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Observations on the Development of Combustion Technique.

READ

By C. P. PARRY (Member).

On *Tuesday, March 10th, 1936, at 6 p.m.*

CHAIRMAN: Mr. T. R. THOMAS, B.Sc. (Chairman of Council).

Synopsis.

THE purpose of this paper is mainly to establish the principles involved and to be observed in the operation of all parts of a modern steam power plant if the boiler units are to give continuous maximum efficiency and reliability, having regard to the cleanliness and freedom from corrosion of the gas side of the surfaces.

Modern methods of treating boiler feed water succeed in maintaining clean internal surfaces, free from corrosion, by excluding non-conducting solids and acid-forming ingredients from the boilers. It will be shown that similar results on the external or gas side of the surfaces are obtained by co-ordinating the operation of the whole of the plant so that non-conducting solid matter, which cannot be excluded from these parts, shall not deposit on the surfaces in forms that are beyond the capacity of available cleaning methods, and that the acid-forming constituents in the products of combustion shall not be permitted to condense and corrode the gas passages.

Slides of various boiler plants will be shown and experiences described in confirmation of the principles and views enunciated, and of their successful application. The paper is intended as a companion and continuation of the Author's "Notes on the Conservation of Heat Energy in Feed Water Arrangements" published in the TRANSACTIONS *of May and August, 1933 and August, 1935.*

At the outset let it be understood that this paper does not purport to be a treatise on the theory of combustion, but a simple statement of facts and practical experiences, connected with the technique of the subject, which the Author necessarily has had to take into account in diagnosing various boiler maintenance troubles brought to his notice by harassed clients, and in prescribing suitable remedial measures.

Where mention is made of the water side of boilers, economisers and superheaters, it is merely incidental insofar as it may affect the combustion side of the heating surfaces and the inner walls of the gas passages, including air preheaters, if fitted.

Chemical and Physical Characteristics

It will be convenient to start with the analysis of one pound of fuel, minimum weight of air for combustion, calorific values, composition of pro-

TABLE I.

OIL.	lb.	COMBUSTION PRODUCTS.	lb.
Carbon	·8352	CO_2 ...	3·0624
Hydrogen ...	·1168	H_2O ...	1·0512
Sulphur	·0327	SO_2 ...	·049
Oxygen	·0136		
Ash	·0017	Ash ...	·0017
	1·0000		4·1643
AIR ...	13·72	N_2 ...	10·5557
	14·7200		14·7200

Dew point 120° F.
Calorific value of oil 18,500 B.T.U.

COAL.	lb.	COMBUSTION PRODUCTS.	lb.
Carbon ...	·801	CO_2	2·937
Hydrogen ...	·055	H_2O	·495
Sulphur ...	·015	SO_2	·022
Oxygen ...	·081		
Nitrogen ...	·021		
Ash	·027	Ash	·027
	1·000		3·481
AIR ...	10·9	N_2	8·419
	11·900		11·900

Dew point 104° F.
Calorific value of coal 14,400 B.T.U.

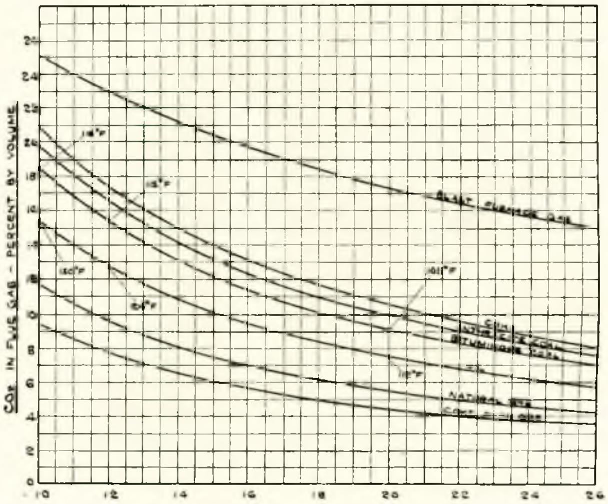
NOTE.—Oil burning produces twice as much water as does coal.

ducts of combustion and dewpoints for one particular quality of oil and bituminous coal, and assuming complete combustion with only the theoretical quantity of air as shown in Table I.

NOTE.—The dew points given in Table I assume that the fuel and air are free from moisture. They have been evaluated from Table II by comparing the weight of vapour in the products with the theoretical weight of air for combustion less the weight of oxygen in the vapour. With regard to the ash content shown, the only property (besides quantity-ratio) that concerns the operating engineer is the fusing temperature. Varying with the metallic oxides contained, this may range from 1,500° F. to 2,400° F. according to information given by numerous authorities.

In practice it is not possible to burn fuel completely in the theoretical quantity of air, and modern developments in combustion technique are mainly to the end that the oxygen from the air shall be more uniformly mixed with the fuel, so obtaining complete combustion with a minimum amount of excess air.

It is common knowledge that ratios of 2/1 for actual to theoretical air for coal firing with natural draught, and 1·5/1 with forced draught were considered good practice until quite recently. Average modern ratios, however, are:—Oil, 1·18 to 1·2/1; pulverised coal, 1·2 to 1·3/1; chain grate stokers, 1·3 to 1·5/1; retort stokers probably 1·2 to 1·3/1.* (See page 4).



RATIO - ACTUAL AIR TO THEORETICAL AIR

POINTS AND FIGURES ON THE CURVES REPRESENT DEW POINTS

By courtesy of a firm of combustion engineers and boilermakers the graph of CO_2 content is included. It should be noted, however, that the curves shown are not based on the particular analyses of coal and oil given in Table I. The

TABLE II (from D. K. Clark).

Temp. ° Fahr.	Quantity of dry air required for 1lb. of vapour in sat. mixture. lb.	Temp. ° Fahr.	Quantity of dry air required for 1lb. of vapour in sat. mixture. lb.	Temp. ° Fahr.	Quantity of dry air required for 1lb. of vapour in sat. mixture. lb.
32	258·8	85	38·4	140	6·61
35	234·4	90	32·5	145	5·62
40	192·2	95	27·6	150	4·77
45	158·9	100	23·5	155	4·03
50	130·4	105	20·0	160	3·26
55	108·5	110	17·1	165	2·83
60	91·6	115	14·6	170	2·33
65	76·4	120	12·4	175	1·92
70	66·0	125	10·7	180	1·54
75	55·0	130	9·1	185	1·22
80	45·6	135	7·74	190	0·93
				212	0·00

Author has added dew points of boiler gases for varying ratios of actual to theoretical air allowing for tropical conditions, i.e. air for combustion having a dew point of 80° F.

It will have been noted from Table I that for every 1lb. weight of oil fuel burnt, as much as 1·0512lb. weight of H_2O steam vapour is formed, whilst for every 1lb. weight of coal burnt, 0·495lb. weight of steam vapour is formed. These figures are irrespective of any moisture initially present in the fuel (this may be considerable with solid fuels) or of that in the air for combustion.

It should also be noted that at all temperatures above the dew point this steam-vapour is *combined* with the flue gases in a finely divided, highly superheated state at sub-atmospheric pressure. Also that the dew point is dependent on the percentage of steam-vapour present and is calculable within close limits.

Should the gases be lowered in temperature to their dew point they are said to be *saturated,* i.e. they cannot hold any more vapour; and in the event of their temperature being still further lowered, vapour-condensation must take place *in the gases* and their dew point will drop with the temperature. Thus moisture will deposit and wet any surfaces which are themselves at less than dew point temperature and with which the flowing gases are in contact. This is, of course, analogous to the formation of rain when a humid atmosphere is lowered in temperature by a cool air current.

It is important to consider the effect of steam soot blowers on the dew point, and also on the completeness of the combustion whilst they are in operation, assuming that they are used only when the boiler is steaming at normal loads. As the simplest form of either forced or induced draught is obtained by the use of steam jets, it is obvious that a steam blower, blowing in the direction of the normal draught in the boiler gas passages, must cause a great increase for the time being in the ratio of air to fuel burning. This increased ratio tends to lower materially the dew point relative to the vapour formed from the combustion of the hydrogen content of the fuel. On the other hand, owing to the further enrichment of the gases due to the steam injected, the dew point tends to rise. As far as the complete consumption of the fuel is concerned the combustion must, if anything, be improved. It should also be noted that the total weight of gas flowing is greater by the weight of steam injected plus the added air drawn through or above the fuel and that the mean specific heat of the gases is raised. The boiler heating surfaces are incapable of cooling this extra weight of gases to the usual temperature. It is therefore impossible for vapour to condense on any heating surface that is free from vapour-condensation under normal conditions.

Within practical limits, steam from a soot blower blowing directly across the normal boiler draught may be taken as neither augmenting nor diminishing the draught, but such steam, by enriching the gases, raises the dew point. It also raises the mean specific heat of gases, and gas outlet temperatures must be higher to some extent. The combustion is not affected.

Steam from a soot blower blowing with a component velocity in the opposite direction to the normal flow of gases must reduce the flow of air into the furnace. This, taken to the limit, results in the dew point rising to 212° F., and combustion being completely arrested. In such conditions pulverised coal and oil burners are extinguished, whilst chain-grate and retort-stoker combustion chambers become heated gas retorts, discharging quantities of unburned volatiles into the boiler gas passages. These products will condense on the surfaces at all periods when there is any positive draught and will continue until normal combustion conditions are restored after the cessation of the blower operation.

