trial a good deal earlier had it not been for the war.

Very little had been said in the discussion about the qualifications of the engineer, but it had been made clear that integrity was more important that anything else. The things that had to be done were not difficult, but they did require a certain amount of attention, and, as Rear-Admiral Dight and other speakers had said, there should be better means of training engineers in the details than existed to-day. At present, it had been said, engineers depended very largely on copying what had happened before. That, of course, was a very ancient trade practice; the apprentice learned the faults and mistakes of his predecessors. The type of training to which Mr. Nithsdale had referred, therefore, was most valuable, and should be very greatly encouraged. The men concerned did not require long practice, for if they knew what to look out for, and if in addition it was possible to rely on their integrity, all would be well.

Mr. S. B. Jackson (Member) said that he proposed to make a few observations on a new influence on marine engineering which might not have become apparent. The present paper, however, assumed great importance in view of the new monetary situation created by the abandonment of Lend-Lease. In the first place, the termination of Lend-Lease required us to supply our goods at a most competitive price, and necessitated improving the economic efficiency of our shipping industry, involving the carriage of our import and export trade at the lowest possible cost. Further, our home position was such that every possible amount of work-power was required to rebuild Britain, and hence labour employed in import and export of goods reduced the amount of labour which could be absorbed internally. Secondly, to produce a shipping industry of the highest economic efficiency we could not afford to neglect modern methods including the highest possible steam conditions, modern watertube boilers and automatic control. The employment of automatic control not only reduced labour but reduced fuel cost. It was his belief that the sooner marine engineers took an active interest in the political and economic aspects of their work and the influence of world developments on them the better, for this country would need all the dollars it could obtain and a very large contribution to this could be made by Britain's shipping industry.

In his view the more general adoption of the watertube boiler would make a marked contribution to the economic efficiency of the shipping industry, for it lent itself to rational automatic control. Taking the present total running costs of operation as 100, approximately 80 per cent. of these costs was represented by fuel and about 15 per cent. by labour. It was quite possible completely automatically to control watertube boiler oil fuel-fired ships, because he believed that manufacturers in this country were quite prepared to adapt their particular controls to the conditions met in the sea service. If this were done it was possible that the fuel costs would be reduced by 10-15 per cent. and the labour costs by something like 75 per cent.

The paper referred to water level control. There he could not agree with the author's view, his disagreement being supported by the very valuable contribution of the late Sir George Preece to the problem of water regulation made in his discussion on Mr. Hillier's paper, a contribution which should be read by those who wished to have a better conception of the problem of water level control and which appeared to disagree with the requirements specified in the paper.

Correct boiler control depended entirely on correct water conditioning, and it would be quite possible to employ modern water conditioning methods as found in all power stations, in marine practice. The fresh water feed could be treated by a zeolite plant which could be subsequently evaporated, producing boiler feed of the highest purity. This permitted the highest initial conditions being used. While he himself would not deal with this subject, he only wished that Mr. Turner had gone into greater detail, for his views would have been very welcome.

Regarding the de-oiling of boiler feed water, attention should be drawn to an electrical process for removing emulsified oil from condensate possessing certain advantages over chemical methods for coagulating the oil. He understood this had found satisfactory application in a number of industrial plants, and no failures had been reported. This process should not be confused with electrical water softening, which in his view was unsatisfactory.

Regarding automatic boiler control, control of pressure, temperature, draught, combustion, and gas temperature in relation to its dew point could all be automatically performed. In his opinion it was possible to produce *rational* and economic controls for service at sea and he hoped the day was not far distant when completely automatically controlled ships would be operated. In using the word *rational* he implied that existing controls did not necessarily fall within this definition.

While the paper referred to the operation of watertube boilers it seemed to infer that steam turbines were going to remain, and while it was important in indicating some of the problems to be faced in the immediate future, say for the next five or ten years, he felt that attention should be drawn to the gas turbine. If the gas turbine drive was adopted, then all the problems enunciated in the paper, including educational ones, would entirely disappear. The trend would not be neglected as the only alternative to the gas turbine drive was the completely automatically controlled steam drive, for the competition of gas drives would promote the more complete employment of automatic controls. He learned that even within the last few weeks Continental firms had actually tendered for up to 30,000 kW. and 40,000 kW. gas turbines for power stations, so it appeared that the gas turbine drive was just round the corner. He thought that the day was not far distant when gas turbines would be used for marine operation and those who wished to retain steam drives would have to make up their minds to use automatic controls.

By Correspondence.

Mr. H. W. Arkell. I hope I may not be considered out of order as a manufacturer in making one or two comments on matters referred to during the meeting. I am interested in a CO_2 recorder, a number of which have been installed on ships both before and during the war. At one time, we were able to give adequate assistance to ships' engineers in such a way that there was not too much difficulty in keeping the apparatus in order. Under stress of war conditions, this has not been possible, but we should hope that with a degree of return to normality to be able once again to assist in the manner indicated. Another difficulty has I believe been due to the fact that during war time engineer personnel on ships was continually changing, which would not assist individual engineers to master the details of such auxiliary equipment.

With regard to remote water level indicators, I do not think any difficulty has been experienced with our design once they have been correctly installed.

I was also interested in the remarks on automatic control. It does not follow that the last word has been said in regard to this type of equipment. My Company fitted out the boilers of the "Nieuw Amsterdam" before the war, and as far as I am aware, there have been no difficulties in keeping this equipment in satisfactory use. Pressure of work and other difficulties have prevented us from investigating this field thoroughly, but in land practice great strides have been made in design during the war years in this interesting side of combustion control.

Mr. F. S. Batey, B.Sc. There are two comments that I should like to make on Major Gregson's paper:—

(1) That calcium hydrate can be used to fix CO_2 without forming a scale, leaving a suitable organic treatment to deal with any oxygen and protect the underwater surfaces, and that calcium hydrate is preferable for this purpose to caustic soda.

(2) That tri-sodium phosphate is a sludging medium for treatment of fresh, not distilled water, and if the system is a properly closed one the only factors that require to be guarded against are CO_2 and oxygen corrosion from the original water with which the boilers were filled.

Captain (E) C. H. H. Brown, C.B., R.N. I think the paper covers the ground pretty thoroughly, but would suggest a little more emphasis on the importance of external cleaning, and the necessity for rain gutters in the uptakes to prevent rain water from getting access to tube surfaces. Much damage can be done to idle boilers by accumulations of damp soot in contact with the tubes, in fact this is often a more fruitful source of trouble than internal corrosion.

