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Automatic Combustion Controls for Marine Boilers

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The more widespread use of automatic controls for the regulation of the air and fuel supplies to a boiler being of fairly recent date in the British merchant service, this paper has been prepared with the object of providing a comprehensive survey of the subject for the use of marine engineers. Although details of control equipment and descriptions of typical recent installations which are included have had to be limited to the more commonly used systems, an attempt has been made to deal generally with the subject.

The possible advantages which may result from the use of automatic equipment are discussed in some detail and, although the reduction in fuel consumption compared with an efficiently run manually controlled installation may be small, it appears that other advantages might justify the wider adoption of such equipment.

Consideration is given to the principal elements of control systems, and the various ways in which they may be arranged are discussed. In view of the importance of the methods adopted for measuring and controlling the flow of air and fuel, separate sections are devoted to these points. The paper concludes by summarizing some of the main factors which might prevent the best use being made of combustion control equipment.

INTRODUCTION

In recent years an increasing interest has been shown by shipowners in methods of automatically controlling the operation of boilers, and it appears that with the tendency to widen the field of application of highly-rated watertube boilers there will probably be more widespread use of such equipment It was therefore felt by the British Shipbuilding Research Association that the time was ripe for an impartial review of the subject and this paper gives the results of a recent survey in which the possible advantages of automatic combustion controls and the various methods of control were examined.

Boiler controls employing varying degrees of automatic operation have been used for many years in land installations but the application of combustion control equipment to marine boilers is of comparatively recent origin. Development of such equipment has taken place mainly in the United States where large numbers of vessels built in wartime were fitted with automatic boiler controls. The use of automatic controls was also favoured in Germany, particularly in the case of naval boilers. Comparatively few British built ships in service are so equipped, but a considerable number, particularly tankers, now building in this country are being fitted with boiler combustion controls.

The limited use of combustion controls in this country is largely due to the fact that a high proportion of the merchant ship tonnage fitted with steam propelling machinery has Scotch boilers, operating at comparatively low steam pressures and temperatures. In moderately powered vessels with boiler installations of this type the advantages to be gained by the use of combustion control equipment are not so marked as in the case of watertube boilers working at higher pressures. The sensitivity of modern designs of watertube boilers to changes in load and variations in firing rate, particularly those with water-cooled furnace walls, is much greater and consequently it is probable that automatic controls will be used to the greatest extent in installations of this type.

Full automatic boiler control embraces equipment for the regulation of feed water and superheat temperature and, although steady operation of the fuel controls is affected by fluctuations in the water level, discussion of feed-control systems is not included in this paper since most combustion controls operate satisfactorily with the various types of feed regulators. Control of the steam temperature within close limits is also of great importance at the high superheat temperatures now frequently adopted but equipment for this purpose again may be considered independently of the combustion control system, which in itself goes a long way towards maintaining a comparatively stable superheat temperature.

Since stoker-fired coal-burning boilers have almost disappeared from the marine field, the application of control equipment to oil-burning installations only has been considered.

FACTORS INFLUENCING THE ADOPTION OF AUTOMATIC BOILER CONTROLS

Before dealing with details of the various control systems, it was considered desirable to examine the case for automatic control of marine boilers in general. In this section, therefore, an attempt has been made to assess the relative importance of the various advantages which may result from the use of combustion controls.

The performance of a manually controlled boiler from the point of view of efficiency of operation and cost of maintenance depends to a large extent upon the skill and experience of the operator. This, in effect, amounts to the ability to set the burners and air registers and oil fuel pressure and temperature for optimum combustion conditions, and to interpret changes from the initial condition, as indicated by the various gauges fitted, in terms of appropriate adjustments to the fans and oil burning equipment. The primary function of automatic combustion control is to relieve the operator of certain routine adjustments by substituting mechanical setting of the oil fuel and air supplies to the furnace in accordance with a signal set up by a change in the steam pressure. In the case of balanced-draught installations the furnace pressure is also maintained constant by automatic control of the induced draught. In addition to varying the rate of combustion with the steam demand, so as to avoid appreciable pressure fluctuations, the equipment is usually capable of maintaining a constant ratio of air to fuel which is initially set to give the best combustion conditions.

It will, therefore, be seen that from the aspect of maintaining efficient combustion, the operation of automatic controls is limited to the control of the air-fuel ratio. Although this is of great importance it must not be forgotten that in practice inefficient combustion can probably be more often attributed to incorrect adjustment of the position of the burners and setting of the air registers, together with poor atomization due to low oil temperature or pressure. With the heavier fuel oils now generally in use, these points are of particular importance and it it evident that, even when automatic controls are adopted, the satisfactory operation of a marine boiler depends on the vigilance of the engineers and firemen. It should also be pointed out at the outset that installations in which the normal pressure jet atomizers are used cannot be made fully automatic owing to the limited output range of these burners; to cover the full power range necessitates the manual cutting-out of burners or the substitution of smaller burner tips.

Accurate control of the fuel-air ratio can result in (a) saving in fuel; (b) reduction of smoke and sooting-up of the boiler; and (c) control of furnace temperature.

Dealing first with the question of fuel economy, there is little doubt that a saving in fuel could often be effected by more accurate apportioning of the fuel and combustion air to suit the particular boiler installation. The use of CO_2 recorders facilitates the setting of combustion air supplies but comparatively few vessels are fitted with such instruments; where they are fitted, only too often they do not receive the constant attention necessary to ensure satisfactory operation and cannot be relied upon for accuracy. It is possible, of course, to obtain highly efficient combustion by relying on the appearance of the flame, maintaining the lowest funnel gas temperature and avoiding making smoke but except under very steady steaming conditions it is unlikely that the excess air could be manually regulated to within such close limits as are possible by the use of automatic equipment.

Since a deficiency of air is readily detected by the formation of smoke, it is likely that too much excess air is a more common fault than not supplying sufficient for efficient combustion; in either case wastage of fuel results. It is, of course, impossible to state with certainty that appreciable fuel savings could be made in any particular case since manual methods of control may leave little margin for improvement, especially in the case of vessels which operate for comparatively long periods at full power. Moreover, in modern boiler installations having economizers or air heaters which reduce the funnel gas temperatures to very low values, the probable saving in fuel by reduction of excess air is not large. This is illustrated clearly by the curves shown in Fig. 1,* from which it will be seen that the possible gain in boiler efficiency by close control of the excess air decreases rapidly with reduction of the uptake temperature. Taking as an example an average modern boiler

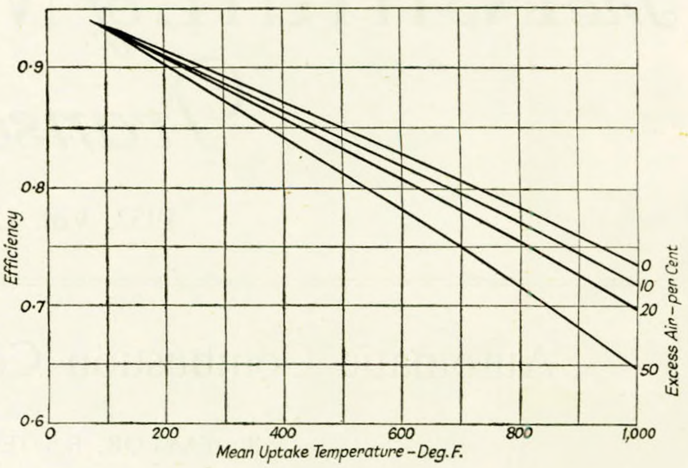

*FIG. 1—*Variation of calculated efficiency with excess air and uptake temperature for "standard" oil fuel (gross calorific value 18,500 B.Th.U./lb.)*

installation in which the funnel gas temperature is 350 deg. F. with an air inlet temperature of 100 deg. F., and supposing that by the use of automatic controls the average percentage CO_2 could be increased from 11 to 13, which is equivalent to a reduction in excess air from 40 to 20 per cent, the decrease in fuel consumption would be little more than 1 per cent.

Figures have been published claiming reductions in fuel consumption of 5 to 10 per cent[1] or more[2] but these must be treated with some reserve, since there are so many variables involved which can influence the results of tests carried out under normal sea-going conditions. Bailey and Dickey[3] give results of carefully conducted tests carried out on a turbine driven vessel of about 3,600 s.h.p. in which the fuel saving when using automatic, as compared with manual combustion control, varied from 0·7 to 3·1 per cent.

Incomplete combustion resulting in the formation of smoke also leads to sooting-up of the convection heating surfaces of the boiler. The reduction of this trouble has obvious advantages, not the least of which is the saving in water resulting from the less frequent use of sootblowers. Although the use of automatic controls, by ensuring an adequate supply of air to the furnace under variable steaming conditions, goes a long way towards preventing smoke emission, it is not the complete answer; incorrect adjustment of the oil burning equipment may be an equally common cause of such trouble.

The third point mentioned above, i.e. the control of furnace temperature, is of importance in connexion with the performance of the refractory lining of the combustion chamber. In any given boiler the peak furnace temperatures attained depend on a number of factors inherent in the design, discussion of which is beyond the scope of this paper, but, in general, an increase in the proportion of excess air supplied leads to a decrease of furnace temperature. With an all-refractory furnace the effective life of the brickwork may be considerably reduced at high furnace ratings and it is therefore desirable to

* Baker, L. 1950. "The Design of Marine Water-Tube Boilers". Charles Griffin and Co., Ltd. Diagram reproduced by permission of the publishers.

increase the air supply under such conditions. In certain modern boiler designs where the area of exposed refractory is greatly reduced by the use of water-walls, which also leads to a reduction in furnace temperatures, this point is not of such importance, however.

At reduced loads, excess air should be kept to a minimum to ensure sufficiently high furnace temperatures for complete combustion of the fuel. To allow for economical operation at all loads therefore calls for variation of the fuel-air ratio; this can be readily effected in most automatic control systems simply by the manipulation of a handwheel on the control panel, an indicator usually being provided to show the actual value at which the air to fuel ratio is being controlled.

A further advantage of close control of the combustion air is the avoidance of excessive steam temperatures which may result from a high proportion of excess air causing an increase in the heat flow to the superheater elements by convection.

The control of steam pressure within close limits of the desired value by automatic combustion controls may be considered as secondary to the maintenance of efficient combustion. By relieving the watchkeeper of the necessity of close attention to steam pressure, however, the adoption of automatic controls may result in more attention being given to the careful adjustment of the oil burning equipment, the lack of which is the cause of so much routine maintenance work.

It is, of course, impossible to prevent any fluctuation in the steam pressure, since the operation of the automatic controls depends on changes in pressure to indicate the variations in steam demand. The change in pressure required to actuate the controls need only be very small, however, and most systems are designed so that the pressure returns to the desired value after a change in load.

Summarizing the foregoing, it is apparent that the question of whether the advantages to be gained in any particular installation would justify the use of automatic controls must depend on the type of boiler and machinery installation and service of the vessel. It would appear that the best use could be made of such equipment in ships where the service entails much manœuvring, but it is in just such cases that automatic controls cannot be used to full advantage, unless wide-range burners capable of adjustment over the desired output range are fitted.

On the whole, it appears that automatic controls can offer definite benefits in certain applications but for satisfactory operation there are various factors which must be taken into account, some of which are discussed later in this paper.

AUTOMATIC CONTROL EQUIPMENT

The various elements which go to make up an automatic combustion control system can be conveniently divided into four groups, namely automatic controllers, relay equipment, transmission system and regulating units. Reliability and accuracy are the first requirements in any system and, particularly in marine service, the equipment must be sufficiently robust and simple to give trouble-free operation without frequent attention. It is probably for this reason that electrical control systems have not attained very great popularity for use on shipboard. Satisfactory functioning of the controls also depends on the controllers being adequately sensitive to the operating signals and, by ensuring a rate of change in the fuel and air supplies comparable with the speed of response of the boiler to changes in the steam demand, prevent hunting of the controls.

In this section the principles of operation of some of the main types of control instruments are summarized but it is obviously beyond the scope of this paper to give details of all the various types of equipment in use. Descriptions and diagrams to illustrate the operation of the equipment have therefore been limited to some of the principal elements of the two systems most widely used in this country.

Transmission System

For the transmission of signal impulses and operation of the regulating devices, hydraulic, pneumatic, or electrical means, or a combination of more than one of these may be employed. Each system has its advantages and disadvantages, but, for marine use, pneumatic controls are almost exclusively used.

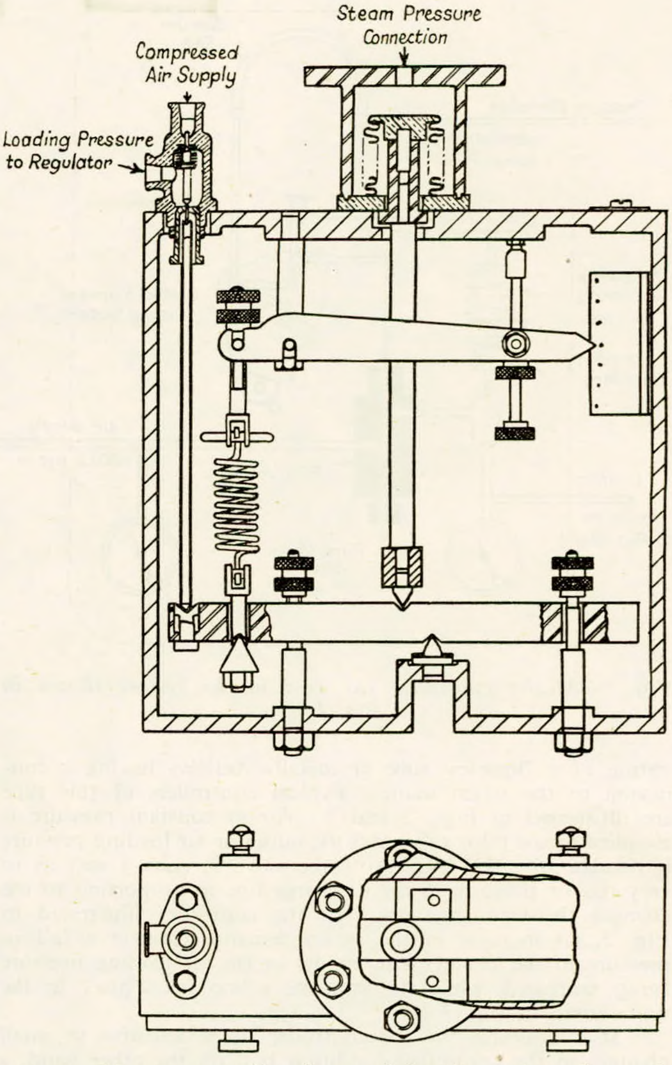

FIG. 2—*Master controller (as used in the system shown in Fig. 10)*

Automatic Controllers

An automatic controller may be defined* as a mechanism in which the value of a controlled condition is compared with a desired value and which operates in such a way as to reduce the deviation by imposing control action on a regulating unit. It comprises the measuring unit and the controlling unit.

Instruments included in most combustion control systems which may be described under this heading are master controllers and fuel and air flow controllers. The functions of more than one of these units may be carried out by one mechanism in some systems, however.

In pneumatically operated systems the function of the master controller is to convert steam pressure changes, resulting from changes in the steam demand, into equivalent air loading pressures for operation of the devices controlling the air and fuel supplies. This is usually accomplished by the movement of a compressed air control valve which is operated through a lever system by the pressure detecting element, con-

* The terms and definitions used are those recommended in British Standard 1523:1949 (Glossary of Terms used in Automatic Controlling and Regulating Systems).

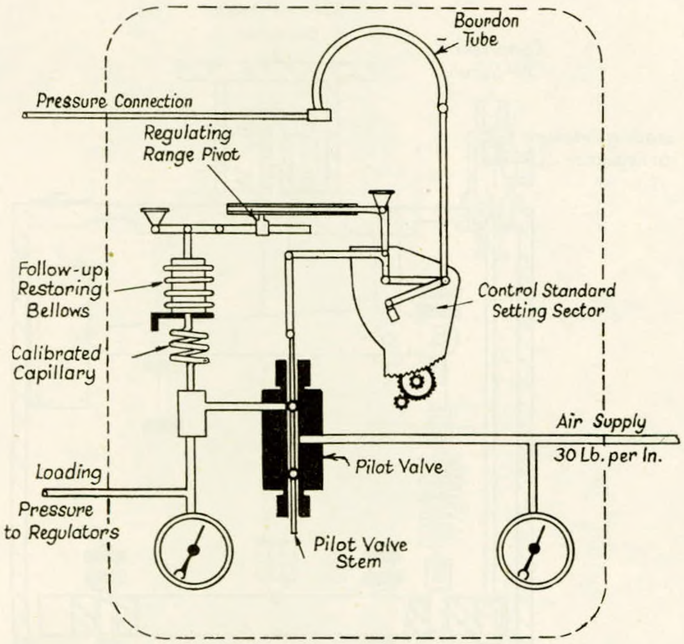

FIG. 3—*Master controller (as used in the system shown in Fig. 11)*

sisting of a Bourdon tube or metallic bellows having a connexion to the steam main. Typical controllers of this type are illustrated in Figs. 2 and 3. Air at constant pressure is supplied to the pilot valve and the outlet or air loading pressure is regulated by the opening of the valve in such a way as to vary the air pressure in the discharge line in proportion to the changes in steam pressure. In the controller illustrated in Fig. 2, an increase in the steam demand, causing a fall in pressure in the steam main, results in the air loading pressure being decreased, while the opposite action takes place in the unit shown in Fig. 3.