Corrosion and Acid Formation.

Some 30 to 40 years ago marine engineers were content to explain any corrosion on the gas side of the boiler heating surface as due to the combination of SO_2 from the products of combustion (see Table I) with water formed by the condensation of vapour from the gases when raising steam from cold. As there was always free oxygen in the products, it was accepted that the H_2SO_3 formed during the more or less gradual raising of steam, combined with free oxygen forming H_2SO_4 (sulphuric acid) which attacked the metal, forming sulphates of iron.

As this corrosion did not occur on boilers the water of which was heated by injection of steam to temperatures up to 280° F. before the fires were lit, it was assumed that acids could not form on the surfaces so long as the gases were never cooled below their natural dew point. Probably, 150° F. would protect the boiler itself, but the higher temperature was considered necessary to ensure that warm air circulated through the boiler gas passages, thus thoroughly warming (and therefore protecting) air heaters and uptakes, etc.

It was, and still is, believed that SO_2 is innocuous unless brought into contact with water when a chemical, as distinct from a physical, change takes place. Continental engineers quote a German chemist who states that SO_2 in the products causes the dew point (condensing or saturation temperature) of the boiler gases to be higher than the natural dew point of vapour-laden air (see Table II). This is difficult to follow as both SO_2 and CO_2 are condensable vapours existing in boiler gases but at such low pressures that at any temperature above the natural dew point they are highly superheated and cannot condense. On the other hand some British engineers now quote American chemists (Bulletin on Boiler Corrosion published by the Illinois University) who claim that boiler gases have a much higher dew point than the natural, i.e. 180° F. to 190° F., owing to the presence of sulphuric acid vapour. It is stated that sulphuric acid vapour is produced by a catalytic action of flue dust on SO_2 in the hot furnace, causing it to combine with free oxygen and forming SO_3 which in turn combines with the highly superheated steam particles in the cooler portions of the gas passages to form H_2SO_4. The Author has no claims to be considered a chemist, but is inclined to doubt whether SO_3 does, or can, combine with highly superheated steam, and thinks that either wet steam or water is necessary to form H_2SO_4. Be that as it may, it can be stated that in an experience of many years handling of all classes of boilers there has never been seen a single case of corrosion from sulphuric acid which was not accompanied, either from incorrect design or operation of the plant, by gases being cooled below the natural dew point, or by condensed water sprayed into the gas passages from badly-designed and incorrectly-arranged steam soot blowers, hydro-jets for breaking up slag in pulverised fuel combustion chambers, water from gas-washing appliances, etc.

As the chemists only refer to traces of SO_3 in boiler gases and ignore practical matters as discussed in this paper, the value of their conclusions may be discounted.

Furnace Temperatures and Fusible Ash.

On the assumption that the specific heat of the products of combustion is about ·27 throughout the range of ratios of actual to theoretical air (for the present purpose this is near enough), and that the coal burns without loss of heat by radiation before it is completely consumed, the mean rise in temperature of the gases in the furnace during combustion would be 2,340° F. with ratio of 2 to 1, 3,070° F. with ratio of 1·5 to 1 and 3,780° F. with ratio of 1·2 to 1.

It is quite safe to assume that in a modern pulverised-fuel or retort-stoker job the maximum furnace temperatures will not be more than the mean rises of temperature stated. This may not be true in connection with a chain grate, as will be more fully discussed later.

Assuming no loss of heat other than heat rejected to chimney and omitting the latent heat of the vapour in chimney gases, then an exit temperature of 200° F. above that of the external air means the boiler efficiencies are respectively 91·5 per cent., 93·5 per cent. and 94·7 per cent.

(1) It will be noted, from actual experiences to be described, that when any boiler is working with maximum furnace temperatures consistent with durability, any fouling of the superheater, rear boiler passes, economiser or air heater must tend towards the compulsory shutting down of the boiler units through excessive air and furnace temperatures. Apart from the life of refractories—with which the Author is not directly concerned—continuous service of any steam boiler depends on the arrangement and operation of the plant being such as to ensure that the first ash to impinge and deposit on the heating surfaces shall have been cooled below its fusing temperature.

(2) Table I is, of course, subject to the proviso that, except in a laboratory, complete combustion could not be obtained under the conditions. This would also apply in many cases even with modern ratios of actual to theoretical air (see * page 2); in fact, with oil firing combustion is often deliberately not completed in some plants, in which event *some quantity of carbon monoxide gas in the products and unburned hydro-carbons must deposit, more particularly in the cooler parts of the plant.* These deposits do not always affect the steaming period of the boiler, except those that form on the superheaters, economisers and air heaters during banking or manœuvring periods. This matter will be dealt with when discussing the plants referred to in (1).

Fouling and Corrosion of Economisers and Air Heaters.

There are, generally speaking, no economisers nowadays in marine steam plants and therefore there have not been anything like the troubles with marine air heaters that there have been, and which still exist, in the economisers and air heaters of land power plants all over the world.

The trouble has occurred mostly in steel tube economisers and in both plate and revolving regenerative air heaters. Cast-iron economisers, particularly of the gilled-tube type, have in many cases become so badly fouled as to require dis-assembling for cleaning, but they suffer less from corrosion than those made of mild steel.

Air heater trouble is not encountered in oil-fired British Naval and first-class merchant vessels, nor in many foreign vessels, because of the insistence by the various authorities on some or all of the following precautionary measures in boiler operation :—

(*a*) Heating the boiler water prior to igniting burners either by steam injection or by circulating water from boilers through feed heaters and back to boilers.

(*b*) By well diluting the products of combustion with air during steam raising and manœuvring periods, to maintain a low dew point temperature of the flue gases.

(*c*) By-passing incoming air from the air heater during steam raising and manœuvring periods.

With regard to both land and marine type air heaters, and also economisers, in many plants trouble has been eliminated by sealing hot gas by-passes mistakenly included by the makers. It is significant that following marine authorities' decisions some years ago regarding plate air heaters of the turbulent type, the makers of these and of the regenerative type have recently installed air by-pass ducts on many land and marine air heaters. It is also significant that air by-pass ducts are now being installed on land and marine plants with balanced draught for tubular and all types of plate air heaters. It is worthy of note that air by-pass ducts are not necessary in the closed-stokehold system of forced draught, as air can be short-circuited direct to burners clear of the air heaters through openings in the hot air ducts during critical periods.

There is generally much difficulty in maintaining clean economisers in industrial plants owing to low feed-water temperatures cooling the gases in contact with the surfaces below the dew point and so wetting the surfaces. This will occur as the boiler load is decreased. The water level tends to fall in the boiler as ebullition diminishes and the feed regulators cause feed water to pass through the economiser at a much greater rate than the normal boiler evaporation. Continental economiser makers realise this effect and advise their clients to wholly or partially by-pass the feed water direct to the boiler during these periods.

It will be obvious in any plant having both economiser and air heater, whether the feed-water temperature is below the dew point temperature of the gases or not, that at periods when the boiler load is being decreased, unless some water is by-passed from the economiser, gas leaving the economiser must be at much less temperature than normal; and unless the cold air is by-passed the gases will be cooled below the dew point in some part of the air heater, and thus fouling and corrosion are inevitable.

Corrosion in economisers and air heaters has been due to faulty design, natural but misunderstood operating conditions, and to misapplied steam soot blowers installed by boiler, economiser and air-heater makers. Plate air heaters have suffered through the whole of the cold air passing over a small portion of one side of the surfaces with only a minute fraction of gas on the other side, this fraction of gas depositing some of its vapour on the inner surfaces during lighting-up and manœuvring periods. Once started this effect spreads and continues even at full boiler loads. Regenerative air heaters suffer through faulty duct designs in conjunction with their extremely fine laminated passages. Deposits falling or being blown into these fine passages act as valves, causing local overcooling and condensation of vapour, the action again being cumulative. Careful design and operation will maintain every type of air heater free from corrosion and in continuous service.

Feed Heating and its Limitations.

Modern power station practice is to eliminate wasteful steam auxiliaries and drive these electrically, taking full advantage of efficient bled steam feed heating.

Attention is now being paid to the fact that when shutting down a turbine plant the bled steam heaters cease to function, and if the feed-water control is as per Fig. 24 in the paper on condensers and feed systems published in The Institute's Transactions of May, 1935 (reproduced here for convenience), trouble is bound to occur in the economisers and air heaters unless the precautions mentioned are taken, or unless the boiler and economiser are fed from a ring main common to several turbine sets.