The importance of keeping funnel covers on and airing stoves in use when boilers are standing idle might well be mentioned.

I note also that no mention is made of the incidence of corrosion of superheater tube ends where the tubes are expanded into the headers, a fruitful source of wastage which requires regular attention. It is essential that the superheater tube ends should be readily accessible for inspection and the closing plates of the casing made easily packable.

A further point which might well be mentioned, apropos of closing up after cleaning, is the importance of mustering all internal fittings removed from the drums, both on removal and replacement after cleaning, and gear issued for cleaning to ensure that nothing is missed during the final search.

Personnel making the final search must not be allowed to enter the boiler with loose gear in their pockets which might fall out and become lodged in tubes.

All nuts, washers, etc., used for securing internal fittings should be of such a size that they cannot enter any tube.

It may be said that these precautions are self-evident, nevertheless they are often overlooked and cannot be repeated too frequently, especially where personnel unaccustomed to watertube boilers are concerned.

Mr. J. T. Carnaghan, B.Sc. (Member). Major Gregson is to be complimented for presenting a very fair and unbiassed paper which will prove of considerable help to the marine engineers called upon to operate the tanker and cargo vessels fitted with watertube boilers.

Many of these engineers have come from Diesel engined ships and are entering a strange field where a capable engineer with a record of specialised training in watertube boilers and the closed feed system is a rarity, even amongst many of the superintendents; all are interested.

Boiler Explosion Reports.

Will the author give the source of publication of reports upon the early and any recent failures of watertube boilers in U.S.A. land and marine practice? The fact that the previous purchase of the B.O.T. explosion reports from H.M. Stationery Office in this country was worth while was driven home to the writer when a B.O.T. examiner produced a number of these and proceeded to question upon the cause and prevention of boiler failures. Details of failures in the U.S.A. seem somewhat obscure.

New Machinery in Wartime.

Wartime at sea may not seem to have been the best setting in which to become acquainted with new ventures. Yet under convoy speeds and manœuvres considerable skill was required in handling the new layouts in cargo and tanker vessels and an unpremeditated test of the boiler designs, furnaces, layouts and the staff resulted.

Boiler designs have proved sound, economisers faulty, boiler casings weak and far from gas tight and layouts capable of considerable improvement. The future vessels will benefit in consequence and the obvious weaknesses have at long last been accepted as facts by the designers and those who approved the plans.

Training of Engineers for the Watertube Boiler Field.

The American system of training an engine-room staff ashore has been adopted by Messrs. Foster Wheeler, Ltd. The psychological and practical results of this venture are of considerable interest and I hope some mention will be made at the meeting.

I hope the author will advocate an extension to this scheme in advocating that the senior engineer selected for the vessel to be constructed, should spend a period of time at the boiler, tube and steel works. I am certain that Major Gregson will confirm that an engineer who has witnessed drum and tube manufacture from their earliest stages until the final hydraulic test of the built-up unit, and has also witnessed the steel tests, will no longer regard a watertube boiler as something to be feared. Such a training will pay its dividend to all associated and do much to ensure the lead for the United Kingdom in the competition for trade which now lies ahead.

The history of Thyssen watergas-welded drums, Babcock welded drums, English Steel & Chesterfield Tube Co. forged drums and the Union Melt process adopted by the U.S.A. and Messrs. John Thompson with the consequent endeavours of the manufacturers, the classification societies and the insurance companies to provide for and draw up suitable test requirements, cannot fail to captivate any marine engineer. His eyes are now upon Foster Wheeler, Sulzer, Lamont, the Babcock boilers of the s.s. "Examiner" generating steam at 1,200lb./sq. in., Johnson, and other boilers. His training must be well thought out and provided for.

Care of the Watertube Boiler.

Will the author complete his treatise upon the cleanliness of the fire and water side, and the period of steam raising, by including some instruction upon the boiling out process to remove oil and grease, and upon the necessary inspection and cleaning periods during the period when the mill scale and lime sludge is prevalent? I would suggest that the boiler should not at any time be blown down until the steam pressure has dropped to 50lb./sq. in. in order to prevent vibration and subsequent tube end leakage, and now that submarine danger is past, a continuous blowdown valve might be fitted for use as and when necessary during full pressure on the boiler.

The practice of drilling pipe flanges aboard the vessel during fitting out should be condemned, in that the time saved does not compensate for the damage and troubles later experienced at sea due to cuttings inadvertently passing into feed control devices, automatic float fittings and valves and gauge glass fittings.

Superheated Steam Pipes.

Does the author advocate hand scraped face to face joints, and would he suggest a period of time for replacement of the high tensile nickel-chrome steel bolts used in the joint flanges?

Feed Water Troubles.

The advice to have the standby feed pump ready for use through the auxiliary feed main is sound. Failure of water supply with the closed feed system may arise from one of the following causes:—

(a) Incorrect setting of the Robot control device during manœuvring or often full away.
(b) Sticking of the Robot.
(c) Seizing of the Weir's turbo feed pump pressure governor control piston.
(d) Accidental pressing of the Weir's governor cut out button on the turbo feed pump.
(e) Shutting down by governor control of the main and auxiliary stop valves.
(f) Inoperation of the Weir's automatic float valve connecting with the condenser and main feed tank.
(g) Pipeline blockage or failure.
(h) Failure to shut the suction valves on the condenser and/or feed tank lines connecting with the auxiliary feed pump.
(i) Economiser failure.

Normally the water level is easily and quickly regained by operating the Robot flooding device.

Normally the low level alarm devices function satisfactorily in giving audible warning of low water level, and in cutting off the fuel to the burners. They, however, are liable to become inoperative due to scale and sludge deposits both in the water and fuel sides, and should receive equal attention with the Robots during the first months of running in of the boiler.

The turbo feed pump pressure governor piston should be removed periodically and cleaned with naphtha, and no emery or other abrasive should be used. Before replacing the piston, it may be lubricated with a little 3 in 1 oil.

The Robot and Weir's float valve testing devices should be operated at least once per watch.

The following data showing the effectiveness of the Robot device during medium and heavy weather and whilst soot blowing, may be of interest. The boiler drums were fitted athwartship and had wash plates internally.

Moderate weather.

108 r.p.m., superheater pressure 420lb./sq. in., vacuum 28·9in.