It is desirable for the controller to be sensitive to small changes in the controlled condition but, on the other hand, a highly sensitive system tends to over-correct with consequent hunting of the controls. In order to prevent hunting it is necessary to incorporate a stabilizing device to allow the mechanism to take up a position corresponding to the deviation of the steam pressure from the desired value. This is accomplished by applying a restoring force to the lever system by means of a spring or pressure loading device as shown in the controllers illustrated in Figs. 2 and 3. Means are provided for varying the magnitude of the restoring force so that the regulating range or sensitivity of the controller can be altered.

Master controllers of this type provide a stable form of control but have the disadvantage that the steam pressure can only be controlled at the desired value when the boiler is operating at the normal load for which the system is set. At lower rates of steam flow the pressure is controlled at a slightly higher value than normal and *vice versa,* this being due to the fact that each position of the air pilot value of the master controller, and hence the corresponding setting of the fuel and air regulators, is associated with a definite steam pressure. This tendency may be counteracted and control established at the desired steam pressure for any load, by the addition of a resetting device which usually takes the form of an air relay mechanism.

In the automatic control systems generally used in marine service, measurement of the flow of fuel and air to the boiler is carried out by the fuel-air ratio controller which incorporates means for balancing these quantities in the required proportion. The measurement of flow is by pressure sensitive diaphragms or metallic bellows, arranged so that the forces due to the metering pressures oppose each other, the position of equilibrium being when the air and fuel supplies are in the required ratio to each other. Details of design vary considerably but the function of all fuel-air ratio controllers used in pneumatically operated systems is to set up a loading pressure which re-adjusts or sets the regulator governing the air or fuel flow, according to the system, to maintain efficient combustion.

Fig. 4 illustrates the principle of operation of the fuel-air ratio controller used in conjunction with the master controller shown in Fig. 3. It will be seen that if the loads applied by the fuel and air flow measuring units are not in equilibrium, due to a variation in the fuel-air ratio, the instrument becomes unbalanced, causing a movement of the air pilot valve through a system of levers similar to that employed in the master controller. This results in a change in the air loading pressure set up by the controller, which makes the necessary re-adjustments to maintain the desired excess air.

The normal method of adjustment is by means of a handwheel by which the setting of the controller may be modified to make allowance for the number and size of burners in use, etc. A scale is provided which is calibrated *in situ.*

Relay Equipment

Relays are used in most automatic boiler control systems either to supplement or amplify the signal set up by the controller for operating the regulator, by employing energy from another source.

The principle of operation is similar to that of the relay elements of the controllers, namely the magnitude of the air loading pressure sent out from the relay is determined by the setting of an air pilot valve or valves, which control the pressure of air in a chamber by opening or closing ports connected to the compressed-air supply line or atmosphere. It is usual for the pilot valve to be actuated by a spindle which is loaded by a combination of diaphragms and springs by which the required action may be obtained. Thus, if the air loading pressure from a controller acts on a diaphragm

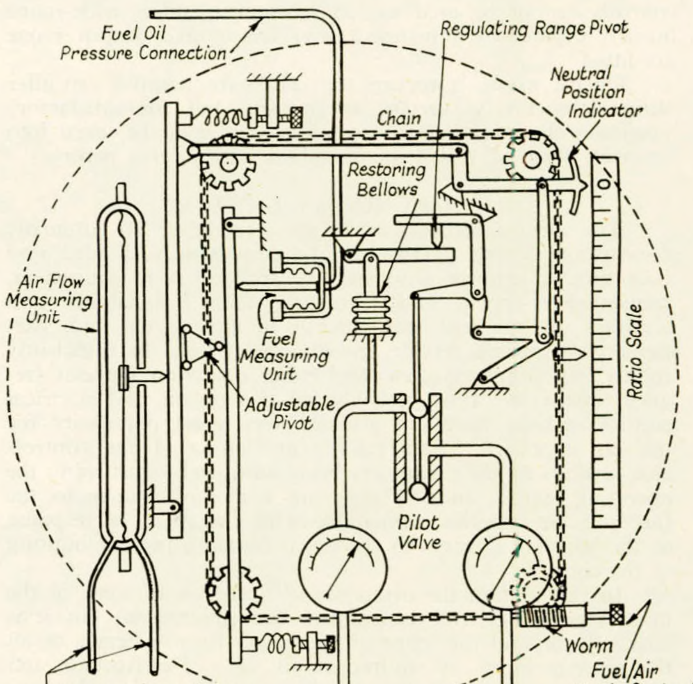

FIG. 4—*Fuel-air ratio controller*

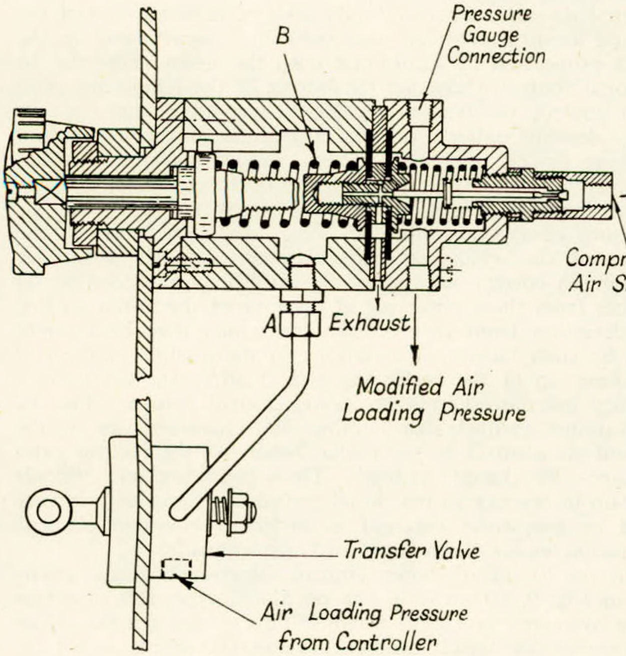

FIG. 5—*Adjustable air relay*

which is also loaded by a spring, as in the relay shown in Fig. 5, the final loading pressure set up by the unit is equal to the initial loading pressure plus a constant value, either negative or positive, determined by the setting of the adjustable spring load. In this way the settings of a number of regulators operated by one master controller may be individually adjusted.

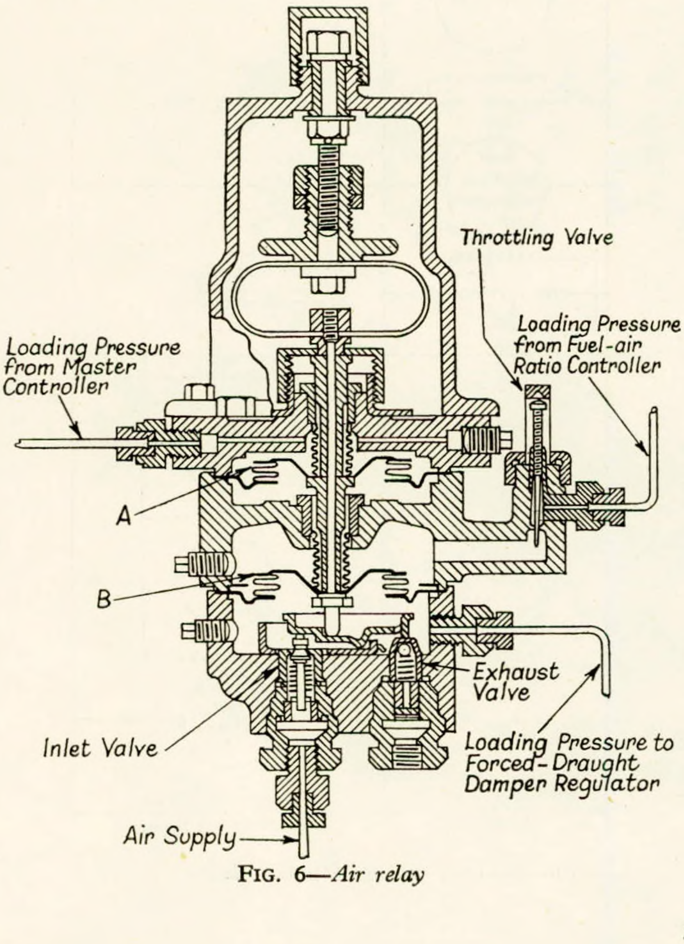

FIG. 6—*Air relay*

Other relays of the type illustrated in Fig. 6 are used to produce a loading pressure equal to the sum of the signal pressures set up by two controllers acting on separate diaphragms in spaces A and B respectively.

In addition to allowing modification of the loading pressures to the various regulating units when operating on automatic control, relays of the type shown in Fig. 5 are used for remote manual control by hand adjustment of the setting of the air pilot valves. Thus, when the transfer valve is set for manual operation, the incoming loading pressure no longer passes through to the relay chamber and connexion A (Fig. 5) is opened to the atmosphere. The pressure sent out by the relay and hence the setting of the air and fuel regulators then depends

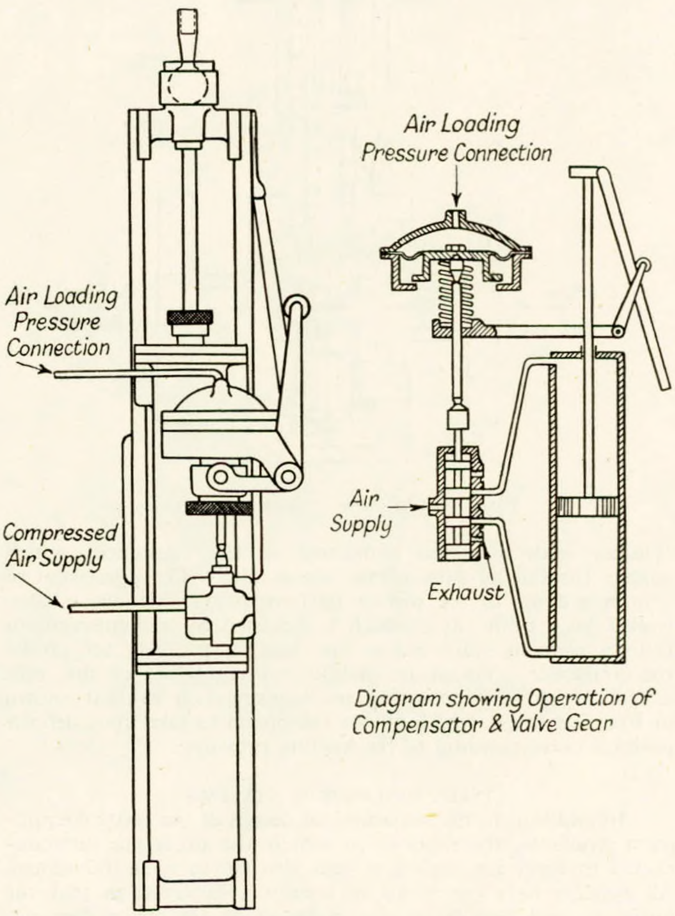

FIG. 7—*Cylinder type regulator*

entirely on the compression of the loading spring B.

Air relays are also used in some systems to modify the speed of control and can be employed to establish control at a constant steam pressure.

Regulating Units

A regulating unit may be defined as the unit comprising those elements which adjust the physical quantity on which the controlled condition depends.

For controls requiring a comparatively large movement such as dampers, speed control rheostats, etc., air operated power cylinders similar to that illustrated in Fig. 7 are normally employed. In certain other applications such as the adjustment of fuel control valves, diaphragms or metallic bellows which have a comparatively small range of movement may be used. An oil-fuel regulating valve designed to maintain a pressure at the burners proportional to the loading pressure applied to the diaphragm is shown in Fig. 8.

Cylinder type regulating units simply consist of a power

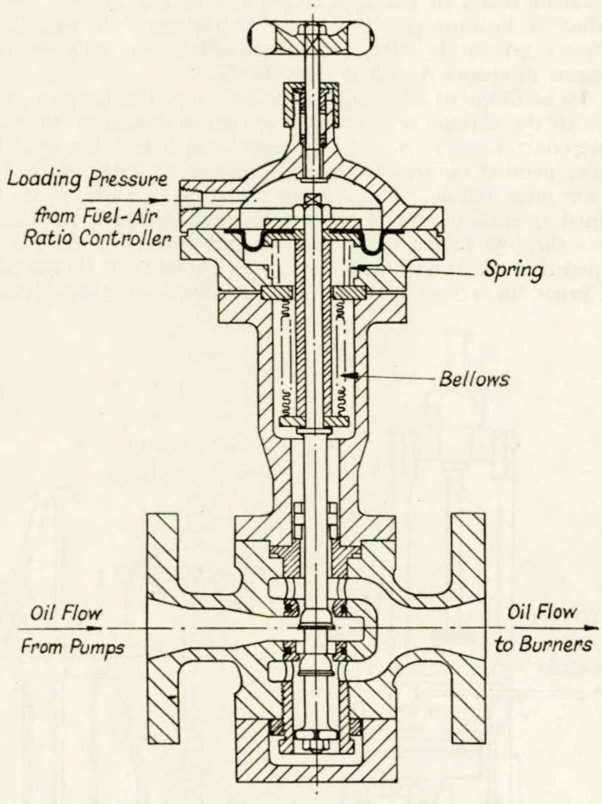

FIG. 8—*Oil flow regulating valve*

cylinder with a piston connected to the equipment which adjusts the rate of flow of the air or fuel. The admission of compressed air to the top or bottom of the cylinder is controlled by a pilot valve which is actuated by a diaphragm or bellows element subjected to the loading pressure set up by the controller. To ensure stability of regulators of this type a "follow-up" compensating mechanism such as that shown in Fig. 7 is fitted, which allows the piston to take up a definite position corresponding to the loading pressure.

TYPES OF CONTROL SYSTEMS

In addition to the variations in design of the control equipment available, the manner in which the units are interconnected to form a complete system also shows wide differences. All systems have one point in common, however, in that the initial control impulse is always based on the steam demand. In order that a change in the steam demand may be detected and the necessary corrections made before the steam pressure has altered greatly from the desired value, it is the usual practice to take the pressure connexion for the master controller from the main steam line, preferably some distance from the boiler. In this way the control apparatus is made sensitive to changes in the rate of steam flow in addition to variations in the boiler drum pressure, since the pressure drop through the superheater or along the steam main varies approximately as the square of the steam flow. A steam flow meter may, of course, be used to measure the steam demand and in certain cases, particularly coal burning installations, this method is used, since the quantity of steam produced, measured by the flow meter, may be taken as a measure of the effective fuel supplied to the boiler. In this way the difficulty of measuring the rate of fuel input in such cases is overcome.

All automatic combustion controls can be broadly divided into two groups, namely positional control and metered control systems. The fundamental difference between the two principles is that positional controls adjust the fuel and air flow regulators to predetermined settings corresponding to the measured demand, whereas in the case of metered control the fuel and air flow rates are measured and co-ordinated in the correct proportion in accordance with the steam demand. In positional control, therefore, the setting of the regulating units which control the dampers, valves, or speed of the fans or pumps depends entirely on the magnitude of the impulse or signal set up by the steam pressure measuring unit. It has the advantage of simplicity and lower cost but cannot guarantee the maintenance of the ratio between air and fuel for maximum combustion efficiency over long periods, since the settings of the regulating units in relation to the controller only remain correct as long as the conditions of operation do not alter from those obtaining at the time of the initial setting. Any deviation from these conditions which may be brought about by such factors as variations in the quality of the fuel or sooting up of the boiler passes will affect the combustion efficiency maintained by a positional control system. The use of positional control also requires the characteristics of the fuel and air controls to be similar, otherwise the fuel-air ratio will vary with changes in load. These conditions are difficult to obtain in practice so that in all probability hand adjustments would be frequently required in order to maintain efficient combustion under fluctuating load conditions.