The closed-feed system as applied to marine water-tube boiler installations has great disadvantages when an economiser is fitted, for in maintaining the boiler level as ebullition diminishes, the feed water from the surge tank is first cooled down to condenser temperature. This cold feed water, if allowed to enter the economiser, would certainly lower its efficiency and also that of the air heater by causing them to corrode and become foul

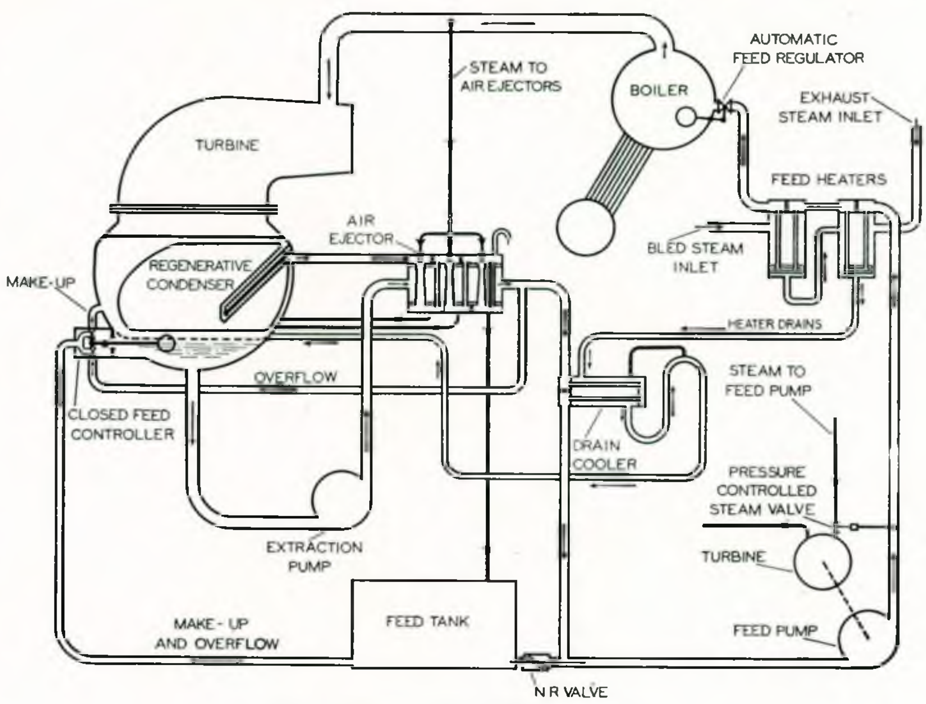


Fig. 24 (from Mr. Hillier's paper).

through vapour condensation. This may be the meaning of the claim that hot feed gives a practical increase in boiler efficiency, but it would be difficult to persuade an engineer in a power station to heat his feed by auxiliary exhaust steam if it was already above the gas dew point temperature, particularly when he realises that he can otherwise protect his economiser and air heater during critical periods.

The significance of the critical periods referred to will be realised by reference to the paper on naval boilers published in The Institute's TRANSACTIONS, Vol. XLIV, Part 12, January, 1933, where it is pointed out that the water level in an Admiralty three-drum boiler steaming at full power would fall about 3ft. upon extinguishing all the burners but for the action of the automatic feed-water controls. Economisers may possibly come back into marine practice; their operation is now better understood, and in that event the closed system of feed-water control will probably be modified to suit.

To the Author it would seem that the modern so-called closed-feed system consists largely of bad practice. He is of firm opinion that water once extracted from a condenser should never be returned to it. The reserve feed water in the surge tank should have passed through the earlier stages of bled steam feed heating when the plant is running, or have been preheated by steam injection prior to starting the plant. There appears to be no practical difficulty in so arranging steam plants, the advantage being that operating engineers would be relieved of complicated precautionary measures with economisers at critical periods whether the engine plant was running alone or in conjunction with others. This is well within modern aspirations —automatic control with no trouble. At present there is a considerable amount of automatic control which produces trouble. Now that air by-passes on air heaters and feed-water by-passes are considered essential, it may be presumed that these will eventually be controlled automatically.

INTRODUCTION TO APPENDIX.

In the following Appendix actual examples are illustrated and described in order to bring out clearly the views and inter-related physical facts enunciated in the paper. In each case cited the Author analyses the various "troubles" which were brought to his notice, and proceeds to show how vast improvements in the running of the boilers were obtained by applying the principles set forth as far as was possible.

It is well known that for many years past boiler users have been put to endless trouble and expense due to the formation of the deposits referred to, which build up in the gas passages and upon the heating surfaces of their boilers, superheaters, economisers, and particularly airheaters. That such deposits are often a source of intensive corrosion is explained in the paper, and once started they will defy all but mechanical means for their removal. Thus it is that many boiler units, ashore and afloat, that should steam uninterruptedly from year to year, have of necessity to be laid off for hand-cleaning every few weeks—despite the frantic use of soot blowers.

It will be seen that the main essentials needed to ensure the continued maintenance of boiler efficiency and cleanliness are:—(1) that the condition of the heating surfaces as governed by the physical conditions obtaining in the plant be at all times within the capacity of the steam soot blowers provided, and (2) the use of a scientifically applied soot blower equipment at regular intervals—as required.

The object of the foregoing paper is to describe how such "troubles" can be completely overcome; how corrosion may be entirely eliminated; and how considerable savings may be effected in time, fuel and money due to the many advantages gained.

The object of the following Appendix, on the other hand, is to prove the effectiveness of the above recommendations by actual examples which have come within the Author's personal experience during recent years, bearing in mind that it is only by frank and honest discussion that ultimate success can be achieved.

APPENDIX.

Example "A"

Fig. 1 shows an arrangement of one of five boilers in a British power station and constitutes a typical example of operating trouble due to the mistaken policy of holding the manufacturers of the several parts of the plant responsible for their efficiency and cleanliness, and of allowing each such manufacturer complete freedom irrespective of how this might affect the plant as a whole.

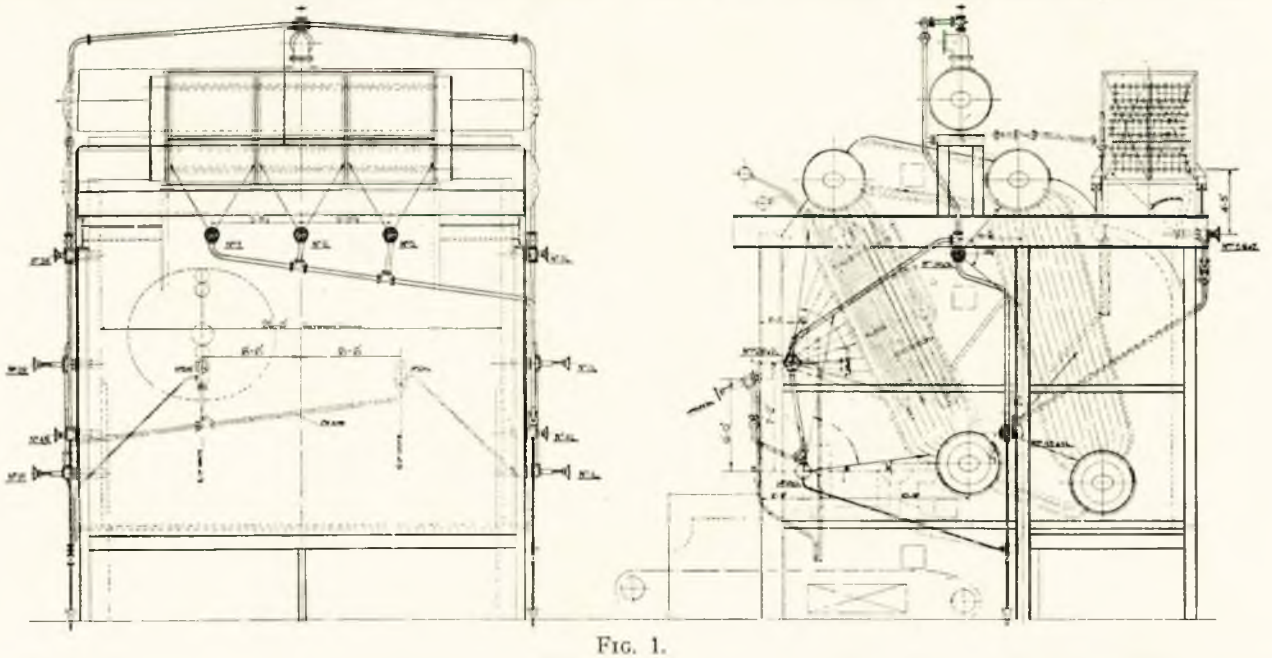


Fig. 1.

The figure shows the plant as originally put into service, except that the two steam soot blowers in the front wall of the combustion chamber were installed after the plant had been working for some time. The rotating regenerative airheater with horizontal axis, taking the flue gases from a horizontal duct above the economiser, is not shown, but attention is drawn to the stop valves for supplying steam to the airheater maker's soot blowers.

These boilers were initially filled with water at a temperature of 180° F., and when put on the range were intended to work night and day continuously for a considerable time. There were no air by-pass ducts on the airheater; gas by-pass ducts, although shown on an early arrangement drawing, were not fitted—whether on account of the Author's objections is not known. The adverse effect of the airheater soot blowers was predicted, but recommendations for countering this were overruled.

The boilers were worked for some time at a reduced pressure of 250lb. per sq. in. (and presumably at reduced evaporation), and if minor troubles were experienced it was thought (but not by the Author) that these would disappear when the plant was worked at the full designed pressure of 400lb. per sq. in. and the soot blowers thus became more powerful.