Extraction Pump Discharge Pressure.		*Turbo Feed Pump Discharge Pressure.*
25		460
24		480
23		460
24	Simultaneous readings	480
24·5	every 15 seconds.	480
24·5		480
27		500
		490
24		490
26		500
25		480
26		500

Heavy Rolling.

106 r.p.m., superheater pressure 425lb./sq. in., vacuum 28.5in.

24	490
10	470
9	600
25	490
27	640
	640
23	470
24	490
18	580
25	500
23	470
27	600
10	420

Blowing Soot Blowers.

108 r.p.m., superheater pressure 420lb./sq. in., vacuum 28·8in.

Extraction Pump Discharge. lb./sq. in.		*Turbo Feed Pump Discharge. lb./sq. in.*
29		530
29		530
30		550
34		570
33	Simultaneous readings	550
35	every five seconds.	580
33·5		540
33		550
34		560
34		560
37		580
32		550

(Continued)

Extraction Pump Discharge. lb./sq. in.	*Turbo Feed Pump Discharge. lb./sq. in.*
31	540
31	540
36	580
40	600
36	550
42	550
	590

Soot Blowing.

The following figures from observations in a fast tanker vessel may be of interest.

The feed water level in the feed tank was observed to have dropped 5″ after blowing both boilers. Eight blowers per boiler. 15 minutes per boiler.

Feed tank size 4′ 0″×6′ 6″×15′ 0″.

Before Blowing Sootblowers:—

Funnel Gas Temperature	430° F.
Superheat Temperature	710° F.
CO_2	9%

After Blowing Sootblowers:—

Funnel Gas Temperature	410° F.
Superheat Temperature	720° F.
CO_2	11%

Would the author comment upon "Exzit" powder, a grey sandy substance in appearance which the writer has seen blown into the furnace of a Babcock and Wilcox boiler by air, prior to operating the sootblowers?

The American Vc 2-5-ap. 2 type of vessels with Foster Wheeler boilers built by the Wicker Boiler Co., Saginaw, were observed to have sootblowers propelled apparently by air. Will the author comment upon the maintenance of sootblower valve spindles which the writer has found seize in with the valve in the "open" position, under superheated steam temperatures? Honing of the valve stem proved effective.

Distilling.

The M.o.W.T. tanker and cargo vessels are fitted with a 4″ bore distilling connection from the Scotch boilers connecting with the main condenser through a reducing valve. In port there is no difficulty in producing large quantities of distillate for the systems, storage and flushing the boilers. Make-up at sea is required due to gland leakage and sootblowing, and in the vessels fitted with an h.p. feed heater, a wet steam line connects with this heater and can be used provided the h.p. turbine bled steam is not in service. If h.p. bled steam is heating the h.p. heater, then the only source of make up is the distilling line to the condenser. This raises an interesting point, in that the writer contends that the practice of using this method at sea causes loss of vacuum and is liable to draw the steam from the Scotch boilers with considerable rapidity and so cause a dangerous condition. Loss of vacuum will arise through alteration in the designed temperature difference between the exhaust steam temperature and that of the condensate, usually between 1° F. and 2° F. and through alteration of the pressure drop.

Calculation dispels the writer's contention, yet in practice one finds support in that on one vessel using this method, low vacuum is blamed, due to the size of the condenser, whilst one firm regularly running trials of the vessels has discontinued the practice, having found that the vacuum is affected adversely.

If a small bore distilling connection is fitted for sea use, care should be taken to see that this has a suitable reducing valve fitted, and a suitable baffling arrangement provided either in the condenser or in the original distilling line.

Water Testing.

It is suggested that the work done by the British Standards Institution Committee, and by the marine boiler makers and feed treatment specialists on the subject of water treatment and testing should be carried a stage further by the examiners of candidates for the M.o.W.T. certificates of competency. A question set in the written papers and a practical test of a sample in the presence of the examiner would no doubt lead to the coaching schools giving their students laboratory facilities and training.

The tests are simple; it is in the care with which one takes the specimen, cleanliness in use of the apparatus, and in the understanding and analysis of the results that one requires skill.

Many interesting test samples can be taken, especially after the initial treatment, during the first manœuvres, during various loads, and before and after scumming and partial blowing, as well as those during the voyage and after treatment of the boiler contents.

The following figures have been observed employing the Afloc No. 11 (I.C.I.—Alkali Ltd.) treatment and tests, which briefly summarised are:—

Hardeners (H).

70 mm. of sample. Add Wanklyn's soap solution 0·2 mm. at a time, shaking vigorously after each addition, until a permanent lather is obtained. Deduct from the total volume of soap solution used the lather factor and record the difference as H.

Alkalinity to Phenolphthalein (P).

70 mm. of filtered sample. Add two drops of phenolphthalein indicator and see in N/50 sulphuric acid from a burette until the pink colour is just discharged.

Record the volume of acid used as P.

Chlorides (CL).

After completing the (P) test above, add 1 min. of acid in excess and then twenty drops of potassium chromate indicator. Run in N/50 silver nitrate solution from a burette, stirring meanwhile, until the yellow colour of the sample is changed to a dirty brown. From the volume of silver nitrate solution used, deduct 0·2 mil. and record the difference as Cl.

The figure thus obtained is grains per gallon as calcium carbonate, to convert to grains per gallon of salt (NaCl); multiply the above figures by 1·17.

Where a cooling coil is not used for drawing samples, the test figures should be multiplied by 0·73 in the case of boilers working at about 450lb./sq. in.

Tests every second day.			*Test Results.*		
Boiler A.	H.	P.	Cl.	TDS.	Sulphite.
Boiler being run in.					
	0	11·0	1·0	72	0
	0	11·8	1·3	72	3·9
	0	12·5	1·9	72	3·8
	0	13·1	2·8	72	3·9
	0	13·5	3·1	70	3·8
Return voyage after cleaning.					
	0	9·2	0·9	46	0·2
	0	9·9	1·1	46	2·5
	0	10·3	3·1	40	2·7
	0	10·7	10·3	40	2·9
	0	11·2	11·4	39	3·4
Outward voyage.					
	0	14·1	1·1	40	2·7
	0	12·9	1·7	40	2·3
	0	11·3	1·8	53	2·8
	0	10·7	2·1	53	3·1
	0	9·0	2·5	62	4·0
Return voyage.					
	0	12·3	2·1	40	3·7
	0	10·1	3·4	41	4·1
	0	4·6	5·1	43	4·3
	0	20·4	6·0	43	4·3
	0	22·5	5·4	48	2·9

During manœuvring the (Cl) and oxygen content rises, the latter being controlled by the sulphite present.