In the "Unified" boiler control, illustrated diagrammatically in Fig. 9, which is of the positional type, this objection can be overcome to a large extent. This system consists of an arrangement for simultaneously varying the speeds of all the boiler auxiliary motors through a centralized control. The Ward-Leonard system of speed control is employed, in which the d.c. motors of the fans and fuel pumps are supplied with a variable voltage current by means of a buck and boost

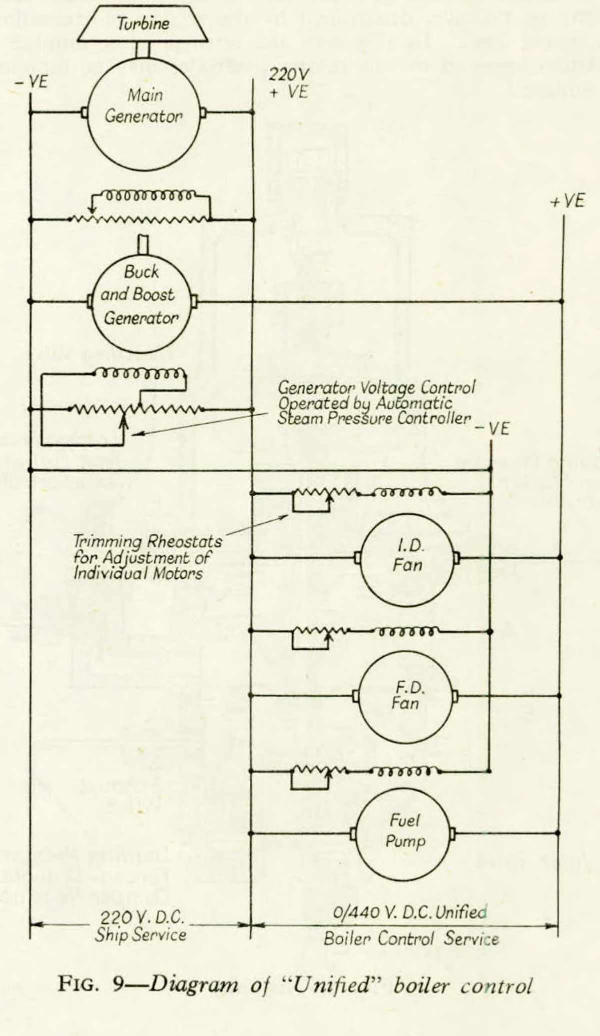

FIG. 9—*Diagram of "Unified" boiler control*

generator with reversible field, in series with the main generator. The most economical arrangement is for this generator to be driven from the main generator set. Regulation of the generator voltage is effected by automatic adjustment of the field rheostat by a master controller and regulator operated by the steam pressure. On a change in steam demand, the setting of the generator field rheostat is automatically adjusted in proportion to the deviation of the pressure from the desired value. This causes a corresponding change in the voltage of the d.c. supply to the armatures of the auxiliary motors, which have a constant field strength, and consequently a change in the rate of fuel and air supplies is brought about by the change in speed of the motors. By suitable design of the auxiliary-motor windings, it is possible to give each motor a speed-load characteristic to avoid variation of the fuel-air ratio with changes in boiler load. To allow for alteration of the fuel-air ratio or for changes in the operating conditions, hand-operated trimming rheostats for regulation of the current supplied to the separately excited field windings of the individual auxiliary motors are fitted.

Metered control systems do not suffer from the disadvantages of normal positional controls, since adjustments are automatically made to the fuel and air supplies until the desired conditions are actually obtained, the accuracy being limited only by that of the measuring and regulating units.

For maintaining the combustion rate there is little to choose between the two systems but, from the point of view of efficiency, metered control is to be preferred. In certain vessels, however, the additional complication and greater cost of metered controls may not be justifiable and in such cases simple positional control, even with its disadvantages, may find application. It would also appear that where the boiler installation is comparatively simple, and the function of the automatic equipment is to control the boilers under relatively steady steaming conditions, positional controls would be satisfactory provided that the setting of the regulators could be checked at fairly frequent intervals to maintain efficient combustion.

Automatic control systems may also be classified according to load control characteristics as falling pressure or constant pressure systems. Falling pressure systems have the advantage of being somewhat simpler and, as the name implies, controls of this type operate over a predetermined pressure range, the maximum steam pressure occurring at the lowest load, with each pressure value corresponding to a particular combustion rate. This results in the boiler pressure being controlled at a slightly lower value when the steam demand is above normal and *vice versa*. In the majority of cases, however, this is not a serious objection.

Constant pressure systems must allow a small initial drop in pressure on increase in the steam requirements, since the method of indicating change in load by a drop in pressure in the steam main is common to both systems. The control apparatus is so designed in constant pressure systems, however, that continuous adjustments are made in the firing rate until the pressure returns to its correct value again.

Most of the automatic controls used in marine work are of the metering type; such systems may be subdivided into two further groups, usually known as series and parallel systems. These are defined by the sequence with which the air and fuel controls are adjusted.

In both systems the basic principle of operation is the same in that the master controller delivers a signal, the magnitude of which may be modified by a relay, to the regulating

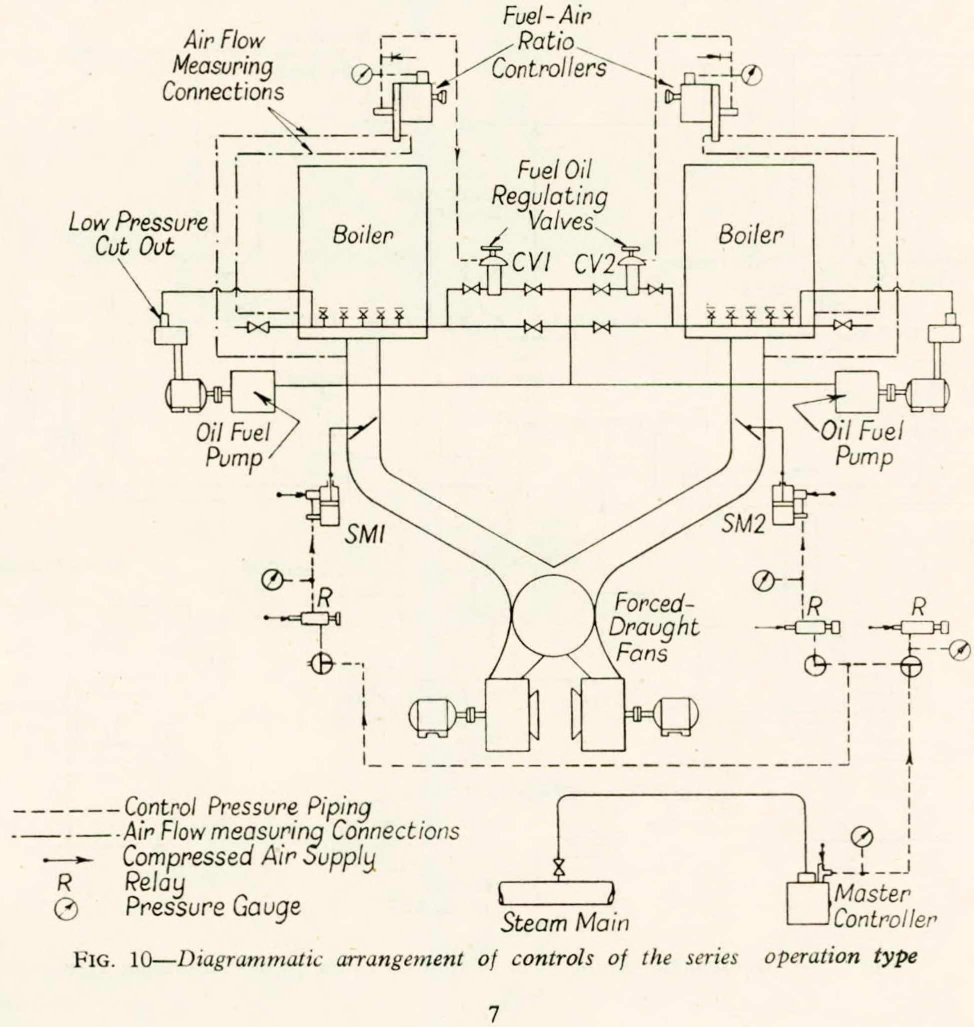

FIG. 10—*Diagrammatic arrangement of controls of the series operation type*

units controlling the dampers, valves, rheostats, etc. The units controlling both the fuel feed and air flow are modified simultaneously in the parallel system, in accordance with the signal received from the master controller. In order to ensure correct combustion conditions the fuel-air ratio controller makes any necessary re-adjustments to the fuel or air flow, depending on the arrangement of the system, to suit the measured value of the air or fuel supply. In the series system, on the other hand, the signal from the master controller actuates either the air flow regulator unit or the oil fuel supply regulator. The resulting change in flow is measured by the fuel-air ratio unit which transmits a correcting signal to the regulator controlling the other controlled condition. Control of the furnace pressure, which is an additional controllable variable in balanced draught installations, is usually effected by equipment independent of the fuel and air controls and is designed to maintain the required negative pressure in the combustion chamber by control of a damper or speed of the induced draught fan.

The normal arrangement in multi-boiler installations is for one master controller to be fitted to control the output of all the boilers, the distribution of load between the units being adjustable by means of relays in the signal pressure transmission lines. A separate fuel-air ratio controller is used for each boiler.

Series Control

In systems of this type, as pointed out above, the controls may be arranged to operate in two ways:—

(a) Air flow regulator actuated by change in steam pressure. Fuel supply determined by metered air flow and controlled by fuel-air ratio controller, or

(b) fuel supply regulator actuated by change in steam pressure. Air supply determined by measured oil flow and controlled by fuel-air ratio controller.

A typical system of type (a) is illustrated in Fig. 10. This shows the arrangement of controls recently fitted on a tanker having two La Mont boilers with all-electric auxiliaries. Compressed air at a pressure of 50lb. per sq. in. provides the motive power for the various elements of the system. Briefly, the operation of the equipment is as follows:—

On an increase in the steam demand causing a fall in pressure in the steam main, the master controller, of the type illustrated in Fig. 2, decreases the air loading pressure sent out to the regulating units SM1 and SM2, which actuate the dampers in the air-supply trunks. In this way the supply of air to the boilers is increased in proportion to the steam demand. The increased air flow causes a change in the differential air pressures between the boiler air casings and the combustion chambers, which act on the diaphragms of the fuel-air ratio controllers. These units, being unbalanced by the increased draught pressures, alter the air loading pressures sent out to the fuel regulating valves CV1 and CV2, thus increasing the oil pressure at the burners. Since these valves, which are of the type shown in Fig. 8, are designed so that the fuel pressure bears a definite relationship to the air loading pressure, movement of the valve takes place until the oil flow is proportional to this loading pressure. By adjusting the loading pressure to maintain the required ratio with the pressure applied to the air flow measuring diaphragm, the fuel-air ratio regulator therefore increases the oil flow while at the same time maintaining efficient combustion conditions.

On an increase in the steam pressure the reverse actions take place.

To allow for differences in draught loss through the boilers and for setting the regulators, relays of the design illustrated in Fig. 5 are fitted in the loading pressure lines from the master controller to the air flow regulators, as shown in Fig. 10.

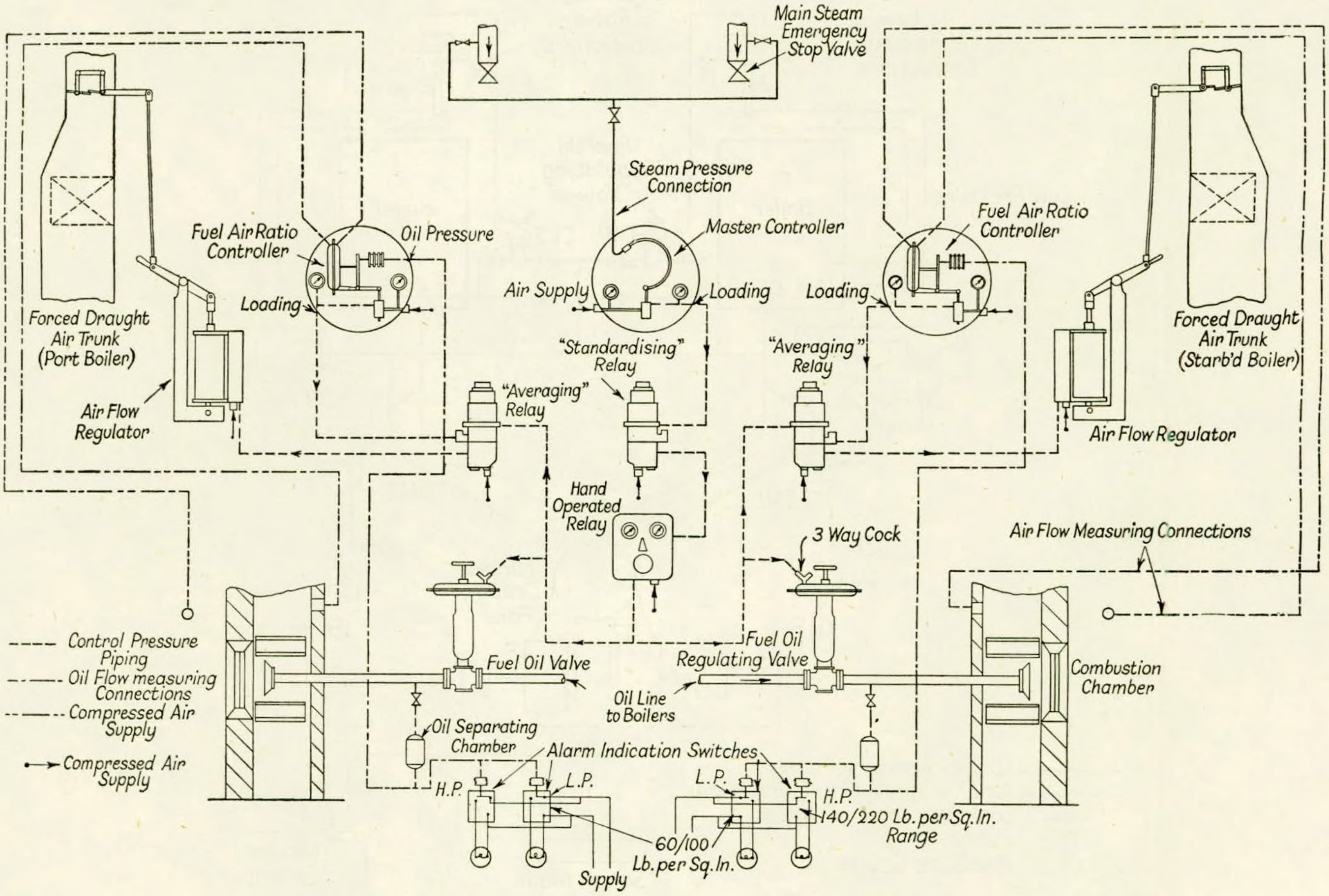

FIG. 11—*Diagrammatic arrangement of controls of the parallel operation type*

These relays also enable the controls to be operated manually from the boiler-control panel by cutting-out the master controller by means of the transfer valves.

To prevent the oil pressure being controlled at too low a value, a pressure loaded switch is fitted to each oil-fuel pump motor in this particular installation so that in the event of a sudden reduction in load the pump motors are shut down.

Parallel Control

In this system, although the rates of fuel and air flow are modified simultaneously, differences in the characteristics of the controls may necessitate some further re-adjustment to maintain the correct ratio of air to fuel. The controls may therefore be arranged in two ways, as follows: —

(c) Fuel and air adjusted simultaneously. Re-adjustment of air flow, as necessary, by fuel-air ratio controller.

(d) Fuel and air adjusted simultaneously. Re-adjustment of oil flow, as necessary, by fuel-air ratio controller.

Controls of this type used in marine work usually employ the principles of operation of system (c), a typical installation being illustrated diagrammatically in Fig. 11. This particular arrangement was adopted in a number of recently built passenger and refrigerated cargo liners, each fitted with two Babcock and Wilcox single pass header boilers. Compressed air is again used as the operating medium.

In the layout illustrated, the master controller, of the type shown in Fig. 3, is supplied with compressed air at a pressure of 30lb. per sq. in. and establishes an air loading pressure determined by the position of the pilot valve which is actuated by the Bourdon tube connected to the steam main. The magnitude of the air-loading pressure, which varies inversely as the steam pressure through a range of 5 to 25lb. per sq. in., determines the setting of the oil-fuel regulating valve and the forced-draught fan damper. Air flow measuring connexions to determine the draught loss through the burner registers and an oil-fuel pressure connexion are led to the fuel-air ratio controller which is illustrated in the previous section (Fig. 4). This unit superimposes a loading pressure on that established by the master controller, through an "averaging" relay (shown in Fig. 6) in the control air line to the forced-draught damper regulator. In this way the loading pressure controlling the setting of the air-flow regulator is modified, if required, in order to maintain the correct ratio of air to fuel.

It will be noted that a relay device is fitted in the air-loading line from the master controller, the function of which is to introduce a re-setting form of control in order to maintain a substantially constant steam pressure regardless of the load on the boiler. A hand-operated air relay with a transfer valve is also fitted to enable the setting of the regulators to be adjusted and allow for manual operation of the controls.

A simple arrangement of indicator lamps is also provided which shows when the pressure of oil to the burners reaches the limits of operation for the particular sizes of burners in use.

The arrangements of the controls used in the two installations described above are commonly adopted, but the details are subject to considerable variation depending on the number and type of boilers, number of auxiliaries and methods of air and oil flow control.