When, however, the boilers were set to work at the higher pressure the results were as follows: The air-heaters remained clear, being thoroughly washed with hot water twice every eight hours! On further investigation it appeared that the steam consumption of the airheater blowers was at the rate of about 1,000lb. weight per minute. There were two blowers, one blowing with the draught and one against it, operated independently. These blowers, using saturated steam and being fitted too close to the rotor, made it impossible for the steam jets to mix with a sufficient quantity of hot gases before entering the very fine passages. Practically 800lb. steam and about 200lb. weight of water, at a temperature of 212° F., were blown through the airheater in one minute's operation of each blower. (Note: steam expanding from 400lb. per sq. in. to atmosphere condenses by nearly 20 per cent. and this water can only be re-evaporated by the conversion of the kinetic energy of the mixture into heat, or by heat imparted to it while mixing with hotter gases). Corrosion must have been taking place in the rotors, but probably the hot water temporarily removed the evidences. With one exception, dealt with later, these are now the only regenerative airheaters fitted with blowers within the Author's experience, that have not to be periodically washed with hot water and soda.

As anticipated, the effect of the counter-draught blower on the airheater was that, on shutting down, the second bank of boiler tubes was usually festooned with hanging bituminous matter which could not be removed by the blowers provided to clean this particular part. The gas temperature between boiler and economiser rose to about 900° F. instead of the calculated 620° F. The boilers could be worked only from 8 to 35 days before being shut down, owing to the first bank of boiler tubes and the face of the superheater being almost completely blocked with thick layers of slag. Towards the end of the working period the nozzles of soot blowers in the combustion chamber were completely blanked by thick accumulations of slag on the side walls.

The fuel at this station contained ash of very low fusing temperature, but this had caused no difficulty on previous boilers installed by the same makers. The superheater supports being of very heavy design, the slag first built up on these, and the fly ash, having impinged on the hot metal at higher than fusing temperatures, was not in the usual granular form in which ash first deposits on a water-cooled tube. This slag adhered to the supports, elements and even to the water tubes themselves, with the tenacity of barnacles on a ship's bottom, and it was quite beyond the capacity of steam soot blowers to shift it. The contributing factors to this serious state of affairs were as follows:—

(1) The airheater blowers, by producing impossible conditions on the boilers and economisers for the cleaning of these parts, had caused the temperature at the gas inlet to the heater to be much higher than normal, and therefore the heated air supply to the grate to be also at a much higher temperature than normal. This in turn produced unduly high furnace temperatures, which became higher still as the slag accumulated owing to the added draught resistance decreasing the ratio of air to fuel burnt.

(2) The removal of alternate water tubes in the fire row. This was done to allow gas of higher temperature than usual to reach the particular design of superheater, reducing the radiant heat absorbed from the gases before the gas and ash impinged on the fire rows, with the result that the fly ash struck the tubes at higher than fusing temperature and practically welded itself on to the metal.

(3) The chain grates were operated under great intensity of forced draught and without secondary air above the fuel. The gases rising from the bed of fuel at the front were therefore at temperatures corresponding to those in a steelmaker's furnace, i.e., abnormally high temperatures produced by incomplete combustion with just a little less than the theoretical ratio of air to fuel. At that time this method was considered necessary to produce high enough temperatures to rapidly consume the volatiles. The combustion was then more or less completed by blowing excess air through the burnt out products at the back of the grate, thus causing large volumes of ash, which otherwise would have been carried into the dump at the rear, to be blown into the intensely hot zone near the front of the grate, with the result that the critical parts of the first bank of tubes and the superheater were constantly bombarded by myriads of molten ash particles.

The troubles were ended by the following measures:—

(1) The airheater blowers were suppressed. This produced an almost unbelievable improvement. The whole plant, including airheaters, remained perfectly clean, excepting that small deposits of ash were not removed by the blowers from the fire row of water tubes within the approximately circular zones marked on the front view of the boiler. Evidently these patches were in the intensely hot stream of gas rising from each of the two grates.

(2) Fitting soot blowers, as shown in the front wall, to act directly and more powerfully on the critical zones.

(3) Superheater clips and supports were re-designed and re-positioned, to prevent parts beyond being shielded from the blower jets.

(4) Modifying the arrangement and construction

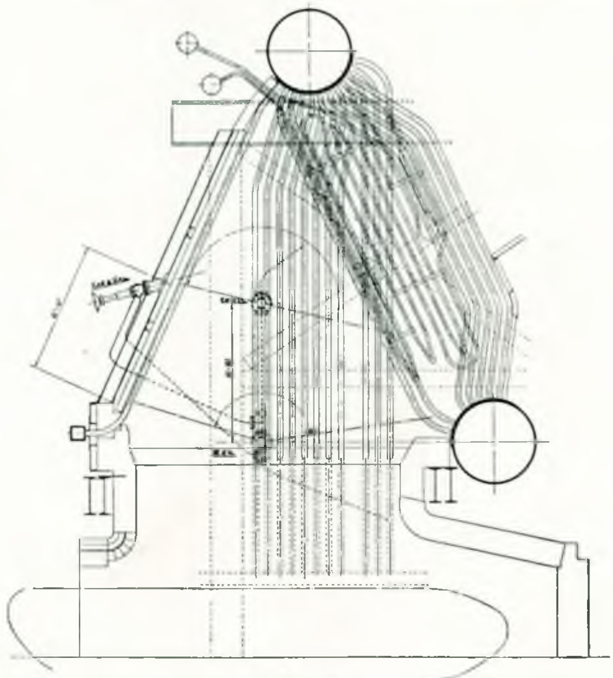


Fig. 2.

of the boilers and of the soot blowers to suit as in Fig. 2. The extra water-cooled surface in the combustion chamber walls must reduce the temperature of the gas and ash impinging on the fire row of tubes and superheater, and to compensate for loss of superheat temperature the rear of the superheater was cleared of the cooling influence of adjacent water tubes.

(5) Probably also by the application of the methods of combustion practised by marine engineers for many

years, and as insisted on by contractors and clients controlling more recent installations having the same type of chain grate, i.e., by the efficient use of secondary air at the front of the grates, with the back of the grate kept covered by fuel from which the volatiles have been consumed. This ensures more uniform temperature along the length of the grate, and minimises the bombardment of the tubes and elements with molten ash.

Example "B"

Fig. 3 shows one of ten boilers installed at a British power station on which heavy slagging and bird-nesting troubles were experienced in the combustion chamber and on the first pass and superheater. The notes relate how

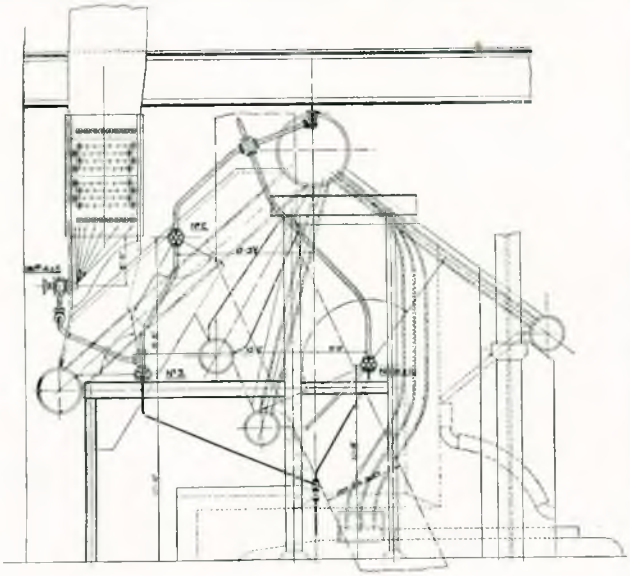


Fig. 3.

the source of the troubles were traced and later eradicated.

Prior to this contract, the engineer had overcome serious airheater and combustion-chamber troubles on other boilers by by-passing air from the plate airheaters during lighting-up periods, light loads, etc. On this new contract the plate airheaters were similar, but with air admitted at one side instead of at two sides, which made them twice as vulnerable. The airheaters were manufactured by the firm who also supplied the chain grates, and means were provided for re-circulating some of the warm air. The airheater makers insisted that there should be no soot blowers on their heaters.

The principal contractors (boilermakers) have always agreed with the views put forward in this paper, and their practice, both ashore and afloat, embodies every precautionary measure advocated, so far as the boilers are concerned. As, for some years, they had fitted steam blowers to clean their own tubular airheaters with success, and as soot blowers were essential for the economisers, they made no objection and, in fact, willingly modified the rear casings of these boilers to accommodate steam blowers in the most advantageous positions for cleaning the economisers and also the airheaters directly above.

Incidentally it may be mentioned that the airheater makers, some time previously, had invited the Author to give his views as to the great amount of trouble experienced with this type of heater all over the country; they attributed the trouble to the effect of steam soot blowers and this had led them to rely on re-circulation of air. It must be admitted that they had reason to blame certain wrongly-applied arrangements of steam soot blowers. Moreover, when it is considered that the ratio of cold air to gas over a small portion of the surfaces at the air inlet is practically infinite, it is obvious that, so long as the air temperature is less than the boiler gas dew point temperature, the gas passing over this surface must give up all the vapour it contains above the amount of saturation at the cold air temperature, when the gas and air velocities are below some particular figure, i.e., when air and gas are a sufficient time in contact with the surfaces for the exchange of the necessary amount of heat. There is usually only sufficient time during lighting-up (and perhaps manœuvring) periods for such vapour condensation to take place, *so long as the surfaces are maintained clean.* If, however, surfaces are not clean, eddies of low velocity gas will occur behind the obstructions even when the boiler is on load, and these gas eddies must be cooled below their dew point and their vapour condensed. It is obvious that re-circulation of air cannot save an airheater on lighting up from cold water, as there is no hot air then available; but naturally it will protect the airheater from further trouble when the boiler is steaming if the air is at a temperature approaching that of the gas dew point. When on the range, so long as the air is not too cold, vapour condensation on these surfaces cannot take place for the reasons stated, and also because some heat is conducted by the metal casings from where the gas and air are both relatively warmer.