Analysis of the test results may show that the boiler contents become balanced up, with a two boiler lay out, should there be carry over into the condenser and feed system.

In this respect the water wall return has been known to impinge on the steam strainer and so give misleading results.

The writer suggests that a separate stand pipe should be arranged on the boiler drum for the sampling connections. The practice of using the same stand pipe for the injection of the chemical and for drawing the test sample may lead to false data.

The cooling coil for the test sample is frequently to be found in a cylindrical vessel into which is run cold sea water as the cooling medium—this may overflow out of the open upper end and also overflow during heavy weather, thus the test sample may be contaminated; a closed vessel is recommended.

Tube Repairs.

The maker's instructions both for cutting out the old tube and refitting the new one are generally fully illustrated and explicit. It is suggested that the tube ends should be gauged for thickness, and inside and outside diameter. After being thoroughly polished externally, and reference being made to the British Standard Tables to see that they are up to standard, the tube hole seating grooves should receive careful inspection.

The instruction booklets of Messrs. Babcock and Wilcox, Messrs. Foster Wheeler, and others, are worthy of study and appreciation of the work that has been entailed in producing them.

Burning of Fuel.

Care should be taken that a defective burner should not be allowed to remain in the furnace. It should be removed at once in order to prevent fuel dribbling and carbon accumulation. The furnace wall air spaces and furnaces are liable to become filled with liquid fuel, and explosion and/or furnace tube collapse are possible in consequence. If a burner is not required it should be drawn back; in so doing no fuel will pass through inspection, cleaning, and furnace repairs. If such vessels once again return to running 300 out of 365 days per year, one visualises all the skill and workmanship of the boiler construction companies being wasted and heavy repair bills producing unfair statistics.

Mr. B. P. Fielden (Member). The author states that the majority of the U.S.A. shipyards are concerned with purely shipbuilding, and not with building marine machinery. This is probably because other firms have specialized in the new types of machinery, which the shipyards find it cheaper to purchase than to make. In my opinion they have little to learn about economics or thermal efficiency.

It is a remarkable fact that, notwithstanding the advance made in the U.S.A. by the use of high temperature steam, turbines and watertube boilers, they still have in service three ships over 40 years of age and which are fitted with steam reciprocating engines and Scotch type boilers. They are the "Virginian" and the former "Mongolia" and "Manchuria" (now re-named) whose history was published last month in the "Shipbuilding and Shipping Record". They are owned by different owners, so it is obvious that they have been worth keeping, although old fashioned. They have proved their reliability.

Theoretically ships should not have any boilers at all in the propelling equipment, nor crank shafts either, but should have rotary internal combustion engines.

The operation of watertube boilers at sea has to be more closely attended to than that of Scotch boilers, which are not very fussy about the liquid supplied to them, and the former are not so easily cleaned in port. They are, however, good for the fire-brick industry; they have the advantage of being lighter than Scotch boilers, and are more suitable for supplying high temperature steam to a turbine. On many vessels they are therefore a necessity.

The author mentions operation in American and British vessels. My experience was that engineers very quickly learned to handle any kind of machinery, whether steam or oil driven. It is all a question of intelligence, guts, and fair treatment.

Ships are constantly being improved; marine engineers have to keep in step, and directors should do likewise. There is nothing so good as team work for getting ships along.

Mr. J. K. Gibbon (Member). Major Gregson has characteristically put a great deal of very useful material into a short paper. He has dealt with the subject in a manner which should make his paper a valuable guide to marine engineers who have not had the opportunity of operating these types of boilers at sea and who may feel a little apprehensive at the undoubted increase in the number of ships fitted with them.

There is nothing that I could criticise in any section of this paper although, naturally in so short a paper, there is much room for elaboration of detail which should lead to a most interesting discussion.

I am surprised to find, though, that Major Gregson has not commented on the necessity for really first class maintenance of boiler casing joints, casing doors and packings between headers and around nipples and drums, particularly in boilers operating under the closed stokehold system of forced draught.

I have invariably found air leaks, through neglect of these items, to be the greatest individual cause of high coal consumption and inefficiency.

Boiler casings, with their many cleaning and inspection doors and attachments to the parts of the boiler itself, cover an extensive area and the cumulative effect of a number of small leaks of cold air to the heating surfaces is most amazing to anyone who has taken the trouble to fully investigate them.

Packings, usually asbestos rope, between the headers, around nipples and even below the mud drum are inclined to harden and, if not actually fall out, loosen sufficiently to allow many streams of cold air to pour on to the heating surfaces. These should receive frequent and detailed inspection for air tightness using the flame of a duck lamp for testing purposes.

The header type of boiler has a particularly robust constitution and, while there is need for care, there is no occasion for anxiety on the part of any intelligent engineer in its operation.

In the many Babcock and Wilcox boilers in my charge, shore water only is used to fill them and as make up feed. This water has some 3 degrees of permanent hardness and water-softeners have only recently been installed.

The fire-tubes, steaming-tubes and those in the line of the feed inlets are scaled annually and the remainder scaled every two years, i.e. half of them each year. The amount of scale removed is not very great in spite of the fact that calcium hydrate is the only reagent used and that the chlorinity and alkalinity are maintained at 15°/20° and 850°/900° respectively.

In boilers of 17 years of age a few representative tubes have been taken out for examination and have proved to be in extraordinarily good condition. Apart from these no other tubes have had to be replaced while the boilers are on ordinary service.

A trial was made some years ago of trisodium phosphate as a reagent, but the results were most unsatisfactory. It certainly had the effect of converting the scale-forming matter into sludge, but the sludge could not be got rid of sufficiently by blowing down. During periods of slow circulation small pads of sludge settled on the tube and drum surfaces and remained there. Active corrosion, resulting in some cases in deep pitting, was found to have taken place beneath these pads of sludge and the use of this reagent was promptly discontinued.

I shall be glad if Major Gregson will let us have more details of his experiences of the effect of trisodium phosphate as a reagent.

In the past condenser leakages were all too frequent and had a most disastrous effect on the boiler tubes and drums. I can, however, positively confirm that modern condenser tube materials and packings have practically eliminated trouble from this source.

Mr. J. E. M. Payne (Member). The author has rendered a very useful service by epitomising certain essentials if satisfactory service is to be obtained from watertube boilers.