Since the fuel is burned in suspension, oil burning is very sensitive to changes in the rate of air or fuel supply and therefore, in theory, the parallel system in which the re-adjustment of both fuel and air is simultaneous would appear to be preferable where frequent load changes occur. In series controlled systems in which the fuel-air ratio controller actuates the oil supply regulator (type (a)), there is a temporary increase in excess air when the steam demand is increasing since re-adjustment of the fuel lags behind the air flow. Similarly, a temporary decrease in the excess air occurs during reduction in the boiler load. If, as in system (b), the air supply is controlled by the ratio controller, however, the reverse will apply. It is doubtful whether the parallel control system is much better in this respect, since in order that the correct proportion of air to fuel may be maintained during changes in load it would be necessary for the flow-characteristic curves of the air and fuel supply regulators to be similar. If these conditions do not obtain in practice, deviation from the desired fuel-air ratio will occur initially on a change in setting of the controls. Since the oil flow characteristics vary with the number of burners in operation and the sizes of burner tips being used and the air flow characteristic varies for different fan speeds, it is quite likely that the correction required to be made by the fuel-air ratio controller in a parallel control system may be as great as that required when the rates of oil and air flow are not altered simultaneously. From this point of view it therefore appears that there is little to choose between the various arrangements.

The question of whether the oil or air flow should be modified directly by the master controller in the series system, or whether the controlled condition re-adjusted by the ratio controller in the parallel system is the air supply or fuel, is of importance from an operational safety aspect. It will be seen that if the fuel supply depends on the air flow, as in systems (a) and (d), there is no chance of an excess of oil being supplied to the furnace in the event of a failure in the air supply. The only effect would be a fall in the boiler pressure and the possibility of an explosion occurring is obviated. If, on the other hand, the primary control is to the fuel supply, the flow of oil to the furnace would continue if the air flow were cut down unless some safety device is incorporated which would stop the fuel pumps in an emergency of this nature.

The dependence of the oil supply on the air flow has one disadvantage in that the accurate measurement of the small differential air pressures, by which the air flow is metered, presents considerable difficulty at low ratings. There is therefore a minimum load below which automatic regulation cannot be applied satisfactorily. This difficulty in measuring very low values of air flow is also encountered in those systems in which the oil supply is directly controlled. In this case it is usually arranged for the damper or fan speed control to have a stop, determined by the safe minimum air flow, below which only the fuel supply is varied.

In view of the importance of the methods adopted for measuring and regulating the flow of air and fuel, further consideration is given to these matters in the following sections.

MEASUREMENT AND CONTROL OF AIR FLOW

Since the flow of air through a boiler, for a given pressure head at the fan, depends on the resistance of the air supply system, boiler tube banks, air heaters, etc., the flow for any particular damper setting or fan speed is not constant owing to the variation in resistance caused by deposits on the heating surfaces. For accurate control of the fuel-air ratio it therefore becomes necessary to introduce some form of flow measuring apparatus.

The most convenient method of obtaining an indication of the flow of air is to measure the pressure drop across a section of the system, the velocity being proportional to a function of the differential pressure. Connexions may be made to measure the drop in pressure across a section of the boiler or through the burner registers; alternatively, an orifice plate or venturi throat could be fitted in the air supply trunking. The method of measuring the pressure drop across a section of the boiler has the advantage that the total gas flow is measured, i.e. casing leakage is taken into account, but the available pressure drop in most marine boilers precludes accurate metering. Other disadvantages are that the density of the gases does not remain constant owing to furnace temperature variations, and the draught loss for any given gas flow is liable to differ from the calibrating conditions due to sooting-up of the tube surfaces.

To overcome these objections, the method most commonly adopted is to measure the pressure drop through the registers, pressure tappings being taken from the boiler front air casing and the combustion chamber, as in the two systems illustrated in Figs. 10 and 11. Arrangements of this type have the great advantage that adjustment of the fuel-air ratio controller should not be necessary when the number of burners in operation is altered, provided that the fuel flow is indicated by the oil pressure at the burners. This follows from the fact that the required ratio of oil pressure to air pressure remains substantially constant regardless of the number of burners in operation.

This method takes advantage of the comparatively large pressure drop through the registers and allows automatic control to be used even if the steaming rate is reduced to the point where only one or two burners are required. Arrangements for shutting off the air supply to a burner when the sprayer is cut-out are not usually wholly effective, however; errors may therefore result from air leakage through closed air deflectors and in practice it is often necessary to make slight trimming adjustments to the fuel-air ratio controller to maintain the desired excess air when changing the number of burners. Since the brick tubes are, in effect, being used as measuring orifices the accuracy is affected by wastage of the quarls; another possible source of error is variation in the temperature of the air supply and also, in installations having balanced draught or closed stokehold forced draught, there is invariably some leakage of air through the boiler casings. Nevertheless, it would appear that the advantages of this method of air flow measurement outweigh the disadvantages.

In some cases the pressure tapping from the combustion chamber is omitted, the pressure in the boiler air casing being taken as a measure of the air flow. Although the possibility of stoppage of the furnace pressure measuring connexion is eliminated, this arrangement, in effect, only indicates the total pressure drop through the boiler and uptakes; it therefore suffers from the disadvantage of inaccuracy due to changes in resistance through the tube banks.

Probably the most accurate method of measuring air flow is by the use of an orifice plate or venturi meter in the air supply system. This method has not been used to any great extent in marine installations, however, since it is necessary for a venturi meter to be inserted in a straight section of trunking of considerable length to obtain accurate results. There is also the objection that an orifice plate introduces additional resistance and difficulties arise at low steaming rates owing to the small pressure differences obtained. Unless a similar method was also used for the measurement of oil flow, re-adjustment of the fuel-air ratio controller would be necessary on changing the number of burners in operation. It therefore appears that although the normal method of air flow measurement by the differential pressure across the registers is not the most accurate that could be used, the practical difficulties arising from the adoption of alternative methods would outweigh their advantages.

Regulation of the rate of flow may be accomplished by dampers in the forced draught fan discharge ducts, by alteration of the fan speed or by a combination of these two methods.

For any given fan speed the volume of air delivered depends on the pressure head in the discharge trunking, which in turn depends on the resistance of the system. Control of air flow by damper amounts to regulation of the resistance and therefore by introducing additional resistance in the air passages, in order to limit the air flow to the required value, the fan power is increased. In view of the fact that the power required to drive the fans accounts for a high proportion of the boiler auxiliary plant load, this may be a factor of some importance in certain types of installations such as those in which the fans are driven by constant speed motors or where the boilers may be operated for considerable periods at reduced loads.

Regulation of the air supply by the normal type of single leaf damper has a second disadvantage in that the flow characteristic is not a straight line, the effect of any particular angular movement depending on the amount the damper is open. A greater movement is required when the damper is open than when it is nearly closed to obtain a similar change in air flow. This tends to cause sluggishness in response when operating at loads approaching full power. Improvements may be effected in this connexion by restricting the movement of the damper to less than 90 deg., so that when closed the damper is inclined to the axis of the trunking.

Control of the air flow by variation in fan speed reduces the loss of power incurred by the use of dampers but in order to operate a multi-boiler installation by fan speed alone it would be necessary to have a separate fan for each boiler owing to the variation in resistance from one boiler to another. The application of fan speed control is also limited by the fact that the speed of the motor would need to be infinitely variable; if speed variation is made in steps, hunting between two consecutive speeds is likely to occur when the required fan output is not obtained exactly at one of the controlled speeds. Fan speed regulation alone also has the disadvantage that the speed of response to changes in demand is not so rapid as with damper control, owing to the rotational inertia of the fan.

For marine applications the combination of fan speed and damper control appears to be the best arrangement since the advantages of both systems can be utilized. There are various ways in which a system of this nature can be arranged: for example, the dampers could be arranged normally to occupy a position giving practically maximum flow so that on a demand for a change in the air supply, initial adjustment would be made by movement of the dampers, followed by a change in the fan speed. The dampers would then return to their initial position, which would allow for further opening on an increase in load. Rapid adjustment in the rate of air supply could therefore be made without the loss of fan power which would occur if dampers alone were used. In some multi-boiler installations, primary control of the air flow is carried out by adjustment of the fan speed and the distribution of air to the individual boilers is effected by dampers. Parallel type control systems may also employ combined damper and fan speed air control, the fan speed being adjusted at the same time as the oil flow by the master controller, final adjustment by the damper being controlled by the fuel-air ratio controller.

With the possibility of a wider use being made of alternating current on shipboard, methods of controlling the air delivered by constant speed fans may become of importance, since the a.c. motor is essentially a constant speed machine. In such cases a method often used in land installations may be adopted in which the air flow is regulated by adjustable radial vanes fitted in the fan inlet. By alteration of the angle of these vanes, which impart a swirl to the air before entering the impeller, the output of the fan can be modified at constant speed without affecting the resistance of the system. The fan can therefore be operated more efficiently than in the case of damper control.

MEASUREMENT AND CONTROL OF FUEL

Manual regulation of the fuel supply in oil fired marine boilers is normally accomplished by control of the pressure of the oil supplied to the burners. Primary control by means of the speed of the oil fuel pump is usual whilst close regulation is effected by the adjustment of a valve in the oil line. Both these methods can be adapted to automatic control but it is not usual to install equipment for both valve regulation and pump speed control, either one or the other being used. Automatic adjustment of the opening of a valve in the oil supply line is the more common method, the valve being actuated by an air loaded diaphragm or power cylinder.

The same difficulties arise with regard to speed control of oil pumps as in the case of fan speed regulation, which was considered in the preceding section. This method, however, may have the advantage of economy in power. Since a secondary control is not normally fitted as is sometimes the case in the control of air flow, it becomes more necessary for the speed of the pump to be controllable within close limits in order to avoid hunting.

Measurement of oil flow does not present such great difficulty as the determination of the air supply and the usual practice is merely to take a pressure connexion from the oil line supplying the burners, thus utilizing the sprayer tips as measuring orifices. As already mentioned, this is a very convenient arrangement when the air flow is measured by the pressure drop through the registers and should give accurate control providing that the temperature of the oil is maintained within close limits. With other methods of air flow metering it may be more convenient to measure the oil flow by means of an orifice plate in the supply line, the pressure drop across which would be approximately proportional to the square of the oil flow. The degree of accuracy obtainable by this method is not likely to be much greater than that of the normal system, however, unless some wear takes place in the burner tip orifices.

FACTORS AFFECTING FUNCTIONING OF THE CONTROLS

Even though controls may be fitted which are entirely satisfactory for the service required, the efficient operation of an automatically controlled boiler depends on a number of other factors, neglect of which may prevent the best use being made of the control equipment.

A point which cannot be overstressed is the necessity for close co-operation between the designers of the boilers and auxiliaries and the manufacturers of the automatic control gear. Serious limitations may be placed upon the operation of the control equipment by lack of appreciation of the requirements for satisfactory functioning of the automatic controls. As an example of this, the case may be mentioned of a recent vessel in which trouble was experienced due to the speed range of the electrically-driven oil pumps being insufficient to cope with the reduced output required on cutting down the number of burners.

Boilers having a low water storage capacity and a high proportion of radiant heating surface have a much more rapid rate of response to changes in the firing rate than those having refractory walls and large water drums, regardless of the details of the control equipment used. It follows that for efficient operation of the controls, their action must be more rapid and precise the more quickly the boiler responds to changes in the steaming rate. The methods to be adopted for control of the fuel and air should therefore be chosen with this in mind.

Any gain in economy of an installation obviously depends on the initial setting of the fuel-air ratio controllers; this should be done by determining the optimum conditions for various steaming rates by analysis of the funnel gases, while at the same time maintaining the desired furnace temperatures. The routine use of an Orsat apparatus is hardly practicable, however, so to give an indication of any variation from the initial setting a reliable and carefully maintained CO_2 recorder should invariably be fitted. It must be remembered that such equipment can only be taken as a guide to the efficiency of combustion and, as pointed out earlier, adjustment of the burners to give the best conditions depends on the operator.

As mentioned above, accurate control of the oil flow is dependent on the maintenance of a steady oil temperature, which is also of the utmost importance to ensure correct atomization. Thermostatic control of oil temperature is therefore highly desirable but control within reasonably close limits over a wide power range by thermostat only is not easy. In cases where there are frequent load fluctuations it would seem desirable to make use of an oil-flow meter as well as a thermostat to control the oil-heater steam supply.

The power range over which boilers may operate completely automatically is usually severely restricted by the type of burners used. The pressure range over which the normal type of pressure-jet atomizer can operate efficiently is of the order of 90 to 290lb. per sq. in. and, therefore, since the volume of oil delivered is roughly proportional to the square root of the pressure, the output can only be reduced by about 45 per cent. This would probably correspond to a decrease in the ship's speed of not much more than 20 per cent. In cases where the service requires frequent load changes, serious consideration should therefore be given to the use of wide range burners.

Various types of oil burners capable of a greater range of output than the pressure-jet atomizer are available but none is used to any great extent in marine boilers. The return-flow burner is easily adapted to automatic operation but, together with the plunger type, probably does not have a sufficiently variable capacity to allow automatic control under all conditions. Burners capable of maintaining efficient atomization over a greater range are operated by compressed air or steam; the latter type are being used to some extent in recent American ships but the loss of water involved usually precludes their adoption.

It would appear that the only variable capacity burner having a sufficiently wide range to allow complete automatic operation of a marine boiler installation is the rotary-cup type, the output of which is capable of being reduced in the ratio of 18 : 1, i.e. approximately ten times that of the pressure-jet atomizer. Burners of this type, driven by an air turbine, were used in German warships and others of a similar type are widely used in the United States for industrial boilers. It is doubtful, however, whether the added complication and greater cost of fitting such equipment would be justified, except in special classes of ships such as cross-channel vessels or others where the steam demand is subject to rapid fluctuations.

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Discussion

CAPTAIN(E) W. GREGSON, M.Sc., R.N.R. (Member) said it was difficult to open a discussion on this particular paper because the paper itself was essentially factual and objective. It dealt with a subject which all who were interested in steam propulsion were studying pretty widely at the present moment, because prices of bunker oil were such that they could not afford to let anything slide which promised higher efficiency.

His own first contact with automatic control had been in the middle 'thirties. At that time he had been looking into the possibilities of adapting certain types of Continental forced circulation boilers to marine practice. Some of these boilers, particularly the Benson boiler which was a "once-through" design with practically no reserve of water or steam, had of necessity to be automatically controlled. He remembered making several short trips in German ships with boilers of this type. The controls were fully automatic; the sort of thing where you pressed button A, the lights on the board went up, the boiler was lit up, and everything (theoretically) worked automatically. He remembered the German engineers pointing out that they had been able to effect quite a considerable reduction in the stokehold personnel by adopting this type of automatic control but he had not been impressed by this statement as the ships seemed to be full of white coated scientists who spent their time keeping the controls working.

His next contact with automatic control had been the new American ships coming into service just before the war. They had been fitted with controls of designs which we ourselves were now adopting and they were much simpler and more effective.

He thought that, apart from the urge for fuel economy, the reason the Americans had taken to automatic control at that time was because they were expanding their merchant marine and had not the supply of seagoing engineers coming forward to run these ships, so they had of necessity to adopt automatic combustion control. These controls seemed to work satisfactorily and the chief engineers of all the ships he had visited seemed very contented with them.

Until then he had always maintained that any experienced operator could, when conditions were stabilized, set any modern boiler plant to optimum operation very quickly and without any recourse to automatic means. The error in that statement was, of course, that any modification to draughting such as a change in the direction of the wind or the course of the ship meant a re-set of air conditions.

In the early days of the war, a number of modern American cargo ships fitted with automatic controls had been taken over, and these ships had been manned with our own people. This had given an opportunity of studying in more detail the operation of automatic control and also of getting log figures and seeing the reaction on fuel consumption. Theoretically, the efficiency gained by fitting automatic combustion control, compared with good hand control, was very small, but in practice they compared most favourably with similar vessels without automatic control. British engineers who took over these ships liked the controls, and they operated entirely satisfactorily.

As the lecturer had told them, more and more ships were being fitted with automatic combustion control, and in a very short time they would be able to say what sort of real gain could be obtained on voyage returns as against short tests. It seemed to him from what he had seen of these controls that they must not expect too much and, incidentally, that the makers must not promise too much. The great advantage of automatic control was this: it took away a good deal of the running about operational work of the watchkeeper in the boiler room, and that enabled him to pay more attention to what he (Captain Gregson) called "static" adjustments as against differential adjustments. The automatic controls would look after the air/fuel ratio quite satisfactorily, but that was only part of the story; the "static" adjustments covered the correct positioning of burners, registers, etc.—in many ways more dominant factors in getting economic running, than pure air/fuel ratio. That was a big gain from automatic control; the watchkeeper in the boiler room could pay attention to the things outside the range of differential control.