The results on this plant were uniformly excellent as regards the cooler parts, economisers and air heaters being kept perfectly dry and clean continuously. There was, however, the slagging trouble on the fire row tubes which had to be overcome.

Generally, this type of boiler (Fig. 3) is not subject to slagging trouble. The closely-pitched small tubes in the fire rows rapidly absorb radiant heat as the gases approach them. The opposite blind bank of tubes also absorbs radiant heat and there are eddy convection currents set up by this cooling bank, causing a quantity of cooled gas to mix with the normal flow to the uptakes through the open tube bank.

The coal contained ash of very low fusing temperature (its composition indicated that it may have come from or near the same mine as the coal used in the boiler shown in Fig. 1). The methods of controlling combustion were much the same as in the boilers previously discussed, and bird-nesting formed very rapidly on the fire rows and succeeding rows of tubes. As these rows became dirty the gas temperature approaching the superheater rose until bird-nesting formed on the face of the superheater, whence it could not be dislodged by the soot blowers provided, and the boilers had to be shut down frequently. Upon investigation it was found that there had been, as would be expected, considerable melting away of the front brick arches by excessive local gas temperature. The fuel had evidently contained iron pyrites as there were stalactite formations of fused refractory and iron hanging from the arches which had wasted by as much as from three to four inches in thickness. Later, frequent use of the steam blowers prevented the formation of bird-nesting on the face of the superheater and enabled the boilers to be maintained in commission.

Still later information was that the fuel was found to contain an ingredient which acted as a flux on the ash and, upon obtaining coal from a different part of the same mine which did not contain that ingredient, the boiler operation became normal.

To protect the arches, it seemed reasonable to expect that the old proved methods of regulating combustion would be adopted later, as indicated in connection with the first plant discussed (Figs. 1 and 2), and as provided for at the outset in the next plant (Fig. 4), and voluntarily with every similar grate since.

In view of the great amount of combustion-chamber trouble still existing in many plants through partly-choked airheaters of this type (the choking being due to bituminous deposits; no means being provided for by-passing cold air when re-raising steam after banking periods; and the general disinclination to use soot blowers on them), it was fortunate that the airheaters on this plant were properly protected and cleaned.

Briefly stated, slagging troubles tend to start as air-heaters gradually choke; and these troubles will become worse as the furnace temperature rises owing to the restricted draught and the consequent reduction in air to fuel ratio.

Example "C"

Fig. 4 shows one of three boilers in a power station in the London area which have never been hand-cleaned since being set to work some three years ago. At the outset all the measures advocated in this paper were agreed upon by the principal contractors and all interested parties.

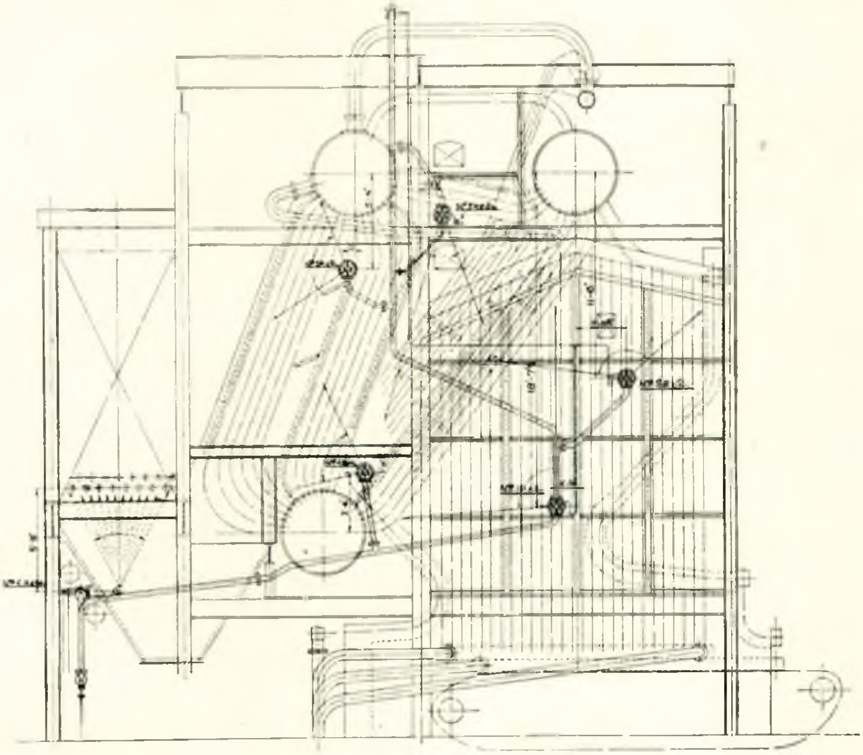


FIG. 4.

In view, however, of the type of superheater and of experience gained with boilers as in Fig. 1 and others, the Author's firm, which was required to give irrevocable guarantees as to *continuous cleanliness* of the plant, had first to obtain the principal contractors' views on chain grate operation. It was reassuring to find that the boilermakers were agreed that it was not only necessary to maintain high temperatures but also imperative to bring sufficient air into intimate contact with the volatiles to ensure that these were completely burned, and that they had provided air ports to give an adequate supply of secondary air, as and when required. The Author's firm was also given to understand that excess air would not be blown through the rear of grate to project clouds of ash into the hot gas stream rising from the front.

The grates, however, were first operated, for a short period, much as in the last two plants described, but upon flames being observed rising up the front of combustion chamber and into the superheater space, the secondary air ports were brought into action, to the satisfaction of all concerned.

The refractory linings of these combustion chambers have so far required no renewals, but even the water-cooled front arches could not have lasted long if the initial methods of operation had been continued. The air-heater fitted was similar to that in Fig. 3, except that in this case there was no re-circulation of hot air.

Example "D"

Fig. 5 shows one of two boilers, installed at a London power station, on which chronic trouble was experienced as a result of soot-blowing against the normal draught, combined with conditions brought about through frequent stopping and starting of the retort stokers.

In the first place it might be mentioned that, extending over a period of some 12 years, the Author's firm had supplied this particular company with a considerable number of combustion chamber soot blowers for their steam generators and, incidentally, they were among the first to use single-nozzle blowers inserted through combustion chamber walls. Invariably, however, the Author was called upon later to investigate what were considered unsatisfactory results, and on each occasion the authorities were informed that better conditions could not be expected unless the parties directly concerned co-operated in re-positioning those soot blowers on the rear passes of the plant which were known to operate against the normal boiler draught. Whenever these earlier boilers were examined, no part could be deemed satisfactory (as in Examples B and C) and the observed conditions were attributed to the wrongly-applied soot blowers in the final boiler passes.

When therefore considering the plant shown in Fig. 5, it was natural that the Author, whose firm had been

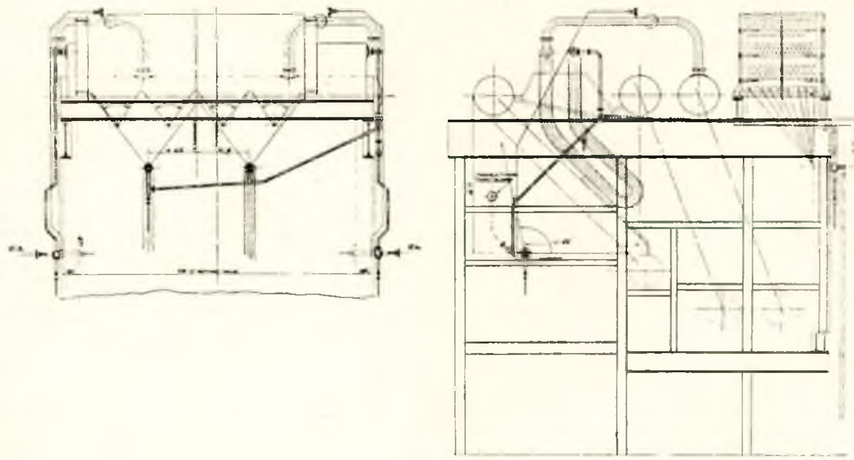


FIG. 5.

entrusted with the equipment for cleaning the first boiler pass and the economiser, was again obliged to point out that perfect results were impossible unless all the counter-draught soot blowers were modified to blow only with the draught.

Finally, four blowers through the combustion chamber walls were proposed, but only two were fitted (numbered 1R and 1L in the illustration). The economiser was equipped with two soot blowers (as proposed) with the proviso that, in the event of the boilers not steaming continuously or being laid off for some hours each night, sanding appliances might be considered necessary later.

The fact that the new boilers were to have retort stokers had also to be taken into account. Correctly designed retort stokers are a sound modern development, for in the Author's opinion they tend to bring furnace efficiency and reliability in line with first-class pulverised fuel practice. Nor does there appear to be any reason to doubt the advantages claimed by this type of stoker. The movement of the fuel on the bars, and the thick fuel bed maintained, ensures such uniform mixing of the primary air with the gasified fuel that the volatiles are completely consumed without secondary air being necessary. (With the best adjustment yet obtained with secondary air on a chain-grate stoker, the mixing is probably not so uniform as with a retort stoker, and this may lead to variations in temperature in the combustion space and to continued slagging and refractory troubles).