From the writer's experience during the war it seems to be not sufficiently appreciated that distilled water with a slight alkalinity is absolutely essential even when filling up. Incidentally zinc plates are still desirable and whether they are electrically all they claim to be or not, they are certainly excellent collectors of air bubbles if they are initially cut off sharp and square. The author's opinion on this subject would be appreciated.

The ship's engineers need only a simple testing outfit employing standard nitric acid, phenolphthalein and methyl orange and the usual measuring appliances to know the relevant facts.

The author's comments on brickwork are interesting and informative, and in this connection the importance might be emphasised of extending the brick side walls of three drum boilers above the point of entry into the drums of the tubes exposed to radiant heat.

Subsequent to boiler cleaning and polishing with a graphitic substance of approved origin all tubes should be carefully tested to ensure they have been cleaned, and this should be done by a responsible person and with care.

Cases have been found, though not common, of boiler tubes on "A" and "B" rows eroded near the upper end of three drum boilers of say five or six years of age. Chemical and metallurgical examination revealed no abnormality and in the light of the author's comments it may be observed that fuel nozzles are now in some designs arranged to converge to approximately the centre of the combustion chamber, thus reducing risk of tube flame contact for example through carelessness or other cause. The erosion is generally of pan shaped appearance and mottled. The first impression is that the defect is due to intense heat flow due to excessive steam generation in the radiant area. In this connection what is the author's opinion as to the conservative ratings for present day practice?

The old practice of referring to pounds of steam per square foot of heating surface is dying out apparently owing to the illogical nature of the conception in relation to watertube boilers. Heat release per unit of furnace volume and per square foot of radiant surface seems the more practicable method. Some years ago another interesting paper was read before this Institute on which occasion 15lb. of steam per square foot of heating surface was quoted as high but obtainable. To be consistent all such figures should be converted to conditions from and at 212° F.

Mr. J. M. Smethurst (Member). I understood Major Gregson to say that flame impingement on the tubes should be strictly avoided. If this is correct, I would like to pass on the following information.

I have four Stirling boilers under my charge and flame impingement constantly takes place. During the past six years I have only replaced one tube, which suddenly developed a medium sized blister. The cause of this was apparently excessive scale due to faulty boiler cleaning.

We have no special water softening plant, but the feed water is treated with a patent boiler fluid. Scale approximately $\frac{1}{32}$in thick forms on all internal surfaces after running 2,500 to 3,000 hours. This is usually found to be fairly soft in most places and is easily removed by hand scraping the drums.

An electrically driven scaling machine has little difficulty in dealing with the scale in the tubes. There are thirteen tubes in a row, and the front bank which receives the flame impingement are all hogged where this takes place, about one-third up the length of the tubes. The hogging varies from ½in. to 1⅜in. in a few worst cases but the amount of increase during the past six years has been negligible. Some of the worst hogging may be due to the boilers being worked very hard in earlier years.

They are now 21 years old and work at approximately 7,500lb. per hour evaporation. They are rated at 8,300lb. the pressure is 200lb. temperature 388° F. superheated to 580° F. Coal is the fuel used, with mechanical stokers of Babcock and Wilcox type.

I shall be pleased to give any other details and would appreciate any comments Major Gregson cares to make on the subject of flame impingement, which did not come up during the discussion.

The Author's Reply to the Discussion.

The author, replying to the verbal discussion, pointed out that as the paper was short it only really summarised the subject under review, so naturally a good deal of the substance of the discussion was by way of amplification of the paper itself. Dealing with specific points and questions raised, he was afraid he had not made himself clear on the subject of de-aeration; of course, every effort should be and was made to get rid of air *before* the feed pump, and his suggestion that provision should be made for de-aeration on the pressure side of the circuit was by way of an added precaution, as it was so essential to give boilers an air-free feed. This replied to one of the points brought out by **Mr. W. Lynn Nelson.**

With regard to Mr. Nelson's other points: (*a*) sticking feed water regulators—he (the author found that this trouble sometimes occurred during or immediately after trials and was due entirely to dirt in the system. Once the boilers and feed circuit were clean his experience with all the well-known types of feed regulators was that they were excellent and reliable. Point (*b*) dealt with furnace ratings; this was a good way of comparing *like* designs, but utterly unreliable for comparisons between different *types* of boiler as so much depended on the lay-out of the radiant surface and above all the circulatory system.

Mr. W. Sampson pointed out that the permissible density range quoted by the author was about double that given in the B.S.I. recommendations. This was correct, as the author had in mind the header-type boiler operating at normal Merchant Navy ratings where (owing to characteristics of design) the steam/water mixture did *not* pass through the drum water but into a separating chamber in the drum above the water line, and the figures given were quite safe in practice for that type of boiler. In all other designs—where the mixture bubbled up through the drum water—greater care was necessary, and the B.S.I. figures should be adhered to. The author instanced the fitting of a special form of cyclone separator in certain types of boiler with which he was concerned, and where the steam would normally pass through the drum water, in order to assist in this function of separation, and reminded the meeting of the case of the U.S. Aircraft Carrier "Franklin", which, after heavy damage from air attack, had steamed home on heavy density water due to salt contamination, the cyclones having quite adequately dealt with the density factor. The author agreed with Mr. Sampson on the necessity for marine engineer officer personnel being trained in the general subject of combustion.

Mr. H. J. Wheadon had also raised the question of permissible density and asked whether tests had been carried out on the subject of carry-over. The author stated that his sister company in the U.S.A. had done a great deal in this connection but it was such a complex subject, being linked up with a wide series of variables, that it really offered scope for a complete paper in itself. Mr. Wheadon mentioned that the use of lime was the simplest way to eliminate CO_2—but the trouble was that eventually lime so used resulted in scale formation unless other precautions were taken. The case of the boilers in two ships under Mr. Wheadon's control, where in spite of perfect alkaline boiler water it was found that acid water had collected in the non-drainable sections of the superheater elements (due to CO_2 liberated from carbonates), had also occurred in other ships and showed the importance of "killing" CO_2 properly, or better still avoiding its formation, also the desirability of superheaters being as self-draining as possible.

Engineer Rear-Admiral S. R. Dight, C.B.E., raised the important point of co-relating boiler operation to engine requirements owing to their lack of storage capacity compared with Scotch boilers. This was important—but not so difficult outside the Royal Navy, as Merchant Navy ratings were only about one-third those which obtained in Naval practice and it was usual in both services to keep the boiler room informed by telegraph from the engine room as to steam requirements. The author agreed with Admiral Dight that there was no need to make smoke when getting up steam; the use of the small lighting-up burner tip combination should be insisted on. He (the author) thanked Admiral Dight for his further remarks on oil burner operation and control—Admiral Dight had more experience on this subject than any other member of the Institute.