Mr. Taylor mentioned one important advantage of automatic control apart from combustion—the reaction on boilers not fitted for superheat control either by attemperators or double furnaces, etc. With the simple boiler there was a tendency for superheat to fly about when manœuvring due to a rush of hot gases passing over the superheater with reduced steam flow. With automatic control you could keep superheat on a steady line irrespective of load and quick manœuvring.

As to fan control, Captain Gregson said he had had experience with plain damper control which was reasonably simple, and a combination of damper and fan speed control. This latter was more efficient because you could run the fan at the speed appropriate to the duty. On the other hand, it simplified the whole installation if you eliminated the additional items necessary for speed control.

The real crux of the method of fan control centred on the fact that it was no good gaining a little efficiency by better combustion, and losing all you gained by inefficient operation on the auxiliary side. If the merchant service began to adopt a.c. current where speed control of motors was more difficult, constant speed machines would become standard for fan drives and maybe some system of vane control would allow fans to run at optimum efficiency.

Mr. Taylor had pointed out that it was no use having automatic combustion control without some form of wide range burner. The ordinary straightforward pressure jet system gave satisfactory atomization within a range of 100/300lb. pressure; taking the square root law, that gave a range of oil burning of 1 to 1·73, which was inadequate for manœuvring. Under those conditions, when getting down to low power or manœuvring, oil burners must be shut off or brought into action as required. That was not really difficult because the men in the boiler room had not to worry about oil/fuel ratio controls and, provided they were advised on the telegraph as to what was doing, it was a quick operation to shut burners off or bring them on again. Incidentally, you could never completely shut the registers and stop excess air getting into the furnace.

The author had mentioned particularly the rotary cup type of burner for wide range working; Captain Gregson said that he had seen a fair number in pre-war years aboard German ships. Also, the bulk of the German warships had been fitted with that type of burner, and quite a number of people had had an opportunity of seeing them at work after the war. He thought the disadvantage was that, although the rotary cup burner was excellent at full power, with low powers and with the spinner operating at a much lower speed, atomization was poor and, irrespective of air/fuel control, the actual efficiency was very low and CO_2 fell to a very small figure indeed. It appeared to be a bad design if required to operate in the lower power ranges.

Whenever anything new was adopted there were so many operational factors which cropped up that (as we were all human) there was a prompt urge to blame the apparatus. He remembered one case in a ship where the controls had been working very satisfactorily and then a signal was received saying they were haywire; when the ship got back they found the controls operating perfectly. The ship was in excellent hands and there was therefore no imagination about the fact that there must have been something wrong at the time of the report. The trouble had occurred during heavy weather and heavy rolling and they naturally thought it was something to do with the mechanism of the control apparatus, although it seemed stout enough. Further investigation showed that the failure had occurred when the ship was passing through a zone with a very humid atmosphere, i.e. the air entering the compressor operating the controls was heavily charged with moisture. The air left the compressor at high temperature so the water was present as vapour; it duly condensed on cooling in the pipework connected with the various operational portions of the apparatus, and slugs of water wandering through the pipe system had upset operation. After knowing the cause, the easy way to get over the trouble was to fit an adequately sized after-cooler in the compressor line with a receiver which was readily drainable even when the ship was rolling heavily.

MR. W. LYNN NELSON, O.B.E. (Member) said the author had described in fair detail the two types of automatic oil burning systems at present predominant in the United States, which were now being manufactured in this country, and being extensively fitted to new British built tonnage.

From the descriptions given, it was observed that the major difference of the two systems was as follows: on one the air/fuel control was in series, which meant that the steam pressure fluctuation actuated a master sender which altered the air pressure to the furnace, which alteration in turn changed the fuel pressure in the correct air/fuel ratio. In the other system, the furnace air and fuel pressure were controlled in parallel and simultaneously by the master sender, and kept in correct ratio by the controller.

Personally, he preferred the latter system, as his experience had shown that there was a certain element of lag in the series actuation, in spite of the finest of adjustments.

Mr. Nelson said he applauded the remarks of the author in which he had stressed the necessity for the closest co-operation between the designers of the boilers and auxiliaries and the manufacturers of the automatic control gear. It had been found that if there was any variance in the uniflow in the air ducts and dampers in each of the respective boilers which caused turbulence, this could seriously affect air/fuel balance, and could make quite a lot of trouble. At this point he felt there was room for revolutionary design in the dampers of high pressure watertube boilers of the integral tube type.

Did the author consider that a damper of the stream-lined multi-vane uni-operated design—like a Venetian blind, so to speak—would be an improvement in giving more sensitive control of air?

He noticed that the oil flow regulating valve as shown was specially designed to give very sensitive control of the oil flow within fine limits. However, as this unit merely shut against the positive displacement fuel pump, would the author tell them if the same consideration were given to the design of the relief valve, which was an imperative fitting, and was presumably part of the oil burning installation? If it were not, then the object was defeated.

Mr. Taylor had not mentioned the 300lb. per sq. in. by-pass valve burner prevalent in the United States.

The author had stressed a salient point when he mentioned the wider range of fuel control when manœuvring; with the usual type of atomizer the pressure at the tip dropped to govern the amount, making for inconsistency in atomizing, which was not good, and naturally the shutting off of fires was essential. Maybe some day they would have a burner in marine installations which would eliminate this problem.

The description of unified electric control fuel pumps and fans had interested him very much. He believed there was a future for development on these lines as opposed to damper control, and was inclined to disagree with Mr. Taylor on the question of fan speed control.

The author had referred to the tankers fitted with two La Mont boilers. Mr. Nelson happened to know these ships well, and he could assure the meeting that the auto fuel burning system was giving every satisfaction. It might be mentioned that the ships had electrical rheostat control of the fan and fuel pumps over and above the other controls. They had met certain snags at first, mainly due to the fact that the range characteristics of the rheostats were not responsive enough over the wider ranges.

MR. R. L. J. HAYDEN said that while the paper gave a thorough description of certain typical systems of automatic combustion controls for marine boilers, he felt that more emphasis might have been paid to the economic justification of automatic control equipment. The author had referred to the savings possible by means of a reduction in the excess air content of the flue gases and the elimination of incomplete combustion due to the formation of smoke. There appeared to be several other important features to be taken into consideration when assessing whether automatic combustion control was desirable: in the first place, the possible elimination of smoke and smuts on deck under manœuvring conditions; secondly, a possible reduction in the operating personnel. As against these items, and the items the author had already mentioned, must be offset the cost of maintaining a set of automatic control equipment. He would be glad if the author could give any indication from operating experience of the cost of these various items.

The author had mentioned that electrically controlled systems had been little used. There was, however, at least one system of electrical automatic combustion control which had found considerable application in American ships, although no British counterpart was made, or had been installed, in this country.

On page 7, the author gave the impression that the system of unified boiler control, which he referred to as "positional control", was cheaper than an air operated metered control. Mr. Hayden said he would like to query whether this was a correct interpretation of the author's meaning. It was very doubtful whether simple positional control could be successfully applied to marine boilers with groups of burners.

The author had mentioned damper control of fans, and it might be well to point out here that if the induced draught fan was to be damper controlled from the pressure in the combustion chamber, there was a minimum damper opening required by classification societies, and the restriction on the damper opening could lead to too high a suction being carried in the furnace under low loads, although the furnace pressure controller had set the damper as far in the shut direction as possible. The author's opinion would be welcome as to whether the system of bypass control on the fans, which would bypass gas from the discharge of the fan to the suction, could be adopted, thus leaving at all times a clear passage through the fan. The fan characteristics and the amount of gas flow through the bypass would have to be considered to avoid overloading the fan motors.

On page 11 the author suggested the use of an orifice for measuring the flow of oil to the burners. Mr. Hayden considered that this was hardly practicable with the large range of viscosities likely to occur at the orifice even if the orifice were placed in the hot oil line.

Some time ago there had appeared in the Press references to a system of automatic viscosity control to maintain a fixed viscosity of the oil at the burners. It had always appeared that this would be a worthwhile fitting, as a choice of temperature at which oil should be burnt was usually not decided on any very definite basis, and was usually left to the judgment of the firemen or engineers.

On page 11 also was a statement that no burners capable of a greater range of output than the pressure jet atomizer had been used to any great extent in marine boilers. This was certainly not the case when taking American installations into account, and even in this country there had been quite extensive application of wide range return flow atomizers, having a load range between 3 to 3½ to 1.

The author had inferred that the pressure jet atomizer could only operate efficiently over the range of pressure from 90 to 290lb. per sq. in. The experience of Mr. Hayden's company had been that 90lb. per sq. in. with the present heavy oils was somewhat low for good atomization, and there appeared to be no reason why higher pressures than 290lb. per sq. in. should not be adopted, with a resulting improvement in atomization. The limitations on the upper pressure were not imposed by the efficiency of atomization, but by the cost and design of high pressure oil pumps, heaters and piping.

Reference had been made also to the use of a spinning cup burner, and it was suggested that this might be applied to cross-Channel vessels. Firstly, a spinning cup burner, if driven by an air turbine, brought with it undue complications in the design of air heaters. If the high pressure for the air turbine did not pass through the air heater, then at low load the air heater had practically no air flow through it, and burning of air heater tubes could occur. It was doubtful, in his opinion, whether such an air turbine driven burner, or even a motor burning unit of the same type, showed any advantage over other types of atomizer, and he could not understand why the cross-Channel vessels should be particularly suited to the adoption of this type of burner. Time spent on manœuvring in cross-Channel vessels was not great, and a considerable proportion of their running time was at a full steady load.

MR. Ll. YOUNG said that he thought the author was guilty of, and should be gently chided for, inconsistency. He had stated that the terms and definitions he was using were those recommended in the British Standard Glossary, but he almost immediately reverted to the use of the terms more commonly employed. In one way, perhaps, he was right, as one could hardly expect an engineer at sea to have at hand a Standard Glossary dealing with a matter with which he might be totally unacquainted.

The improvement in efficiency due to automatic control was a matter which must interest both supplier and user alike, since if the user could not be persuaded that he would save money by an initial capital expense, he could hardly be expected to make an expenditure. The author had mentioned one source of information on possible savings. Mr. Young said he would be interested to know if there were others. He felt, however, that one must rely upon the technical considerations rather than actual savings whereby one could say that the machine should do a better job than the fallible human operator. The difficulty was that the cost of obtaining the proof might be excessive when all the precautions necessary were taken into account. It must be remembered, however, that the material being used, fuel oil, was becoming more and more valuable, and it might be reasonable to say that an increase in efficiency, even if it could not be measured, might be worth while, since it could be expected to last through the life of the plant.

While, on the face of it, the lack of wide range burners might be a disadvantage to a fully automatic control gear, it was less a disadvantage than it might seem, and certainly not one that would justify on its own account a high priced alternative. All burners must be changed from time to time for cleaning; the labour in removing and replacing burners was not onerous, and the difficulties involved in carrying out this onerous, and the difficulties involved in carrying out this work while manœuvring was not a serious matter.

One disadvantage of the wide range burner was that it might need more delicate and less robust instruments which formed part of the automatic control. In the case mentioned in the paper, the rotating cup burner, the power available at minimum load to operate the flow meter would be $1/18^2$ which was, say, three thousandths of that available at full load. For this reason the measurement of air across the burner deflectors and oil across the nozzle tip, while not academically perfect, had proved to be a very sound and practical solution, as the changing of the burners provided what was in effect a variable orifice in the case of both oil and air. The author had very rightly stressed the disadvantages of measuring total air flow by means of an orifice or venturi. This differential pressure must be paid for in terms of auxiliary power, and the cost lasted for the whole of the life of the plant. Careful thought was necessary, therefore, before deciding that such a method, which also involved long straight ducting, should be employed.

The author had commented on the efficiency of vanes and dampers. On the whole, Mr. Young believed that at low loads this was very true. There was not a great deal of difference in efficiency at the normal operating loads.

With regard to the output curve—flow against angular displacement of a damper as compared with a vane—he believed there was very little difference, and it was necessary always to make angular adjustment to correct the sharply rising flow curve at low loads against the flattening off at high loads. It was, however, quite simple to provide a lineal characteristic in the linkage.

Mr. Nelson had enquired about the efficiency of the Venetian blind or louvre type damper. This type of damper was frequently employed in land practice and had a better flow characteristic and therefore higher efficiency than the ordinary butterfly damper. What was perhaps more important was the sizing of the damper for its duty so that the ratio between damper resistance and system resistance could be kept to the optimum value whereby both effective control and efficiency were maintained.

The author had made several references to the fouling up of boiler surfaces. Mr. Young suggested that if it was proposed to allow a boiler surface to become so fouled that a measuring device could not be connected across it, then automatic control should in no case be contemplated.

The author deprecated the use of the Orsat apparatus, and appeared to recommend the sole use of a permanent CO_2 instrument. While this was an excellent arrangement, providing the instrument could be properly serviced and maintained, it must be remembered that the CO_2 instrument was in effect an Orsat, that it was a laboratory instrument, and for perfect operation necessitated maintenance at fairly frequent intervals. He suggested, in any case, that a small bracket suitably located so that an Orsat apparatus could be quickly connected at the boiler outlet, thereby permitting relatively easy snap readings to be made at any time, would be a useful investment, whether or not a permanent CO_2 instrument was installed.

The author had further commented upon the danger of explosion due to oil being injected into the furnace without air at the time of fan failure. Mr. Young believed that the danger did not exist at the time when the fan actually failed and when a lack of air was evident but rather when, after a short shut-down, the oil in the furnace had vaporized and the re-injection of fire and air gave rise to an explosive atmosphere, and this could only be overcome by a proper degree of purging. It seemed essential that boiler operational drill should include such furnace purging, no matter what the emergency.

MR. ZOLLER had considered combustion control as a boiler designer and therefore found this paper interesting as being written from another viewpoint. A few minor statements invited comment. The control system was capable of changing excess air with boiler load automatically. When air flow was checked by oil burner resistance, no allowance was made for leakage through shut burners. This was an advantage, because this leakage air was not available for combustion and the air flow through the burners in use was independent of the number in operation.

An automatic control system should only modulate the various elements and the operator should decide when to change atomizer tips, light off and shut down burners, shut down oil pumps and change the speed of two speed fans. Warning lights were useful in calling attention to low oil pressure, etc., and these should be set to prevent smoke or any other change from normal; a dangerous condition might arise if the oil fuel pump were shut down due to a momentary fall in atomizing pressure.

In America it was often more easy to obtain a crew when automatic control was installed. The psychology of firemen should also be considered in the layout of the control board and its associated instruments. For example, the dials should be large enough to permit of the operator moving around the stokehold while watching essential indicators.

Superheat control was steadier when the master loading pressure was used to anticipate changes. This compensated for time lag between altering the burner, damper or steam valve and measuring the change in steam temperature. The final control element was always the thermostat at the boiler stop. In the same way, swings in oil temperature might be avoided when maœuvring; the steam valve to the heater was closed as soon as a change in the loading air pressure indicated a fall in boiler load and *vice versa.*

The term "highly rated boiler" was ambiguous and often related to the evaporation per square foot of boiler heating surface. This had little influence on the choice of an automatic control system. Each control element should be capable of adjustment on the ship until its characteristic matched the inertia of that part of the steam generator it controlled.

Unified control was not automatic and had no relation to "automatic combustion controls for marine boilers". Experience with oil fired land boilers showed the system to be inflexible, and to build the special motors the motor designer required from the boiler, oil pump and fan makers, information that was not available either before or after the ship was at sea. Fan speeds and powers could not be forecast at all loads because all standard codes permitted wide tolerances in fan characteristics. Oil burners required wide variations in oil pressure not directly related to boiler load and oil pump output varied within wide limits. Fuel properties influenced pump leakage and speed as well as boiler performance. Wide trimming ranges must be provided which increased motor sizes and necessitated continual manual follow up. At the best, unified control was positional without the advantage possessed by a positioned system which had been fitted in the German Navy and which had cams that could be adjusted with difficulty to fit the average boiler operating characteristics observed at sea.

The following contribution from MR. J. E. O'BREEN, who had been prevented from attending, was read by Mr. Burns.

On page 2 of the paper the author had referred to loss of water as a result of soot-blowing. Mr. O'Breen could say that without automatic control the chances of the safety valves lifting were far greater. Steam passing through the valves meant a further loss of valuable water.

The author had referred to manual adjustments necessary to vary the fuel/air ratio at different loads; it would be quite an easy matter to vary this ratio automatically, and it would not add much to the cost of the control gear.

Further, the author had stated that most systems were designed so that the pressure returned to the desired value after a change in load. This was quite true, it was a simple matter to design and arrange the control gear so that the pressure always returned to the required pressure, but Mr. O'Breen was not so certain that this was advisable in all cases.