Doubts were expressed, however, regarding the possible cleanliness of the superheater, economiser and airheater, in view of the practice of taking a boiler off the range by simply shutting down the air to the stoker whilst the fuel bed was at its normal working thickness, and restarting by merely readmitting the air. On shutting off the air the furnace must have become what its name implied—a gas retort—and large quantities of unburnt volatiles must have been given off by the fuel to condense on any comparatively cool surface. And on re-admitting the air after the fires had been lying dormant for some time, large quantities of unburnt volatiles must again have risen from the fuel until the necessary temperature had been attained to burn them.

In this connection, it had already been observed in gasworks where boilers were fired by waste heat from gas producers under the retorts, and particularly when the retorts leaked to some extent, that the volume of unburnt volatiles carried by the gases was considerable and these condensed on the boiler surfaces in such profusion, that steam soot blowers became ineffective unless sand was mixed with the steam jets.

When a boiler is on the range, with normally good combustion, gritty matter passing with the gases assists the blowers to remove adhesive or tarry deposits, and parts thus fouled become quite clean after a few normal soot blower operations. This plant, however, being situated in a populous district, had of necessity to be efficiently hoppered and the bulk of the grit was trapped before it reached the economiser. There were some doubts as to whether the economiser blowers could be effective without sand being used to supply the required abrasive, especially as boilers were steamed for only 18 out of the 24 hours and the soot blowers would probably not be operated more than twice in that period.

After the plant had been in commission for some time, there came along the usual complaints that the fire row tubes were not being cleaned satisfactorily. Once again it had to be emphasised that perfect results were impossible unless the number of blowers first recommended were fitted and the counter-draught soot blowers on the superheater, second and third banks of boiler tubes modified.

Following this, the principal contractors and the engineers at the station agreed to run the boiler for a fortnight with all the soot blowers operating only with the draught. Again they claimed that the fire row tubes were not clean and asked for an inspection of the plant to be made. When examined the plant was in the following condition :—

(1) All water tubes in front of the superheater were perfectly clean.
(2) The superheater was uniformly coated with bituminous matter about ⅛in. thick.
(3) The economiser was about 80 per cent. clean, there being bituminous deposits lodging between the gills along the tops of the tubes only.
(4) The airheater was free from scale, but about 30 per cent. was choked with bituminous deposit.

It was explained that by-passing the air during banking periods would have minimised the deposit in the airheater, and a further recommendation was made to the effect that the superheater drains should be opened slightly throughout banking periods with a view to keeping the superheater at the same temperature as the water in the boiler and to minimise the condensation of unburnt volatiles on this part.

The Author's recommendations, however, were not accepted (in fact, the original conditions were reverted to), but had they been accepted there would have been no difficulty in bringing this plant into line with the success achieved in Example "C".

Example "E"

The excessive slagging and bird-nesting troubles experienced with the plant illustrated in Figs. 6 and 7 are of particular interest, despite the fact that, here again, the Author was not permitted to bring matters to a logical conclusion. This boiler, and that described in the preceding example, are owned by the same company, but are installed at different power stations.

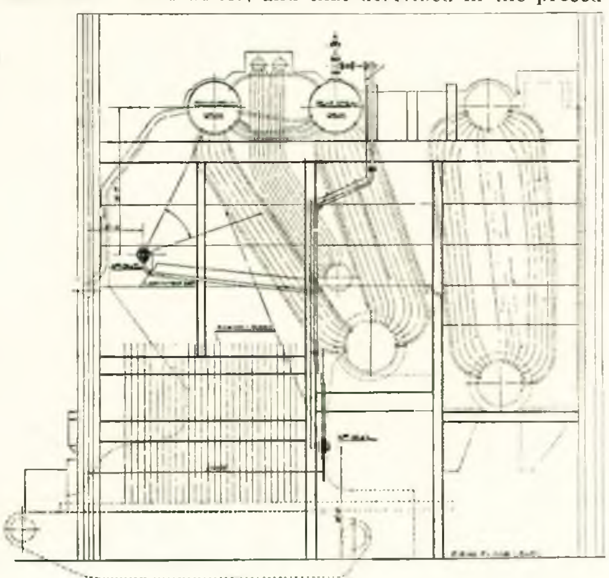


Fig. 6.

In this case no adverse reports were received for some considerable time after the plant had been set to work, but eventually the Author was invited by the principal contractors to investigate the causes of heavy bird-nesting on the first bank of boiler tubes which could not be removed by the soot blowers, and to recommend what modifications were necessary to make the plant satisfactory.

Having been associated with these contractors on several very successful jobs (where "complete" equipments of soot blowers had been supplied), the Author experienced no difficulty in obtaining full information to the effect that all steam soot blowers on this boiler had been arranged for some time to blow only with the normal draught (except one that acted on the superheater), and

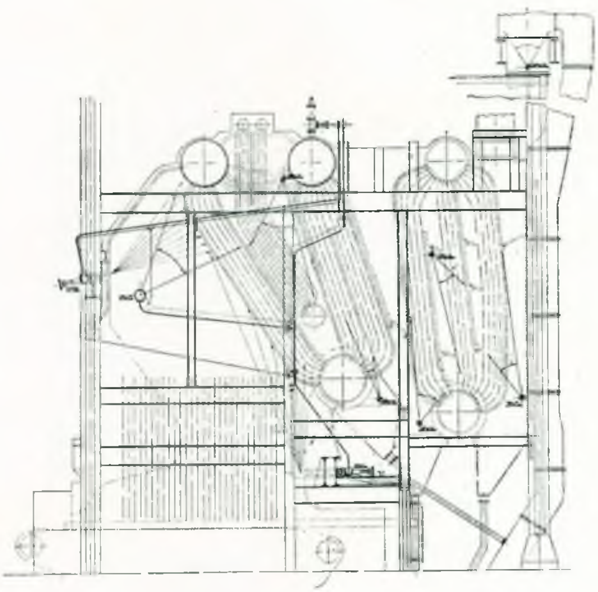


FIG. 7.

that the trouble had only been experienced since the chain grate makers had been experimenting to improve combustion efficiency by the aid of secondary air.

A thorough examination of the plant was made and the following facts emerged :—

(1) There was heavy bird-nesting on the lower half of the first bank of tubes, and also higher up about in line with the top of the first baffle.

(2) Pending the chain grate makers acquiring the necessary experience to make suitable adjustments, the faulty use of secondary air had produced intensely hot zones at the back of the grate which had caused the rear brick apron wall to bulge inwards. Also, the side wall brickwork in way of the No. 1 blowers had bulged and "blanked" the nozzles, making these ineffective.

(3) The second and third boiler passes appeared satisfactory; also the economiser. (It is worth noting that the feed water temperature rose to about 350° F. by bled steam heating at full loads).

(4) The airheater was covered on the whole of its surface in the gas passages with a soft deposit about ⅛in. thick, which meant that more than 50 per cent. of the area was choked. This was considered "normal" after six weeks' working, when the boiler had to be shut down and this part hand-cleaned.

Recommendations included the fitting of one additional blower and modifying the positions of the lower blowers as shown in Fig. 7 (attention is drawn to the efficient trapping of soot and grit shown in this figure), but as guarantees were demanded by the station engineer for cleaning the first pass *without reference to the airheater* the matter was not pursued.

It will be observed that the blowers as modified were in the most favourable positions possible and, so long as the apron wall did not bulge to blank the nozzles, these blowers would assuredly have kept the whole of the first tube bank clean.

(Provision was made to ensure that the lower blowers would remain effective with any bulging of the brickwork that might reasonably be expected). The additional blower (2C) and the existing blowers (2R and 2L) were necessary to clean the top of the superheater, and these were the only safe positions available from which the superheater could have been commanded, bearing in mind the essential feature of blowing only with the normal boiler draught. These three blowers would have effectively cleaned the top of the first bank of water tubes whether the lower blowers were operated or not, and would also have cleaned the superheater so long as bird-nesting was not permitted to form on it, as described in Example "B".

Reservations, however, must be made when soot blowing the combustion chamber, first pass and superheater only on a boiler where the airheater is allowed to choke, and when the fusing temperature of the ash is not known.

It was evident in this case that when the combustion chamber was worked normally at the highest practical temperature, the choking of the airheater, although lowering the heated air temperature, tended to produce abnormally high temperatures in the combustion chamber by reducing the air-fuel ratio at the stoker.

Example "F"

The plant illustrated in Fig. 8 is in a Continental power station and was put into service with the usual arrangements of the boilermaker's steam soot blowers together with the two soot blowers shown in the combustion chamber.