Mr. G. T. Adams asked about furnace brickwork repairs—were they frequent? The answer was that furnace brickwork lasted for years if normal operating precautions were followed, but he (the author) could guarantee to start bringing down any furnace by mal-operation in a couple of watches. Classification authorities did *not* ask for brickwork to be taken down for surveys except in certain cases where actual tube surface was blanketed thereby. Mr. Adams asked about feed regulator failures; as pointed out in the reply to Mr. Nelson these were avoidable if dirt was eliminated from the feed circuit and boilers. Water gauges were not difficult to read on normal jobs; in cases where, owing to the proximity of galleries, etc., they could only be seen from certain fixed points it was customary to fit either reflectors or fitments by way of distance recording gauges. The testing apparatus for controlling the quality of feed and boiler water was very simple—just a small case w[illegible] graduated bottles, using standard solutions. Regarding Mr. Adams' query as to what was the best water treatment, the answer was that there were several ways of doing this—all good, and backed by firms of good repute. It was usual to paint distilled water tanks with Apexior or similar compounds. There was no difficulty in safeguarding a watertube boiler at very low rates of operation and the air heater would be by-passed to avoid sub-normal temperatures in the cooler zones. It was essential to keep up the feed temperature under such conditions.

Mr. W. Nithsdale's remarks contained much sound and good advice, and his Company's venture with the School at their West Hartlepool Works deserved every success. There were a few points in Mr. Nithsdale's contribution which the author did not agree with:—

(a) It was not correct (especially in the U.S.A.) to suggest that all engineers now at sea were really sea-minded. Many had gone to sea as their contribution to the war effort, hence the comparison which Mr. Nithsdale made with the flying personnel of the R.A.F. was not on a sound basis, as the latter were *essentially* air-minded.

(b) It was not correct to compare land power plant practice with sea-going practice in the matter of feed water technique. Make-up feed on land was treated by lime/soda plants *with ample settlement tanks*, often followed by Zeolite treatment.

(c) Watertube boilers were quite satisfactory with reciprocating engines provided they (the boilers) were of suitable robust design, were not unduly highly rated, and that care was taken with feed filters and—as pointed out in the paper—contamination was avoided as far as practicable by the use of graphite, etc. The author's Company had supplied many hundreds of watertube boilers which were working extremely satisfactorily with reciprocators.

The author welcomed **Mr. T. Henry Turner's** contribution, emphasising the importance of evaporator control, and he agreed with **Engineer Rear-Admiral Parnall** that the watertube boiler did not call for a superlative degree of supervision to give trouble-free service. The author instanced the cases of many small ships out East running with all-native boiler room ratings and in some cases with no white engineers aboard at all.

Mr. S. B. Jackson raised the question of all-automatic control. The author thought a better case could be made for this on land—with a constantly fluctuating load—than at sea, as once manœuvring operations were completed everything could very simply and quickly be set for optimum operating conditions. Mr. Jackson referred to the advent of the gas turbine and the author agreed that this was obviously the next major step in marine propulsion, and that by taking advantage of the great advances made in the science and art of metallurgy during the war one of the biggest difficulties to be overcome in the development of this prime mover was already narrowed down. Meanwhile, however, there was a good field for the watertube boiler/turbine combination until the gas turbine had first got over its teething troubles, and had then been developed for other than low powers. The author believed that an experimental unit was being fitted in a U.S. vessel and that certain marine developments were also likely to mature over here.

Replying to the written contributions, the author states that **Capt. (E) G. H. H. Brown, C.B., R.N.,** has brought out two extremely important points—protection from weather, and the importance of avoiding any loose material being left in a boiler after cleaning. **Mr. J. K. Gibbon** has had quite exceptional experience with watertube boilers operating under very onerous conditions in cross-Channel services, where (as the exception that proves the normal rule) it is quite customary to use raw feed make-up at all times for jobs up to 250lb./sq. in. The quite remarkable service which the boilers in such ships are giving is due in no small measure to the fact that the whole of the engineer personnel concerned—ashore and afloat—is thoroughly conversant with what to do, and what *not* to do. Mr. Gibbon has drawn the author's attention to a very important omission in the paper, i.e., the necessity for keeping casings, inspection doors, etc. tight. Not only does lack of this precaution mean working inefficiently in the case of closed stokeholds or when the boiler passes are under negative pressure, but in the case where positive pressure is carried leaky casings are at least the cause of very hot boiler tops and can be a menace to the operating personnel. Regarding unsatisfactory experience with trisodium phosphate, the author believes that if used with a raw make-up it would primarily form a good deal of soft sludge which if not easily removable would blanket the heating surface, and unless the treatment was carried out in big dosage it would not be able to effect its normal mission of conditioning.

Mr. J. E. M. Payne refers to zinc plates; the author does not think these are required nowadays, when care is taken in other directions. Regarding what Mr. Payne called "conservative ratings for present practice", this is a variable factor depending on the type of boiler and its circulatory system and no general figure can be given; each design should be analysed and assessed on its own merits.

Mr. B. P. Fielden refers to three old U.S.A. Scotch-boilered ships—quite rare specimens in American tonnage; the author supposes the reason they are still in service is the same which applies to many ships of about the same age flying the Red Ensign, i.e., that they have been well looked after, and are capable of performing useful work, under which conditions they will certainly be of value in war time.

Mr. F. S. Batey prefers calcium hydrate as a fixer of CO_2 with organic treatment to deal with oxygen. There seems to be a certain difference of opinion between the various feed water treatment specialists as to what constitutes the best form of treatment, but the author believes that lime should be avoided, and that some definite means should be adopted to secure alkalinity—hence trisodium phosphate, although as pointed out earlier in the reply to the discussion this is only one of a number of effective ways.

Mr. H. W. Arkell's contribution on the possibilities of the development of automatic control is noted with interest, although the author thinks that such apparatus offers more possibilities with land plants (see reply to Mr. Jackson). He (the author) agrees as to the effectiveness of both the CO_2 recorders and remote water level indicators to which Mr. Arkell refers.

Mr. J. H. Smethurst instances the case of mechanically-fired coal-burning land boilers where the flames "lick" the furnace-row tubes. This is quite common with coal firing but is entirely different from the local blow-pipe effect which incorrect oil-burning operation can have on the the tubes.