On page 7 the author referred to this point again, and stated that with range control "the boiler pressure was controlled at a slightly lower value when the steam demand was above normal and *vice versa*". This was not the case when the boiler was equipped with a superheater, and under those conditions range control had the advantage of producing a slightly higher average pressure at the turbine throttle valve. The easiest way to make this quite clear was by giving an example: given that safety valves on the boiler drum were set for 425lb. per sq. in. and that the drop in pressure between boiler drum and turbine stop valve on peak load was 30lb. per sq. in., with minimum load 10lb. per sq. in., it would be clear that with a system where the pressure returned to a predetermined point, this pressure could not be more than about 390lb. per sq. in., as otherwise the safety valves would lift. With range control, the lowest pressure (corresponding to peak load) would be 390lb. per sq. in., the highest pressure could be chosen anywhere between 390 and 415lb. per sq. in. (425-10), say, at 405lb., and the average pressure at the stop valve with range control would therefore be well above the predetermined pressure in the other systems.

The author had referred to wide range burners; Mr. O'Breen knew only too well the limitation of automatic control with narrow range burners, and it was surprising to him that burner makers had not been able to develop a burner which would give a wide range, say, from 100 down to 10 per cent. He believed that the reason was that the owners had not insisted on the supply of such a burner.

He was familiar with a design which was used for water spraying and which in his view could, with slight alterations, be used as an oil burner. This design could easily be used over a 10 to 1 range, and further had the advantage of having a large maximum capacity so that it would not be necessary to have five or six burners per boiler.

The author had mentioned that in the controller illustrated in Fig. 2, the signal air pressure decreased with a decrease in the steam pressure. Mr. O'Breen wished to point out that whenever required it was possible to reverse this condition, namely, to produce rising signal air pressure with falling steam pressure; all that was required was to turn the weigh-beam round and put the pilot valve on the other side of the regulator.

He did not quite agree with the author's statement that when using a venturi throat for air measurement a considerable length of ducting was required. He could show the author an automatic control installation where the venturi was in front of a bend. The main thing was that the pressure drop through the venturi always increased with increased flow, but it did not matter if the relation was exactly a square law one or not, as it was possible to correct any irregularity by means of a cam in the air flow regulator.

MR. D. BURNS said Mr. Nelson had mentioned the fact that automatic control seemed to have been started in marine use in the United States, and this country had to some extent lagged behind. He thought that was entirely the shipowners' own fault, because the control systems in question which Mr. Taylor had mentioned had been in use in this country since about 1927, and details had been put forward many times in this country. It was only when the Americans themselves showed what results could be obtained, however, that people in this country became interested.

With regard to the series and parallel systems, he was of the opinion that the advantage of the series system, whereby the steam pressure controlled the air flow, which was then measured and controlled the oil flow, was that if the air flow failed, the oil was automatically shut off.

With reference to the operating gear shown in Fig. 7 of the paper, as a cylinder type regulator, he thought it should be stressed that the compensating mechanism shown could be adjusted so as to take into account the characteristics of a damper or vane, or whatever other regulator was operated.

COM'R(E) J. I. T. GREEN, R.N. (Member) said that although he spoke as a Naval officer he did not represent any views but his own, which were solely those of a student of marine engineering.

The advantages to be gained by and the price to be paid for automatic control of air/fuel ratio, and the many forms such control may take, had been well covered in this and in preceding papers. There were some points concerning the characteristics which did not appear to have been raised, and perhaps it would help to clear up doubts if Mr. Taylor would give some details, for instance, of the variation in respect to time one would expect in the rate of fuel supply and the controlled steam pressure when (a) steady steaming, and (b) the maximum rate of change (say, from "Stop" to "Full Astern") was demanded. Could the author show diagrammatically what these changes would be on a time basis? In other words, could one expect a simple system designed primarily for steady steaming to function without hunting when a large and sudden change was made, and would it be safe to apply such control to a highly rated boiler? He assumed, of course, that wide range burners were in use.

The fans, in this and other papers, were assumed to be electrically driven. In the case of steam driven fans, where the exhaust was condensed through feed heaters, their speed was affected very materially by the exhaust pressure, and therefore by the flow of feed to the boiler. Although this automatic combustion control was not connected to the feed system, its operation would cause fluctuations in the rate of steam release, especially when manœuvring, and this would be reflected in variations in water level, and hence in feed flow. Had trials been carried out with the object of tracking down and eliminating any possibly serious hunting of the whole system from this cause?

In order to bring out some of the details of the system, could Mr. Taylor explain why the master controllers for the series and the parallel operation systems were different? Comparing Figs. 2 and 3 of the paper, it would be seen that in the first the steam pressure was opposed by a spring only, thus giving a set opening of the air valve for any given steam pressure, whereas in the second there was what might be called a hunting gear which shut off the air supply when the desired pressure was reached. Thus for series operation (Fig. 10), the master controller delivered a steady stream of air to the relays feeding the damper control, whereas for parallel operation a fixed pressure was applied to the cylinder type regulator (Fig. 7) and the oil flow regulating valve (Fig. 8).

Commander Green's fourth question concerned the effect of a major disturbance in the operating conditions. Although some safety precautions were discussed in the paper by Bailey and Dickey,[3] he could find no reference to the effect on the system of a boiler tube failure which in some systems would result in an immediate increase of the fuel supply. Knowing what it was like when a tube burst in a boiler, he had a feeling that fiddling about with selector valves would not be a desirable addition to one's duties. The operating personnel must be provided, he suggested, with a quick means of overriding all the automatic controls and dealing with the emergency without them. Could the author explain the action necessary to obtain manual control to meet such sudden emergencies?

MR. G. J. GOLLIN said Mr. Taylor's paper was very valuable as illustrating the great progress made by control designers and manufacturers. He would like to think that oil burning equipment in general had been brought to a similar pitch of efficiency. It was obviously of little use to install automatic controls to operate burner equipment with a 3 : 1 turndown range if the oil burning equipment itself was incapable of operation efficiently over such a range. It was not sufficient to ensure a constant fuel/air ratio over the working range if the air register were incapable of ensuring satisfactory mixing of the incoming air with the oil spray. This was not an easy problem because the degree of mixing depended on the air velocity just as much as on the aerodynamic design of the air register, and with a 3 : 1 turndown range the velocity of the incoming air might be insufficient to ensure good mixing, with the result that one was forced to accept a much lower combustion efficiency at the lower end of the range.

Turning to Fig. 1, he felt that the common mistake had been made of comparing the boiler efficiency at constant exit flue gas temperature assuming that the excess air was reduced, say, from 50 to 20 per cent. It would have been useful if the 100 per cent excess air line had been shown in Fig. 1, because it was by no means uncommon to find oil burning equipment operating with 7·5 per cent CO_2. If the excess air were reduced, the effect was twofold; not only was the weight of waste gas reduced, but with a reduction of excess air one could reasonably expect a reduction in waste gas temperature. As excess air was cut down so the temperature in the combustion chamber increased, and with it the radiating quality of the flame. Thus, decreasing excess air increased the heat transfer in the primary combustion chamber and altered the proportion of the load carried by various parts of the boiler with a consequent decrease in exit flue gas temperature. If, therefore, the writer were comparing operation with 50 or 60 per cent excess air and that with 20 per cent excess air, he would assume that the change in operating conditions would result in a temperature drop of 50-100 deg. F. This would considerably increase the gain in efficiency and fuel saving. Results on land installations showed that the actual saving achieved was often considerably in excess of the theoretical, which was in agreement with the opinions given by the author and Captain Gregson.

He felt that as regards the valve shown in Fig. 8 perhaps it would be better to control oil pressure in the delivery line to a bank of boilers by applying automatic control to a suitably designed pressure relief valve placed across the suction and delivery sides of the pump. This appeared to give more stable conditions than a mere throttling valve in the oil line to the burners. The design of valve shown in Fig. 8, with its relatively small annular oil openings, was apt to act as an oil filter and, therefore, to work efficiently must be protected by a fine filter on the upstream side. In designing valves for handling fuel oil, he considered it was preferable that valves of the piston and port type should be used rather than valves of the poppet type, which presented fine annular openings.

In practice, changing the number of burners in operation usually materially affected the air delivery through registers, as indicated by the drop in pressure across the inlet to the register and the combustion chamber. That, as had been pointed out, was partially due to leakage through idle registers, but the friction in the forced draught casings should not be ignored. In the past, there had been a tendency to make these casings too tight, with the result that the internal friction in the casing became appreciable compared with the pressure drop across the register. There was room for a considerable improvement in the aerodynamic design of forced draught casings if accurate controls through the use of the pressure in the forced draught casings was to be employed.

Mention had been made of the use of spinning cup burners for marine purposes and he was surprised to learn from the paper that a turndown range of 18 : 1 had been claimed. It was even more curious that in the case of the German burner the cup was described as running at a slower speed in the lower part of the range. It was generally understood that to obtain reasonable results from a spinning cup burner operating on fuel oil, the cup speed must not fall below, say, 3,500 r.p.m. Experience on land indicated that rotary cup burners rarely had a range in excess of 4 : 1. In this connexion, it must be borne in mind that the operation of a burner of this type depended as much upon the air blown around the cup as on the action of the cup itself. These burners were really low pressure air burners with a spinning cup used to initiate atomization and also to act as a distributor. They normally operate with about 10-15 per cent of the air for combustion passed around the nose at 4 to 6 inch W.G. If an attempt were made to operate such a burner over a large range, it would be necessary to cut down the primary air by means of a damper which would soon result in the air velocity through the nose being too low to complete atomization and to mould the flame. In contrast, one might envisage the use of air atomizing burners at a pressure of, say, 30 to 40lb. per sq. in., seeing that these burners could operate over a very large turn-down range. He had been informed that such burners had been applied with great success to the boilers installed in specialized vessels designed for the whaling industry and that burners of that type had operated with a very large measure of automatic control in such ships.

Mr. T. R. Alexander (Member) asked the indulgence of the meeting in speaking, not of the application of automatic combustion control in marine work, but in land boiler houses. He believed he was the first man in Britain to install and operate such apparatus and his remarks would be based on his experience with it since 1927.

The plant consisted of four Babcock and Wilcox boilers with chain grate stokers and induced draught; the master controller was similar to that shown in Fig. 7 of the paper. All the movements from the master controller were transmitted mechanically by shafts, rods and cranks, the apparatus was very primitive and clumsy and included over 100 feet of 2in. shafting, yet it was still working very satisfactorily. It was robust and had not cost more than £1 a year for maintenance, including one ring of soft packing in the controller. The improvement in efficiency due to the installation of the apparatus was about 1·5 per cent, but much more important improvements were obtained in the production processes using steam because a much steadier pressure could be depended upon and therefore time cycles could be reduced to a minimum with safety and confidence.

The steam demand varied from maximum down to two-thirds of maximum and it was found advantageous to use the full scope of the apparatus to operate between maximum and minimum demand instead of between full load and no load. This gave much closer regulation on grate speeds, boiler dampers and induced draught fan speeds so that it was possible to keep the pressure within ± 1lb. per sq. in. with efficiency at all loads during the hours of production.

Probably the greatest advantage of the apparatus was that although, of course, it could not anticipate a change of load or fuel, it did respond to a minute change long before it was apparent on a pressure gauge.

Another good feature of the apparatus was its simplicity; this was all-important in a works where it was not possible for the engineer to spend a large part of his time in the boiler house and where the stoker took more responsibility than he did in a ship. The apparatus must be capable of operation and adjustment by the stoker himself, as then he would get the best out of it; furthermore, he would do what he could to keep it working efficiently because it was such a great help to him.

Mr. Alexander said he felt that the tendency in the modern instrument was away from this simplicity; more complicated instruments might give greater efficiency but, without constant supervision by a technican, it could not be continuous.

Mr. Alexander thought that a good way to operate the induced draught fan without damper control was to drive it by a steam engine.

Infinitely variable speed could be obtained by control of the steam through the automatic combustion control and the exhaust could be used in the water treatment plant or feed heater.

Correspondence

Mr. L. Baker, D.S.C. (Member of Council) proposed to confine his remarks to the points of fact and principle on which he differed from the author and to leave the discussion of the various equipment to those with experience.

He doubted whether the proportion of Scotch boilers was a serious reason for the resistance to combustion control equipment; he felt that it was due to the failure of manufacturers to convince superintendent engineers that there was the possibility of an adequate return for the capital outlay. In American manned ships and to a lesser extent in tankers, manning problems seemed to have influenced the decision. As long as one Chinese fireman could look after two boilers at sea, there would not seem to be much scope on financial grounds!

His second major objection to combustion control equipment was that there was *no* satisfactory wide range burner yet available. The German rotary cap burner was hopelessly inefficient except at its design output. In his view, the case for combustion control rested entirely on the existence of a burner with a range wide enough to cope with the full range of steam output, i.e. about 20 to 1. By removing from the fireman personal responsibility for steam pressure control and fuel/air ratio and entrusting to him the more skilled operation of ensuring that the combustion conditions were as designed, merely resulted in the loss of the routine watch keeping which ensured reasonable vigilance.

The author's remarks on the wear of refractory due to high furnace temperature were not understood. Mr. Baker was not aware of any mercantile boiler, or indeed of any Naval boiler in service, in which the limiting temperature of reasonable quality refractories was reached. Deterioration of refractories was mainly due to impurities in the fuel or mal-operation of the burners. Additional excess air did not affect either of these.

He would draw the author's attention to a difficulty in achieving real efficiency by automatic combustion control, namely, that the control of fuel was dependent upon the control of the viscosity of the fuel over a relatively narrow range—to do that automatically appeared to be an extremely difficult problem.

Mr. P. F. Morgan, B.A. (Graduate) wrote that his interest in automatic boiler controls, of which he knew very little apart from what had been learnt from the paper, was occasioned by the remarkable similarity of the problems and principles ruling both automatic boiler control gear and steam turbine control gear for land installations.

The most striking similarity occurred over the "regulation" found in the two cases and indeed in any system of hydraulic control servo-mechanism. In a steam turbine, the regulation was the necessary drop in speed of a speed-governed turbine between no load and full load; this was paralleled by the drop in steam pressure found in the simple boiler control systems between light load and full load. It was necessary for the stability of the system and although it had been shown that the pressure drop could be considerably reduced, care was essential to avoid hunting due to the controls.

It was equally desirable in both cases to obtain straight-line regulation; in the boilers shown in Fig. 10, the air supply should be increased in direct proportion to the load; for a steam turbine, the steam supply could best be increased uniformly with the load by suitably shaping the throttle control valve. Probably it was not desirable to adopt steam practice when controlling air flow. Would it not be more effective, however, instead of restricting the movement of the damper to less than 90 deg. to turn the crank lever connecting the damper to the operating piston rod? It would then be possible to take advantage of the fact that when the angle between the piston connecting rod and the damper crank was small, for a given movement of the operating piston only a small movement of the damper crank resulted and was therefore suitable when the damper was almost closed. When the connecting rod and damper crank were almost at right angles to each other, the same movement of the operating piston produced a much bigger movement of the crank. If this were not adequate it would be necessary to have recourse to the linkages used in steam turbine practice.

The chief advantage of compressed air was its availability on board ship. Did not difficulties arise when using this medium due to the very fact that it was compressible and that therefore expansion was caused by rises in temperature?

MR. S. E. SHAW thought the author was to be congratulated on a factual and impartial survey of the subject, especially on his unprejudiced recognition of the limitations of automatic control as applied to marine boilers. The question at once arose as to whether the additional complication was worth while. As the author pointed out, manual methods of control, as exercised by a well trained fireman, left little margin for improvement in the case of vessels which steamed for long periods at full or nearly full power. On the other hand, no amount of instrumentation or automatic control could eliminate the loss incurred by badly adjusted or dirty sprayers neglected by indifferent operators.

Given the reasonable assumption that ships large enough to be fitted with some form of boiler control did normally steam steadily for long periods, results reasonably comparable with anything shown by automatic systems could be obtained by instituting a series of biennial checks carried out by the shore staff, using full instrumentation, laying down for the fireman a given set of conditions pertaining to maximum efficiency when steaming at loads of, say, 40, 60, 80 and 100 per cent M.C.R. These set conditions could include uptake and superheated steam temperatures, CO_2, air temperature and pressure, oil temperature and pressure and the number and position of sprayers to be used, when possible.

Normally intelligent operators should be capable of the elementary interpolation to secure efficiency at intermediate loadings. This practically amounted to positional control, with maximum efficiency checked at fixed points. In the case of the "Unified" control cited by the author, this was exactly what happened with virtually an infinite number of check points replacing the four chosen in the preceding paragraph. In that system the motor characteristics were so modified that the fuel/air ratio was always in the correct proportion irrespective of boiler load, any long term variations such as boiler fouling or change in calorific value of fuel being met by infrequent hand adjustment of the appropriate trimming rheostats. As the "system" was actually built into the motors, the amount of extraneous auxiliary gear was reduced to a minimum, with reliability correspondingly improved.

The author's fear that variable speed fans might lag behind the rate of change of boiler load might be safely dispelled in this case; the specially compounded d.c. motors had an acceleration which enabled them to keep abreast of the rate of load increase of which any normal boiler was capable. This, coupled with the convenience of having all control concentrated in the single handwheel of the main rheostat, facilitated the rapid manœuvring so often necessary when coming alongside in bad weather.