During the guarantee period it was stated that the superheater could not be cleaned except when the combustion chamber blowers only were operated. On the com-

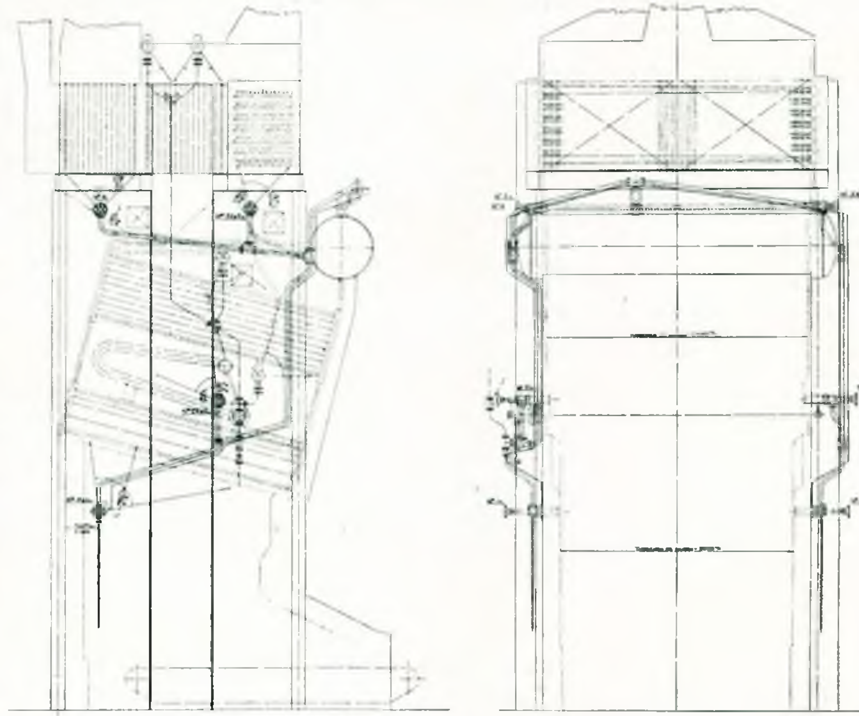


FIG. 8.

pletion of the guarantee period the station officials took control and sent the Author samples of deposit from the economiser and airheater.

There is not much gained by describing or analysing deposits which are preventable; suffice it to say that these were a mixture of soft stuff and hard sulphates of iron. It was reported that the economiser was covered with the hard scale and the airheater with the mixed deposit. Every few weeks the boilers had to be shut down, the airheater tubes plugged at the bottom with clay and filled with a strong soda solution which was left for about 24 hours. On removing the plugs and draining away the solution the tubes could be brushed reasonably clean. It was not known how frequently the economiser and airheater tubes were renewed.

The Author showed that the deposits found were due partly to the counter-draught blowing, partly to condensation of vapour during lighting-up periods, but mostly to water blown into the gas passages from soot blower steam pipes which could not be properly drained. The blower arrangements were modified as in the illustration, and means were provided for steam raising to be performed under induced draught with air by-passed from the airheater, the superheater being kept well drained at all times.

The last report received was to the effect that the boiler had steamed for a period of one year and nine months without any outage for sooting purposes.

Example "G"

Following experience with the last-mentioned plant, the station officials for later units, illustrated in Fig. 9, insisted on the soot blower arrangement as shown on the boiler, but unfortunately allowed the economiser makers to install a blower of their own manufacture on that part. They rightly decided, however, not to connect steam pipes to the airheater blowers which had been supplied by the heater makers. Apparently, from the obsolete position chosen for the superheater, they had been in doubt as to whether this was suitably positioned in the previous boiler design. The change from steel tube economisers and tubular airheaters was also significant.

First reports were to the effect that boiler and airheater were satisfactory but that the economiser was covered with hard scale. It was at once evident that the economiser makers, in trying to ensure the cleanliness of this part of the plant, had given their blower such a great steam consumption that the boiler primed every time it was operated. A reduced orifice was therefore fitted in the economiser blower steam pipe, but this did not entirely cure the trouble as apparently the pipe arrangement could never be properly drained.

It was later reported that the airheaters had been giving much trouble and that there was also a certain amount of bird-nesting in the first boiler pass. On probing the matter further it was ascertained, (1) that some system of automatic combustion control had been installed, (2) that so-called "fly-dust" burners were in use which injected the dust collected in the grit arrester into the hottest zone in the front of the furnace, and (3) that owing to the boiler not delivering the steam at the required temperature, the baffles had been modified. (On another similar boiler a radiant heat superheater had been installed).

The causes of the trouble were defined as follows:—

(1) The badly-drained economiser blower and pipes.
(2) The alteration to the baffling, which caused some of the boiler blowers to blow against the draught.
(3) The fly-dust burner, which caused parts of the fire row boiler tubes to be constantly bombarded with light ash at very high temperature.
(4) The partial choking of the airheater, which was never uniform in the rotor, causing the air to blow in gusts through the grate, the combustion alternating with every revolution of the rotor with correspondingly high and low CO_2 content of gases.

(Attention is called to the efficient hoppers for extracting dust and soot from the pit underneath the economiser which would have adequately protected the airheater had the operation of the remainder of the plant been on the right lines).

Depending on the fusing temperature of the ash it was estimated that (3) would do no harm unless accompanied by (4) when it was fairly certain to do so. Cause (4) was a natural sequence arising from (2), also (1) if the moisture could carry through and condense in the airheater.

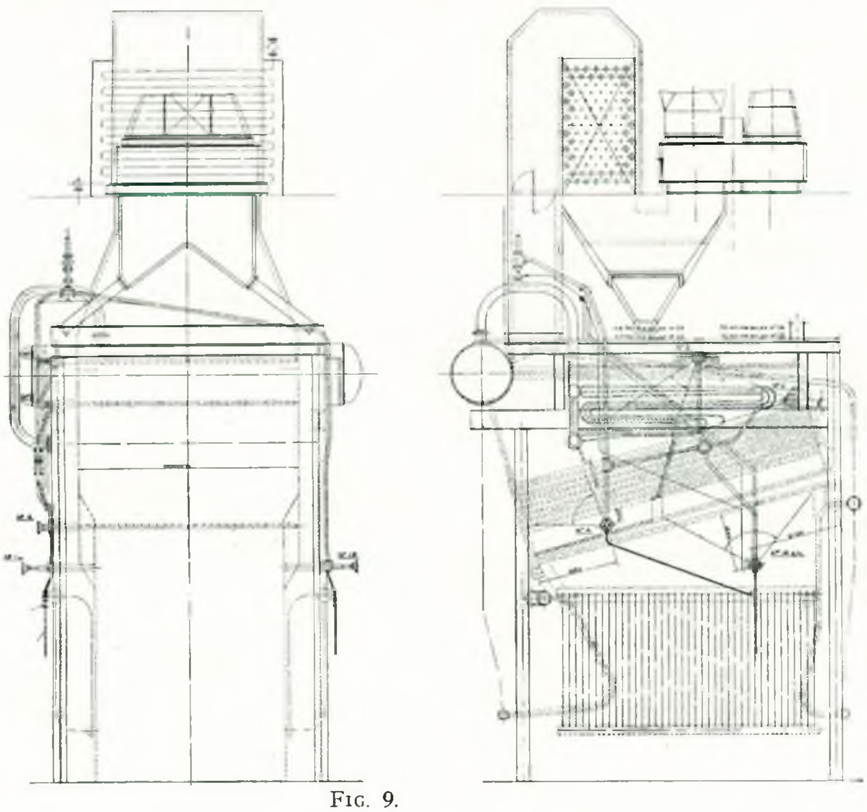


Fig. 9.

Example "H"

The plant illustrated in Fig. 10 is a typical example of severe economiser and airheater trouble and its reaction in the combustion chamber. This also is a Continental plant, and was put into commission with the boiler blowers as illustrated; five blowers on the economiser (supplied by the boilermakers), and two airheater blowers much as described in Example "A".

The boiler could only be kept on the range for about four weeks at a time when the airheater maker's blowers were in

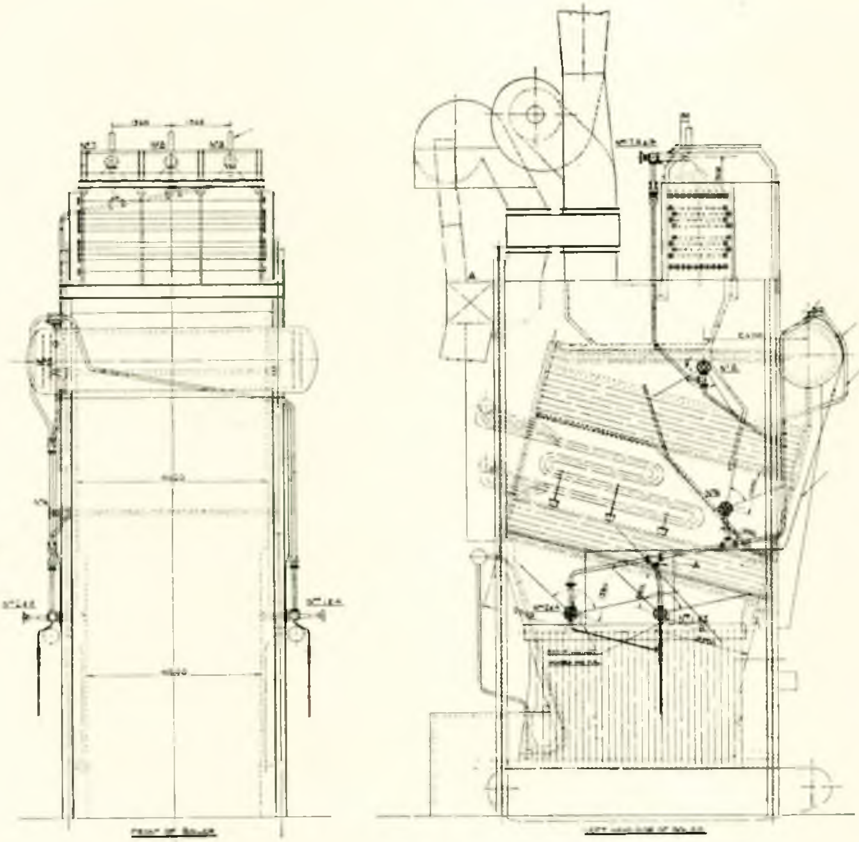


Fig. 10.

temperature, troubles were bound to occur.