Mr. J. T. Carnaghan's contribution is chiefly additive to the substance matter of the paper. Dealing with the questions which he raises:—

(a) The author believes that an appropriate U.S.A. Government Department reports on boiler failures, but he does not know whether reports have been issued during the war.

(b) The type of joints for superheated steam mains varies with pressures and temperatures; for the higher ranges both face-to-face joints and also "gramophone" finish with $\frac{1}{64}''$ jointing have been very satisfactory. The author has not come across any cases of failure of alloy steel bolts.

(c) He has no direct experience with the use of "Exzit" powder as a soot-loosener.

(d) He has not come across valve troubles in the soot blowers he has fitted. "Air-puff" blowers have been fitted in a number of U.S.A. ships.

Finally, the author would like to express his thanks to all who so kindly contributed to the discussion on his paper and trusts that the publication thereof will be of material assistance to sea-going engineers who have to operate wateretube boilers.

ADDITIONS TO THE LIBRARY.

Purchased.

Publications of the United States Navy Department, Bureau of Ships.

Instructions for the Operation and Maintenance of Main Propelling Machinery. Chapter 41—Bureau of Ships Manual. Section II—Diesel Engines.

Instructions for the Operation and Maintenance of Reduction Gears. Chapter 42—Bureau of Ships Manual. Price 10 cents.

Propellers. Chapter 44—Bureau of Ships Manual. Price 10 cents.

Instructions for the Operation and Maintenance of Blowers. Chapter 53—Bureau of Ships Manual.

Instructions for the Operation and Maintenance of Distilling Plants. Chapter 58—Bureau of Ships Manual. Price 25 cents.

Instructions for the Operation and Maintenance of Refrigerating Plants. Chapter 59—Bureau of Ships Manual. Price 30 cents.

The above can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

Centrifugal Pumps and Blowers. By A. H. Church. Chapman & Hall, Ltd., London. John Wiley & Sons, Inc., New York. 1944. 304 pp. Illus. $4.50.

This book, primarily intended for young graduate engineers, deals with its subject in a straightforward manner as adequately as can be expected in 304 pages.

From the principles of fluid flow, the fundamental equations are developed and their inadequacy for design explained, a good deal of empirical data is given and the design of impellers, diffusers and other principle parts illustrated by specimen calculations.

Applications of pumps to various services and special features required for dredger, deep well, boiler feed and other duties are briefly explained.

For blowers, thermodynamic principles, regulation and constructional features, as well as critical speeds and disc stresses, are dealt with.

The book is written by an American professor for Americans, and British readers will find gallons equalling 8·341b. of water, some symbols differing from British Standard, 60 cycle speeds of motors and a very curt dismissal of the type of multi-stage pump most often used on this side of the Atlantic, as being "more expensive"—possibly owing to a confusion between the "ring" and the "barrel" type. However, the laws of nature are independent of national frontiers, and it is only on a few such matters of detail that mental adjustments will be necessary; in general the book can be cordially commended to those interested in its subject.

Presented by the Publishers.

The Modern Gas Turbine. By R. Tom Sawyer. Prentice-Hall, Inc., New York. 1945. 198 pp. Illus. 131 line drawings, halftones, blueprints, charts, graphs and tables. $4.00.

This book gives the most comprehensive account of the development of the gas turbine which has so far been published. The author, by virtue of his position as the Chairman of the Co-ordinating Committee on Gas Turbines of the A.S.M.E., has had unique opportunities of obtaining both data and advice from many engineers closely connected with modern developments in all fields.

The opening chapters deal adequately with fundamental and historical considerations, describing also the chief inventions and applications up to 1926. A chapter on the application of gas turbines for supercharging diesel engines is followed by a contribution by Mr. Ronald B. Smith of the Elliott Company, giving an excellent and concise description of the method of calculating the overall performance of gas turbines operating on several well known variations of the open cycle. This chapter will be particularly welcome to turbine engineers since the method employed is based on the evaluation of heat drop with the assumed values of component efficiencies and parasitic losses clearly stated.

Subsequent chapters deal comprehensively with industrial, marine and traction applications of the gas turbine, a special chapter being devoted to its use in connection with the supercharging of aircraft engines. The final chapter describes various applications of the gas turbine as a prime mover for aircraft propulsion including jet propulsion, and the estimation of engine performance characteristics required for that purpose.

The book is profusely illustrated with charts, diagrams and photographs, and is written in a clear easy style. The use of British units makes it particularly acceptable to British engineers, but its wide scope makes it a work of reference rather than a design manual.

It is unfortunate that war restrictions have prevented the inclusion of recent data regarding metallurgical advances, which alone have enabled the gas turbine to reach its present stage of development.

British Transport: A Study in Industrial Organisation and Control. By Ernest Davies. Issued by Fabian Publications Limited in conjunction with Victor Gollancz Limited. 25 pp. 5¼in.×8½in. Price 1s.

It is as well to record at the outset that there is very little direct marine interest in this brochure. Indirectly, however, it has a particular value, in that it is a statement on transport ownership issued before the present Government came into power. Like all publications of the Fabian Society, it represents only the view of the individual who prepared it, and not the collective view of the Society; the responsibility of the Fabian Society is limited to approving the publications which it issues as embodying facts and opinions worthy of consideration within the Labour Movement. The author summarises the pre-war inland transport position, and the wartime control of railways and road transport. The alleged failures of pre-war transport are considered, and methods for public control of both railway and road transport are outlined. The only references to coastwise shipping, docks, and harbours come under the somewhat misleading heading "The Future of Canals". A Coastwise Shipping Board is envisaged (on the same lines as the boards proposed for other forms of transport) but its acquisitions should be limited, in the view of the author, to those concerns engaged in purely domestic trade, whether liners or tramps.

Lubricating and Allied Oils. (Third edition revised). By Elliott A. Evans. Foreword by the late Viscount Wakefield of Hythe, G.C.V.O., LL.D. Chapman & Hall, Ltd., London. 1945. 202 pp. and index. 39 illus. 15s. net.

This book gives in small compass an up-to-date review of the industry behind lubrication and will be helpfully interesting to practical engineers because many problems are discussed from the standpoints of the chemist and physicist, but with a complete understanding of the necessity of a bridge between theory and practice.

The methods of solvent refining now in general use are dealt with in a manner to make them easily understood, and how clearly the benefits which have accrued thereby, especially for the higher classes of lubrication.