MR. J. A. STEVENS (Member) expressed the opinion that if high pressure steam plant were to maintain a clear cut superiority over the Diesel engine for marine propulsion in the higher power ranges, both in operational efficiency and in maintenance costs, two factors more than anything else would make this possible. These were advancement in the metallurgical composition of boiler components and automatic combustion control.

It was perhaps unfortunate that the credit for the successful installation of automatic combustion control on shipboard should go to ambitious and far-seeing shipowners in the U.S.A. This was perhaps indicative of the approach to marine engineering problems shown by the U.S.A. shipowners and shipbuilders as a whole.

There could be no doubt, however, that automatic combustion control had come to stay and with the heavy fuels now generally in use where air/fuel ratio control was of particular importance, the success of the application still rested with the shipboard operator. It was unfortunately the case that a mediocre operator could obtain only average results from a first class installation.

It was refreshing that, other than a reference to "heavy fuel", no attempt was made to join in the fairly common practice current nowadays of attributing all combustion troubles and deficiencies to the fuel oil.

The soot blower in modern practice was, of course, of almost as much importance as the combustion control equipment itself, with the fact that the more efficient the combustion control, the less the need arose for the soot blower. The water consumption factor, in the case of the more advanced designs of soot blower in present day use, could be ignored, the blowing medium being compressed air.

The paper set out concisely the commoner types of automatic combustion control in use today, but it seemed that not all of the systems employed a positive emergency provision for shutting down the fuel supply completely in the event of mechanical or electrical failure of the forced draught fan.

In actual operation, assuming the forced draught fan to have cut out due to a fault, the water level in the boiler was drastically reduced, if not lost out of sight in the glass, due, it would appear, to the sudden alteration in the heat release in the furnace causing the rapid separation of the entrained steam bubbles from the water itself, with consequently "denser" water. The fuel continued to be injected into the furnace throughout this period.

As could be imagined, fuel sprayed into the furnace with no forced draught available would give rise in the space of a very short time to a highly dangerous condition and had resulted in several severe "soot" fires, especially when the forced draught was restored and the partially consumed oil was carried upstream in the gas path and "secondary" combustion occurred. One method of approach to this problem, of course, was the fitting of low-level water alarms with a positive fuel shut off.

In practice, as stated, the pressure range was from about 90 to 290lb. per sq. in. and some provision must be made to prevent fuel at a pressure lower than 90lb. per sq. in. being allowed to pass through the burner, since below this figure the pressure was not sufficient to atomize it and consequently a highly dangerous condition arose. To eliminate this possibility entirely it was the practice in some cases to fit a distance piece in the diaphragm-operated fuel valve which would not permit a fuel pressure lower than 90lb. per sq. in. This practice was preferable to allowing the fuel to cut back to zero but did demand increased vigilance from the operator.

Although he referred briefly to the hybrid steam pressure jet burner, it was perhaps to be regretted that the author did not mention the electronic type of control fitted to it in some American ships. Although this form of burner was dismissed by the author on account of the loss of water which usually precluded its adoption, with modern installations where both feed and domestic water were evaporated and distilled from sea water, that factor was of little or no relative importance and it was perhaps only a matter of time before this type of installation, which had proved so advantageous in shore practice, would become equally well established in the marine field.

Author's Reply

The author's thanks were due to Captain Gregson for his remarks, which amplified the relevant sections of the paper.

Captain Gregson had referred to the difficulty of assessing any gain in efficiency resulting from the installation of automatic controls. In this connexion, the author had mentioned that the results of trials carried out under normal seagoing conditions were liable to error due to the many variables affecting fuel consumption; even the figures obtained from voyage returns would have to be examined with great care to allow for differences in loading, weather conditions, fouling of the ship's bottom, etc. It would appear that tests on a vessel with turbo-electric propulsion would allow for the greatest accuracy, in view of the ease of power measurement in such cases.

In connexion with Captain Gregson's remarks regarding wide range burners, which had been referred to by a number of contributors, the author pointed out that the main advantage claimed for the German rotary cup burner was its improved efficiency at reduced loads, which was particularly desirable in the case of warship boilers. Some test figures from boilers of the German aircraft carrier *Graf Zeppelin,* fitted with Saake ring type burners, had been published in B.I.O.S. Report No. 382* from which the following are extracts:—

Output t./hr.	Oil fired Kg/hr.	CO_2 per cent.	Efficiency
62·1	5,127	11·3	87·8
47·4	3,840	12·5	89·4
31·3	2,354	13·2	93
17·5	1,258	14·3	94

It was mentioned in this report that the original Saake burner did not give very good results, but with the ring type burner it would be seen that the maximum burner efficiency and CO_2 was obtained at about 25 per cent full power.

As mentioned by Captain Gregson, sufficient care was not taken to avoid condensation troubles in the compressed air lines in some of the earlier installations. The author understood that it was now the recommended practice to fit an after-cooler to the air compressor and a suitable filter was also normally fitted in the air line.

Mr. Nelson's query regarding the efficiency of the louvre type damper had been ably dealt with by Mr. Young and the author had nothing further to add.

In connexion with the second point raised by Mr. Nelson regarding the design of the oil fuel pressure pump relief valve, this fitting was normally supplied with the oil burning unit and as such was part of the standard equipment. The design of this bypass valve from the discharge to the suction side of the oil pump should be such as to maintain a constant pressure on the upstream side of the regulating valve by bypassing fuel in excess of requirements delivered by the pump when the output was reduced below normal.

Owing to limitations of space it was not possible to deal in any detail with the various types of wide-range burners available; a full description of the design and operation of the burner mentioned by Mr. Nelson was given in a paper published in the Transactions of the Society of Naval Architects and Marine Engineers†.

In reply to Mr. Hayden's query in connexion with the cost of maintenance of the automatic control equipment, it was difficult to give any definite figures. Some owners operating ships with automatic boiler controls had a routine examination of the equipment made by the manufacturer's representative every time the vessel returned to a port in the United Kingdom, although it was only rarely that any adjustments or replacements were necessary. The cost, therefore, depended largely on the frequency of such examinations but would be hardly likely to exceed £100 p.a. It was not considered desirable to place undue emphasis on the economics of the subject in a paper of this nature and it was not the author's intention to justify the use of automatic controls but merely to examine the case for and against their use from the point of view of an impartial observer. As mentioned in the paper, no definite figures could be given of possible fuel savings and as Mr. Hayden himself had pointed out, automatic controls might have advantages which could not be directly assessed in terms of £.s.d.

Although the statement on p. 7 referring to the relative cost of positional and metered controls was not intended to refer to the unified control system, Mr. Hayden's interpretation was nevertheless correct since it was claimed by the makers that the adoption of this type of speed control led to a reduction in cost and weight compared with the normal shunt controlled motors. The main savings resulted from the use of smaller motors, since speed control was not effected by field weakening and also separate controllers were not required.

Mr. Hayden's suggestion for control of furnace pressure by the use of automatic bypass control on the induced draught fan would appear to be quite feasible but the use of speed controlled fans seemed to be a simpler method.

In his remarks regarding the control of viscosity Mr. Hayden touched on an important point since, however efficient the operation of the combustion control gear, the best combustion conditions could not be obtained unless the fuel oil were delivered to the burners at the correct temperature. His criticism of the use of an orifice in the oil line for measurement of oil flow appeared to be unfounded, however, because this principle was used in any case, the burner tips normally being the measuring orifices.

With regard to Mr. Hayden's further point in connexion with the difficulty of air heater design when using the rotary-cup burner driven by an air turbine, the author understood that in the German design only 20 per cent of the combustion air was delivered to the furnace via the burner turbine.

The author disagreed with Mr. Hayden on the question of the time occupied in manœuvring by cross-channel vessels as he was not aware of any other class of ship where the proportion of the running time at full load was likely to be smaller. One particular ship came to mind, admittedly on a short sea route, where about 35 per cent of the total steaming time was normally spent in manœuvring at reduced load.

* Plummer, G. A. La Mont Boilers in Germany (For Naval and Mercantile Marine Use). B.I.O.S. Final Report No. 382, H.M. Stationery Office.

† Haynes, G. P. and Letvin, S. 1938. A New Fuel-Oil Burner. Trans.Soc.N.A.M.E., Vol. 46, p. 277.

Mr. Young's censure in regard to the lack of consistency in the terms used was accepted with due humility (the proviso should perhaps have been added that the terms recommended in the British Standard Glossary were adhered to only in the section indicated). As Mr. Young rightly pointed out, however, the terms used were considered to make the paper more readable to those unfamiliar with the subject.

In his remarks on wide-range burners, Mr. Young put rather a different aspect on the question of the desirability of burners capable of an output range sufficient to cover all normal load requirements. Control apparatus of sufficient sensitivity would undoubtedly reduce the reliability and robustness so necessary for marine use and therefore it might be preferable to limit the range of variable capacity burners for this reason.

The author could not agree with Mr. Zoller's statement that leakage of air through closed registers was an advantage; even if only from the point of view of reducing thermal shock of the refractories, it would appear advantageous to reduce air leakage to a minimum. The suggestion by Mr. Zoller that the master loading pressure could be used to control the steam flow to the oil heater would appear worthy of careful consideration and, if operated in conjunction with some form of viscosity control, should lead to more accurate functioning of the system under varying load conditions.

Although the term "highly rated boiler" was not clearly defined, as pointed out by Mr. Zoller, it was often colloquially used to denote one having a high output per unit of weight or volume and gave an indication of the sensitivity of the boiler to changes in the rate of firing.

Mr. Zoller pointed out the difficulties which might be experienced in the application of unified boiler control to marine service and the author agreed that if it were necessary for the motors to be capable of wide speed adjustment by field weakening, the advantages of the system were nullified.

The author was interested in Mr. O'Breen's remarks, particularly those on operating pressures with range control, and noted that in the example quoted the controlled pressure and not the boiler pressure was somewhat reduced at maximum load.

Notwithstanding the fact that a venturi tube for air flow measurement might be used in close proximity to a bend, Mr. O'Breen would agree that it was preferable to fit it in a straight length of ducting where possible; in any case the venturi itself occupied a considerable length which could introduce some difficulty in a shipboard installation.

The author thanked Mr. Burns for his remarks but did not think they called for any comment.

In reply to Commander Green's first point regarding the rate of change of steam pressure and fuel supply, the author regretted that he could not provide any specific data, which would necessarily have to be based on tests, since these variables depended only to a small extent on details of the control system and mainly on the boiler design, fuel pump details, etc. The methods of control adopted for air and fuel flow influenced the rate of response in so far as the time lag between a change in air loading pressure and adjustment of the controlled condition depended on the characteristics of the regulator used. As pointed out in the paper more rapid adjustments could be made by means of dampers and regulating valves than by speed control of the fans and pumps. Means were provided in the control units for adjustments to prevent over correction and consequent hunting in the case of rapid changes in load. It was, of course, not possible for automatic controls to anticipate a sudden change in steam demand as, for example, going from "Stop" to "Full Astern". When the boilers were manually controlled, the fuel supply could be increased immediately the order was received on the telegraph but when on automatic control a reduction in steam pressure on opening the astern manœuvring valve was necessary before the firing rate could be modified.

When dealing with fan speed control, Naval practice was not considered but, where the fans were steam driven, regulation of the speed must be made by automatic adjustment of the governor setting or, as Commander Green pointed out, speed fluctuations would result from variations in the exhaust pressure.

The reason for the differences in the master controllers illustrated in Figs. 2 and 3 was that they had been developed by different manufacturers; their function was the same, namely, to set up an air loading pressure proportional to the deviation of the steam pressure from the desired value. Illustrations of both controllers were included to show the different stabilizing devices employed in commonly used marine controls but, as mentioned in the text, no attempt had been made to describe the many types of control units available.

Commander Green's final remarks dealt with operation of the controls in case of an emergency such as a boiler tube failure. In such a contingency it would appear advantageous to have the fuel and air controls centralized at one point as was usual in automatically controlled installations. All control systems were designed so that the regulators might be easily turned over to manual control and in any case the automatic units supplemented, and did not replace, the normal means of control.

The author was interested in Mr. Gollen's remarks, particularly in connexion with the estimated gain in boiler efficiency with reduction in excess air, and agreed that a corresponding reduction in uptake temperature would account for the greater savings sometimes attained in practice. It was difficult to generalize on this subject, however, since the funnel gas temperature depended on the proportion of convection heating surface, economizer and air heater surfaces and on such variables as the feed temperature to the economizer. Mr. Gollen's estimate of a drop of 50-100 deg. F. in uptake temperature for a reduction in excess air from 60 to 20 per cent appeared to be rather on the high side. It had been found in practice, for example in the case of the La Mont boilers in the system shown in Fig. 10, that an increase in CO_2 from 10·2 to 12·5 per cent at constant output, corresponding to a reduction in excess air of about 25 per cent, had no effect on the gas exit temperature of 300 deg. F.

Control of the oil supply by automatic regulation of the bypass valve on the oil fuel pressure pump, as suggested by Mr. Gollen, would appear to be a satisfactory method but, as mentioned in the reply to Mr. Nelson, this valve was normally supplied as part of the standard oil burning unit. It was with points of this kind in mind that the author stressed the desirability of early co-operation between the manufacturers of the various auxiliaries and the automatic control equipment.

The author thanked Mr. Alexander for his contribution and was interested to hear of the mechanical transmission system described; such a method of control would be hardly practicable in a marine installation, however.

The author agreed with Mr. Baker that manning problems had largely influenced the wider adoption of automatic controls, particularly in the case of vessels built under the United States war-time programme. A number of superintendent engineers had been favourably impressed by the operation of such equipment but, as pointed out by Captain Gregson, the analysis of voyage records over a considerable period would be necessary to obtain a definite measure of any fuel economies obtained.

The question of the operation of the German rotary cup burner had been referred to in the reply to Captain Gregson, but it had been reported by a number of authorities that such burners did not give consistently high combustion efficiency. When considering the application of burners capable of control over the whole output range it must be borne in mind that, as stated by Mr. Young, the sensitivity of the control apparatus would have to be greatly increased.

In referring to the wastage of brickwork in all-refractory furnaces under conditions of high furnace rating, it was not the author's intention to suggest that the refractoriness of the furnace lining material would be exceeded in service. In the presence of fluxing elements, usually associated with the fuel ash or introduced by the inclusion of sea water in the fuel oil, the liquefaction temperature of the face of the firebrick was greatly reduced, often to within the range of working temperatures. Such actions were accelerated at increased temperatures

Annual Conversazione, 1951
(Above) Mr. J. Turnbull, O.B.E., and Mrs. Turnbull; Dr. S. F. Dorey, C.B.E., F.R.S., and Miss Rosamund Dorey.
(Below) Mr. B. C. Curling and Mrs. Curling; Miss Dorey and Dr. Dorey.

Plate 2

Annual Conversazione, 1951

(Above) Mr. J. Turnbull, O.B.E., and Mrs. Turnbull; Mrs. Robertson and Mr. A. Robertson, C.C.

(Below) Mrs. Pemberton; Mr. R. B. Shepheard, C.B.E., and Mrs. Shepheard; Mr. H. N. Pemberton.

and therefore any means of limiting the furnace temperature at high outputs, such as an increase in excess air, would be beneficial from the point of view of refractory life.

Mr. Baker touched on an important point, also referred to by other contributors, when he mentioned the necessity of close control of viscosity of the fuel. The author added, however, that the working conditions normally corresponded to a relatively flat portion of the temperature-viscosity curve and a considerable variation in temperature of the oil could be tolerated without an appreciable effect on the viscosity.

The author thanked Mr. Morgan for his contribution, with which he was in general agreement. As mentioned by another contributor, the regulating mechanisms employed were usually capable of adjustment to give the dampers the required characteristics.

Mr. Morgan also suggested that the main advantage of compressed air for the transmission system was its availability; this was not normally the case, however. Advocates of pneumatically controlled systems claimed that the main advantages over hydraulic transmission lay in the increased facility of remote control, the reduction in transmission piping, lack of importance of leaks in the system, etc.

Mr. Shaw's interesting remarks did not call for any comment on the part of the author unless it were to add that the fireman would probably have some difficulty in making adjustments to give the predetermined optimum conditions at reduced loads when manœuvring.

Mr. Stevens quite rightly pointed out that it was not usual to fit a positive fuel shut-off to operate in the event of failure of the forced draught fan but in this emergency the fuel supply would be automatically reduced to the pre-set minimum value by the ratio controller. It would be possible, of course, to fit an interlock to prevent any fuel being supplied to the furnace on loss of fan pressure but this would be independent of the automatic combustion controls. It must be remembered that the primary function of these controls was to maintain efficient combustion and not to provide for all emergency conditions; the possibility of a dangerous condition arising from a drop in the water level should be taken care of by the low-level fuel shut off normally fitted.

As Mr. Stevens went on to say, it was the practice in some cases to set the fuel regulating valve to prevent the oil pressure falling too low for efficient atomization. It seemed to the author that the simple arrangement which gave an indication by lights or audible means when the fuel pressure reached predetermined limits was the best solution to this problem.