The chapter dealing with additives on which the author is an acknowledged authority will be especially welcome if only as an introduction to what will probably become the most exact branch of the science of lubrication in the future. This subsection is worthy of the most careful study by engineers who will appreciate that modern turbine oils and the lubricants for "high duty" Diesel engines (those exceeding 100lb./sq. in. B.M.E.P.) have achieved greater efficiency and a higher factor of safety by the precise addition of suitable compounds.

The modern methods of testing unused and used lubricating oils are described at length and will assist marine engineers in securing the maximum assistance from collaboration with their suppliers, who in turn will benefit from a better understanding on the part of their clients.

In the chapters dealing with the selection of lubricants and the oils employed for specific purposes, the author has not attempted for his readers the easy but frequently useless method of offering a set of specifications or formulæ, but has with considerable clarity exposed the scientific bases of the production of lubricants so that those responsible can work out their individual problems for themselves, or at least understand the processes of thought by which their suppliers arrive at their recommendations.

Altogether a useful addition to the Institute's library.

AUTUMN GOLF MEETING.

The first golf meeting since the summer of 1938 was held at Hadley Wood Golf Club on Wednesday, September 19th. The 22 members who participated enjoyed an excellent day's sport amid the delightful surroundings of the Course, and really fine weather added to the day's pleasure.

The programme consisted of a medal competition in the morning and a four-ball bogey competition in the afternoon. There were no prizes on this occasion; sweepstakes were arranged in connection with both competitions.

The morning round was won by Mr. H. O. Farmer with a net score of 75, Messrs. J. A. Rhynas and F. Sands tieing for second place with net scores of 78 each.

In the afternoon, Messrs. F. Sands and G. T. McIntyre secured first place by finishing 3 up, and Messrs. E. F. J. Baugh and Lt.-Col. H. Gordon-Luhrs gained the second place with 2 down.

The sweepstake moneys were presented to the winners by Mr. A. Robertson, C.C. (Convener of Social Events), during the tea interval. On the proposal of Lt.-Col. H. Gordon-Luhrs a hearty vote of thanks was accorded to Hadley Wood Golf Club and the Acting Secretary, Miss Carter, for their hospitality and the excellent arrangements which had been made for the meeting.

MEMBERSHIP ELECTIONS.

Date of Election, 2nd October, 1945.

Members.

Kerr Wilson Balfour.
Gordon Charles Boulter.
Samuel Hoole.
Robert McRory.
George Edward Holmes Snell.
Alexander Kenneth Sowter.
George Stell.
Arnold Lawrence Young, Lieut.(E.), R.N.R.

Associate Members.

Milburn Smith Crozier.
Thomas Maddison Pallas.
Arthur Harry Poole, Lieut., R.E.

Associates.

Henry Batey.
Alfred Nicholas Victor Beedle.
John Chapman.
James Robert Pierce Conolly.
John Sinton Elder.

Associates—continued.

Jack Evans, Sub-Lieut.(E.), R.N.R.
Charles Johnston.
Percy Lown.
Malcolm McIntyre McLeod.
John Delargy Neeson.
Robert Curle McKellar Reid.

Students.

Herbert John Rutter Middleton.
Subramaniam Thiruchelvam.

Transfer from Associate to Member.

Donald Fisher Ross.

Transfer from Associate to Associate Member.

Cedric Jennings Holyoake, Lieut.(E.), R.N.R.

Transfer from Graduate to Associate Member.

Kenneth Maddocks.

PERSONAL.

Mr. I. J. C. Aitken (Student) has gained the degree of B.Sc.(Hons.) in Engineering at London University.

Mr. Sterry B. Freeman, C.B.E., M.Eng. (Vice President) has been re-appointed as the Institution of Mechanical Engineers' representative on the Court of the University of Liverpool for the period ending December 31st, 1947.

Lieut.(E.) E. T. Irving, R.N. (Member) has been promoted to Lieut.-Com'r.(E.).

Mr. F. W. Luff (Member) was appointed a Member of the Order of the British Empire (M.B.E.) in the recent Birthday Honours.

Mr. John Nicol (Member) retired from the position of superintendent engineer of the fleets of the Shaw Savill & Albion Co., Ltd., and the Aberdeen Commonwealth Line on July 1st and was succeeded by Mr. R. K. Craig (Member). Mr. Nicol joined the Aberdeen Line in 1903; in 1912 he was appointed chief engineer and in 1918 became superintendent engineer. In 1928 the Aberdeen Line was amalgamated with the Shaw Savill & Albion Company and Mr. Nicol was appointed assistant to Mr. George Adams, superintendent engineer of the Shaw Savill Line, succeeding to that position in 1933 when Mr. Adams retired. Mr. R. K. Craig served during 1914-1918 as Engineer-Lieut., R.N.R., and joined Shaw Savill & Albion Company in 1919. He was appointed chief engineer in 1927, and assistant superintendent engineer in 1936.

Major G. I. Parry-Davies, R.E.M.E. (Member) has been released from H.M. Forces and has taken up an appointment as Chief Assistant Consulting Engineer to Norman D. Chisholm, Consulting Engineer and Engineers' Agent and Merchant, Liverpool.

Mr. E. W. Tanfield (Companion), general agent for Béliard Crighton & Co., Ltd., ship repairers, Antwerp, Ostend, Dunkerque and Havre, has re-established his office in London at Africa House, 44-46, Leadenhall Street, E.C.3.

Mr. A. J. Walker (Member) has terminated his association with the Vacuum Oil Company and has taken over the position of Technical Sales Manager of Kilfrost Manufacturing Company, Ltd.

Lieut.(E.) D. Turner, R.N.R. (Member) has been promoted to Lieut.-Com'r.(E.).

Mr. T. F. Collins, M.B.E. (Member), Chief Engineer M.v. *Tornus,* has received a "Commendation for gallant conduct at sea", announced in a recent issue of the "London Gazette".

Lieut. (E) R. H. Hales, R.N.R. (Member), has been promoted to Lieut.-Com'r. (E).

Lieut. Com'r. (E) H. S. Salt, R.C.N.R. (Member), resigned from Canadian Naval Service on June 18th, 1945, to take up an appointment as Dominion Government Steamship Inspector, and Examiner of Engineers at the Port of Midland, Ontario, Canada.

Mr. D. J. Walsh (Graduate), has taken up the post of Manager of the Bulk Oil Plant of the United Africa Co., Ltd, at Port Harcourt, Nigeria, West Africa.