The author was not familiar with the electronically controlled steam atomizer mentioned by Mr. Stevens unless he referred to the photo-electric cell flame detector which had been developed in the United States as a safeguard against the injection of fuel into the furnace in the event of flame failure. It was the author's opinion that electronic controls would not find wide application for boiler room service.

In conclusion, the author wished to thank all the contributors to the discussion for the many useful comments, which added to the value of the paper.

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting held at the Institute on Tuesday, 27th November 1951

An ordinary meeting was held at the Institute on Tuesday, 27th November 1951, at 5.30 p.m. Mr. J. Turnbull, O.B.E. (Chairman of Council), was in the Chair. A paper by Mr. B. Taylor, B.Sc.(Eng.), A.M.I.Mech.E., entitled "Automatic Combustion Controls for Marine Boilers" was read and discussed. Seventy members and visitors were present and nine speakers took part in the discussion.

A vote of thanks to the author was proposed by Mr. W. Lynn Nelson, O.B.E., and was accorded with acclamation. The meeting ended at 7.55 p.m.

Annual Conversazione

The Annual Conversazione was held at Grosvenor House on Friday, 7th December 1951. The President, Dr. S. F. Dorey, C.B.E., F.R.S., and Miss Dorey received the 1,250 guests; during the dinner which followed, a toast to the President and Miss Dorey was proposed by Mr. J. Turnbull, O.B.E. (Chairman of Council), to which Dr. Dorey replied.

After dinner, Sydney Jerome's Ballroom Orchestra played for dancing until 1 a.m., though there were two interludes during the evening for cabaret, with acts by the "De Vere" Young Ladies, Marga Rita, Jacqualli (assisted by Jean), Ernie Dillon and Partner, the Montmartre Ballet, the Famous Caroli Brothers and the Reiffs.

Hull Local Section

On Friday, 23rd November 1951, the Hull Local Section inaugural dinner was held at the Guildhall and was attended by the Lord Mayor of Hull, Alderman R. E. Smith. The President of the Institute, Dr. S. F. Dorey, C.B.E., F.R.S., and the Secretary, Mr. J. S. Robinson, M.A., travelled from London to be present; a large number of local members and guests attended the function.

(Standing) J. G. Charlton (Vice-Chairman), G. H. M. Hutchinson (Chairman), J. S. Robinson, M.A. (Secretary of the Institute), Dr. B. Pugh, B.Sc. (Honorary Secretary of the Section), and C. J. Potter (Honorary Treasurer); the Lord Mayor of Hull, F. C. M. Heath (Vice-President) and Dr. S. F. Dorey, C.B.E., F.R.S. (President) are seated.

Dr. Dorey proposed the toast of the Hull Local Section; he made a plea for a more serious attitude to their work on the part of the young men and for more co-operation from the older men in passing on the benefits they had themselves received from the previous generation. He said that the establishment of vigorous local sections was a welcome and healthy sign in the life of the Institute. Mr. F. C. M. Heath, Vice-President for Hull, in responding to the toast, referred to the fine tradition of shipbuilding and engineering in the port, where ships had been built since 1693.

J. G. Charlton, the Lord Mayor, F. C. M. Heath, Dr. Dorey, G. H. M. Hutchinson and E. I. Harrison, B.Sc.

Other speeches were made by Mr. J. G. Charlton (Vice-Chairman), who proposed the health of the city of Hull, to which the Lord Mayor responded, and by Dr. B. Pugh, B.Sc. (Honorary Secretary) and Messrs. G. H. M. Hutchinson (Chairman) and W. S. Milner.

Sydney Local Section

The Annual Dinner of the Sydney Local Section was held at the Carlton Hotel, Sydney, on Thursday, 15th November 1951, when eighty-five members and guests were present. The official guests included Messrs. D. Lyon McLarty, Director of the State Dockyard, Newcastle; H. G. Conde, the State Electricity Commissioner; V. J. F. Brain, President of the Institution of Engineers, Australia; Capt.(E) E. A. Good, Engineer Manager of the Garden Island Dockyard; also Professor A. H. Willis, and Messrs. M. D. Athey and J. R. Robertson, who delivered papers to the Section during the year.

Mr. W. G. C. Butcher was in the Chair and opened the proceedings by reading extracts from letters which had been received from Mr. B. C. Curling in reply to a message sent to him on his retirement and also from Mr. H. A. Garnett, the Local Vice-President, who would be returning shortly to Sydney from Britain.

The toast of the Institute of Marine Engineers was proposed by Mr. McLarty in a breezy and interesting address, to which Mr. Ross Cuthbert replied. The toast of "Our Guests" was proposed by Eng'r Captain G. I. D. Hutcheson; Mr. Conde replied on behalf of the visitors and gave a very interesting account of his recent world tour in search of better deliveries for electrical equipment for New South Wales.

Once again the dinner was a most successful function and the whole evening was a great success. The speeches were apt and were greatly enjoyed by those present and after the formal dinner members moved about and remained in conversation for a considerable time. The pleasure taken in this function and the support which members continued to give were most gratifying to the Local Committee.

Junior Section

Barrow-in-Furness Technical College

On Friday, 30th November 1951, Mr. H. Armstrong (Member) gave a lecture entitled "The Construction of Oil Tankers" to an audience of eighty at the Barrow-in-Furness Technical College. The Principal of the College was in the Chair and Com'r(E) J. J. Hughes, R.N. (Local Vice-President for Barrow) represented the Institute.

The lecture, which was illustrated by an interesting series of slides showing tankers in varying stages of construction, was well received and a lively discussion was opened by Mr. L. Redshaw, Shipyard Manager of the Naval Construction Works of Vickers-Armstrongs, Ltd. The discussion, which lasted about an hour, ranged widely from methods of construction, through various aspects of operation and maintenance, to life and conditions on board tankers with particular reference to rates of pay. Mr. Armstrong had no difficulty in dealing with all the points raised. The meeting closed with a vote of thanks to the author, moved by Mr. Redshaw and passed with acclamation.

Poplar Technical College

Mr. J. W. Coulthard, D.S.C. (Member) delivered his lecture, "Welding in Ship Repair Work", at Poplar Technical College on Thursday, 13th December 1951, to a large audience of students from the marine engineering, shipbuilding, barge building and welding classes. The Chair was taken by Mr. W. Laws, M.Sc., Principal of the College, and the Institute was represented by Mr. T. W. Longmuir (Member of Council).

The lecture was divided into three sections, dealing in turn with shipwork, boiler work and general heavy welding, including a cast steel compressor, and was illustrated by numerous slides and diagrams. The lecture provoked a large number of critical enquiries to which Mr. Coulthard replied in detail, the eagerness of the questioners being subdued only by the clock. Mr. Longmuir thanked the Principal for his co-operation in giving facilities for the lecture to be held and proposed a vote of thanks to Mr. Coulthard for the trouble he had taken in collecting such a quantity of practical information. Appreciation was also expressed of Mr. West's services in connexion with the showing of the slides.

CORRESPONDENCE

"Higher Steam Conditions for Ships' Machinery"*

There has been correspondence between Mr. W. Hamilton Martin, the Secretary and Mr. M. Ireland as a result of the use of the term "electro-plating" in the authors' reply to Mr. Martin's contribution to the discussion on "Higher Steam Conditions for Ships' Machinery", in which he describes a new system of electro-polishing. Mr. Ireland contends that a surface cannot be rebuilt and the original dimensions restored by polishing, which is a mild abrasive process. An extract from Mr. Martin's reply is given below:

> "Mr. Ireland is right in saying that electro-plating is a mild process of metal removing.
>
> I have, to my dismay, discovered that the advance information I received on the electro-polishing process, and which formed the basis of my contribution to the paper, was incorrectly conveyed to me. I should not have given the impression that by means of the process surfaces of articles could be rebuilt. In fact, electro-polishing of surfaces of parts used in steam engineering practice and gas turbines, etc., cleans and resmooths them, practically restoring their sectional contour to its original form, as only one or two-thousandths of an inch is removed in the process.
>
> My contribution (p. 265) to the discussion should be corrected by the substitution throughout of the words "resmoothing" for "resurfacing" and "resmoothed" for "resurfaced", and the second paragraph should appear as follows:
>
> "A process of electro-polishing had recently been developed and perfected in this country by a British electro-chemist, by which such parts were successfully cleaned, resmoothed, polished and rebuilt to original overall dimensions. In its present stage of development,

* Published in the November 1951 TRANSACTIONS, Vol. LXIII, pp. 227-269.

parts made from materials such as stainless steels, stainless iron, high duty nickel-chrome alloys and the like could be descaled, foreign deposits removed from entire surfaces, corrosion and pitting reduced and smoothed out, polished and brightened, the original sectional contouring restored and put into service again in little time, avoiding costly renewal."

Membership Elections

Elected 14th January 1952

MEMBERS

Reginald Dudley Howard Abbott
Jan Bakker
Pieter Andrea De Blick
Archibald Corbett Bone
Donald Eadie
Joseph Jones
Alfred George Reed Lott, Lieut.(E), R.N.
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William Marsh
Henry Baron Roberts
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Bryan Taylor, B.Sc.
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John Robert Gilbey
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William Peter Swale Nunan
Hunter Kerr Owen
Jal Pestonjee
Ian Hamilton Stewart
Douglas Murray Thompson
Geoffrey David Turnbull
David Patterson West
Bernard John Worden
John Wilson Young

STUDENTS

Rex Joseph D'Souza
David Robert Speirs
Bernard James Vaughan

TRANSFER FROM ASSOCIATE TO MEMBER

Arthur Borton
Bennett Dodd
Robert Elliott
Joseph William Lamb, Lieut. Com'r(E), R N.
Alfred Noel Thompson
Leslie Arthur Turrell

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

Mahmoud Ahmad Ismail Al-Arabi
Ronald James Hook
Donald MacDonald

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

Trevor Palmer Jones

TRANSFER FROM STUDENT TO MEMBER

Geoffrey Alured Duncan Long, Lieut.(E), R.N.

OBITUARY

W. J. N. BRETT (Member 446) was born at Broughty Ferry, near Dundee, in 1868. When he was four years old, his father died and he was brought to London where he was educated at Buxton College, in the Stratford area. On leaving school, he was apprenticed to Lester and Perkins and remained with them, finally as chief draughtsman, until the company was merged with another firm in 1924. Subsequently, he worked as a sales representative in the London docks area for several engineering firms. Mr. Brett was closely associated with the establishment of the Institute at Stratford in the earliest days; he was elected to membership in February 1891 and for a number of years, until the West Ham Technical Institute was opened in October 1898, he conducted classes for apprentices on the Institute's premises. One or two members, who have also been connected with the Institute almost from its inception, attended these classes. In March 1890, while still an Associate, he read a paper entitled "Friction in Screw Propelling Engines" at a meeting of the Institute. He was proud of the literary accomplishments of his family; his maternal grandfather was James Lees, a lawyer, who wrote "The Laws of British Shipping and Marine Insurance"; his paternal grandfather was distinguished as being the first missionary to British Guiana who, as well as writing many books on the country and the customs of its people, gave them for the first time a written language.

During his last years, Mr. Brett suffered much anxiety owing to the prolonged illness of his wife and, after her death, his own health worsened rapidly; he died on the 29th November 1951.

F. W. DUGDALE (Member 10506) was born in 1892 and educated at Wellingborough and King's College, Durham University, where he obtained a B.Sc. degree. He served an apprenticeship with the North Eastern Marine Engineering Co., Ltd., and then with S. P. Austin and Son, Ltd., both of Sunderland, from 1908/14. He then spent a a year at sea, as fourth engineer with the Ben Line. On his demobilization from the Royal Artillery in 1918, he worked for Dudgeon and Gray, Ltd., consulting engineers and marine surveyors in Newcastle-on-Tyne and London, but returned to S. P. Austin and Son in 1923 to assist his father, who was then managing director. On his father's death in 1929, he was appointed managing director in his place. In 1936, Mr. Dugdale was elected vice-chairman of the Conference and Works Board of the Shipbuilding Employers' Federation and the following year he was appointed chairman; in 1946 he was vice-president of the Federation and in 1948/49 he was their president. In 1942 he was elected to the presidency of the Sunderland Chamber of Commerce; he twice held office as chairman of the Wear Shipbuilders' Association, from 1935/37 and from 1945/46. He was a member of Lloyd's Register technical committee and of the board of the River Wear Commission. He was a member of the Institution of Naval Architects and of the North East Coast Institution of Engineers and Shipbuilders; he had served as a member of council of the North East Coast Institution for many years and was elected an honorary member in 1950 in recognition of his services. Mr. Dugdale was elected a Member of the Institute in 1945.

C. T. INGERSOLL (Member 2070) was born in 1889; he served an apprenticeship with Caird and Rayner of Limehouse and went to sea as a junior engineer with the Uranian Steamship Company in 1908, transferring some years later to the New Zealand Shipping Co., Ltd. In 1915 he joined the Union-Castle Mail Steamship Co., Ltd., and served in their vessels until he obtained a First Class Board of Trade certificate in 1921. From 1921 until his retirement due to ill health in 1945, Mr. Ingersoll was employed by Cable and Wireless, Ltd., and served in all their cable ships, finally as chief engineer. He was at sea throughout the two world wars, in troopships from 1914/18 and on cable repair work from 1939/45. Mr. Ingersoll was elected a Graduate of the Institute in 1908, transferred to Associate Membership in 1915 and to full Membership in 1921.

ARTHUR POLLITT (Member 10129) was born in 1891 and was apprenticed to Browitt, Lindley and Company of Manchester from 1908/12; he attended day and evening classes at the Royal Technical College, Salford, from 1906/12. From 1912/13 he worked as a junior engineer with Hick, Hargreaves and Company of Bolton and in 1913 as an assistant in the engineering department of Metropolitan-Vickers Electrical Co., Ltd., Manchester. From 1913/19 he was contract and constructional engineer with the Brush Electrical Engineering Co., Ltd., Loughborough; from 1919/27 he was employed in the construction department of the Manchester Corporation Electricity Department. From 1927 until 1948 he was chief constructional engineer to the London Power Company, Westminster. In March 1948, on the nationalization of the service, he was appointed chief generation engineer (construction) in the London Division of the British Electricity Authority, and from October 1950 until his death on the 23rd December 1951 he was deputy divisional controller of the London Division. Mr. Pollitt was elected to membership of the Institute in 1945; he was also a member of the Institution of Mechanical Engineers and the Manchester Association of Engineers and an Associate Member of the Institution of Electrical Engineers. He was a member of the Court of Assistants of the Worshipful Company of Horners.

GEORGE FREDERICK ROSS (Associate 10586) was born in Melbourne in July 1887 and after leaving school studied at the Melbourne Technical College, where he obtained a diploma in electrical engineering. He obtained employment at the Jumbunna Coal Mine in Gippsland and in 1906 joined the engineering staff of the Melbourne City Council Electric Supply Station where he worked until he was seriously injured in a railway accident. He joined the staff of Babcock and Wilcox, Ltd., in Sydney in 1911; from 1915/20 he was employed at the Dumbarton works and later helped with the erection of new works for the company in Spain. On his return to Sydney in 1921, he was appointed assistant works manager of the company's new works at Regents Park; in 1929 he was promoted works manager and acted in that capacity until his retirement from active duties in December 1950. Mr. Ross played an active part in the activities of various professional engineering bodies and in the work of the Standards Association of Australia, of which he was chairman for a time. He was elected an Associate of the Institute in 1945. He died in England on 20th September 1951.

JAMES SALTER (Member 8926) was born at Liverpool in 1885. He served an apprenticeship with the Liverpool Engineering and Condenser Company from 1901/05 and at the Barrow works of Vickers-Armstrongs, Ltd., from 1905/07. He spent thirty-two years at sea, until 1912, with the Union Castle Steamship Company, when he joined the New Zealand Shipping Company. He was appointed chief engineer in 1926 and supervised the building of new tonnage in Belfast and Clydebank from 1935 to 1939. He was appointed assistant superintendent engineer in 1939, being stationed at London and Newport, returning to London in 1945, from which office he retired in June 1950. Mr. Salter, who had been a member of the Institute since 1939, died on 9th December 1951.

ROBERT STEWART (Member 8893), born in 1895, served an engineering aprpenticeship with the Fairfield Shipbuilding and Engineering Co., Ltd., Glasgow. After six months sea service with the Anchor Donaldson Line, he joined the Clan Line Steamers, Ltd., and sailed in their ships for six years, by which time he had obtained a First Class Board of Trade certificate. After six months ashore with D. and W. Henderson, Ltd., Glasgow, he joined the Southern Railway Company as third engineer in 1925; he was promoted chief engineer in 1929 and remained in this capacity until 1939. In that year he was appointed assistant superintendent marine engineer of the company's marine workshop at Dover, being promoted later to superintendent marine engineer, the appointment he still held at the time of his death on the 25th November 1951. Mr. Stewart was elected a Member of the Institute in 1939.