The original five soot blowers on the economiser were therefore replaced by three new blowers and sanding appliances as shown in Fig. 10, well drained and at the best vantage points. Nos. 1 and 3 soot blowers were re-positioned in the front wall of the combustion chamber.

After a further run the station engineer reported that (1) the economiser was maintained perfectly clean and free from corrosion, (2) the fire-row tubes were satisfactory, and (3) the airheater performance was improved, but washing down was still necessary about once in every six months.

The Author believes that (2) was accomplished not so much by the re-positioning of the combustion chamber soot blowers as by a reduction in the temperature of the gases rising from the front of the grates. It was probable that, coupled with an improved all-round performance due to the clean economiser, more efficient use was made of the secondary air ports and a lower CO_2 content of the gases maintained.

With regard to (3), the airheater can never be entirely satisfactory under the conditions obtaining until air by-passes or re-circulating ducts (shown in the illustration but not fitted) are provided for use during soot-blowing periods, and until better means are provided for evacuating the deposit from the pit underneath the economiser and airheater.

use. After these had been suppressed, the boiler could run from four to six months when the economiser and airheater became practically choked. For some three years the economiser and airheater were periodically washed, there being an ingenious contraption for catching the water to prevent it running through the holes in the tiles at the top of the boiler.

On examination when laid off, the whole of the boiler was found clean except for stalactite formations adhering to the fire rows of tubes above the front half of the furnace. The rear half was perfectly clean.

After the airheater blowers had been suppressed, the continued combustion chamber trouble could only have been due to, (1) the effects of the badly positioned and drained economiser blowers which fouled this part, (2) the blowing of trapped deposits from the economiser pit into the air heater, and (3) the falling of deposit from this pit (through the holes in tiles over the top boiler tubes) down the first pass into the hottest zone of the combustion chamber, from whence it would be carried with the draught at very high temperature amongst the fire row tubes.

The trouble was certainly aggravated by the so-called slag screen formed by widening the pitch of the bottom rows of tubes, which prevented the fly ash being cooled as much as it would otherwise have been before impinging on the tube metal. The stalactites could only be removed by hammering.

Asked for his advice, the Author gave it as his firm opinion that this hard deposit only formed as the economiser and airheater became foul; that with a regenerative type of airheater (as this was) the rise in air temperature was much the same whether it was clean or dirty; and that when a foul economiser allowed the flue gases to enter it at considerably higher than the normal

Example "J"

The Lancashire plant illustrated in Fig. 11 furnishes yet another interesting example of regenerative airheater fouling and the measures taken to overcome this. Before analysing the various contributory factors, the following preliminary remarks concerning the arrangement and detail of the economiser and airheater installed should be fully appreciated.

From unfortunate experience, economiser makers have long known that horizontal cast-iron pipes are liable to fracture through water-hammer action when filled partly with steam and partly with water. Nor do economiser safety-valves give full protection against this. Naturally, therefore, makers will use every possible means to ensure that, when in operation, economisers of this pattern shall be kept at all times full of water at a temperature below that of the water in the boiler.

When raising steam, ebullition causes the water level in the boiler to rise and, for a time, the feed-water regulators prevent water being fed through the economiser into the boiler. Thus, British economiser makers invariably ask for gas by-passes to be fitted and for these to be used during steam raising periods in order to prevent steam forming in the economiser with probable resultant damage. These gas by-passes have undoubtedly accounted for a great deal of the vapour condensation and corrosion which has occurred both in economisers and airheaters. The dampers are usually not shut quickly enough, and when shut they are seldom gas-tight, with the result that *some* gas circulates through the economisers whether the by-pass is in operation or not. It is obvious that when

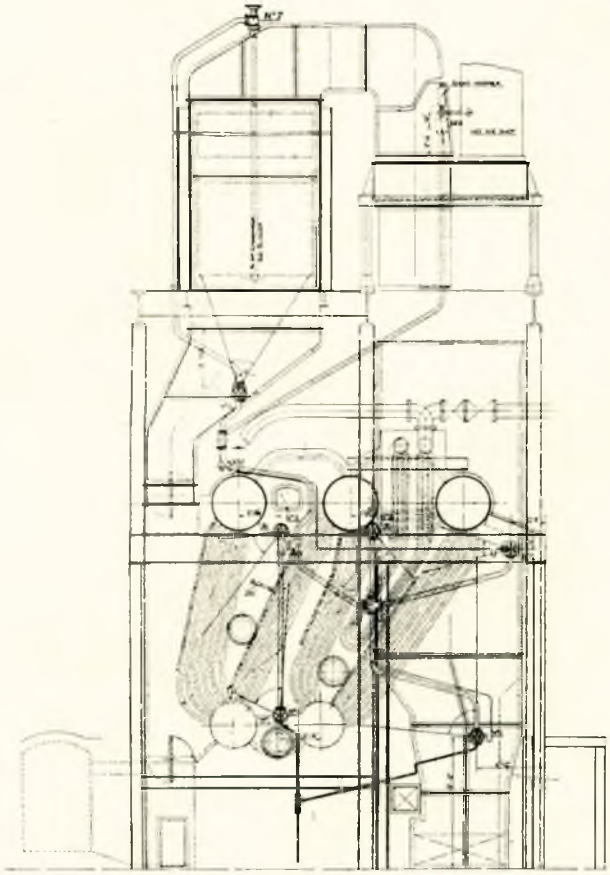


FIG. 11.

the flue gases are by-passed and the normal weight of feed water is passing, any small amount of gas leaking through the economiser must be cooled practically to the inlet feed-water temperature; and if this latter is *only slightly* below the gas dew point, vapour condensation and corrosion must take place on the economiser tubes. Thus, the gas is saturated with vapour on reaching the airheater and, as air by-passes are only now being made the rule with new plants, there is no occasion to search further in accounting for the heavy airheater corrosion which has occurred in the past. On entering the airheater the gas must be further cooled by the cold air circulating, with the result that the equivalent to rainfall is produced. As it is cooled the gas must give up, in condensing on the surfaces, all the vapour it contains in excess of that required to keep it saturated at the lower temperature. Even when the boiler is steaming and the feed-water inlet temperature is considerably above the gas dew point, vapour condensation must take place towards the gas outlet end of the airheater during periods when the flue gases are by-passed from the economiser.

Continental economiser makers have been brought to realise the above facts and now insist on gas by-pass dampers being eliminated or hermetically sealed during any period for which a guarantee of performance is given. Also, they provide a thermostatically-controlled switch which, when water near the outlet of economiser rises to a pre-determined temperature, starts a small electric motor which in turn operates a balanced water valve, allowing some of the hot feed water to escape back to the feed tank, and the pumps to deliver cooler water from the tank to the economiser. This latter arrangement is effective so long as the feed pumps are ready to work and the water in the feed tank is above gas dew point temperature. The Author, however, does not recommend such an arrangement, as there is the risk of a maladjustment of the apparatus cutting off the direct feed-water supply and overcooling the gases approaching the airheaters.

Reverting now to the plant illustrated in Fig. 11, provision was made on this to protect the economiser from overheating and damage from water-hammer action, by incorporating both British and Continental ideas. The gas by-pass dampers are shown; also, there were connections on the economiser which could be used to feed an adjacent boiler which had no economiser.

The boiler and economiser could not be satisfactorily cleaned until the two badly designed and arranged soot blowers on the airheater were suppressed and the No. 7 blower on economiser was installed.

A year or two later the station engineer invited the Author to assist him concerning the cleanliness of the airheater, which necessitated shutting down every three months to clean this part by a washing process which he was anxious to avoid. At the end of each three months' steaming period, portions of the rotor were completely choked with scale whilst other portions were partially choked. On service, this state of affairs was indicated by the necessity to increase the draught pressure, and by the pendulum-like motion of the draught gauge pointer which synchronised with the rotation of the fouled rotor.

The following precautionary measures of operation were drawn up and adopted:—

(1) Before lighting fires, steam was raised on the boiler to a pressure of about 40lb. per sq. in. by the aid of steam injectors.

(2) During this period the airheater was rotated and thoroughly heated up by warm air currents circulating through the gas passages.

(3) The gas by-pass was sealed shut.

(4) The connections on the economiser for feeding the adjacent boiler were blanked.

(5) Steam raising was completed under induced draught, with air (short-circuited from the airheater) drawn through openings provided in the trunks between the airheater and grate.

Results were little, if any, better on the airheater. Next the plant was worked with all precautions (1) to (5), and also:—

(6) The carefully placed steam soot blower and sanding appliance for the airheater shown in the illustration.

Results were still no better, and the Author was faced with the following alternatives:—(1) Accepting the chemist's view that dew point temperatures were even still higher than the calculated figures—as there was no apparent indication that the gas outlet temperature from the airheater ever fell much below 200° F. when the boiler was steaming; or (2) finding a valid reason to account for some natural physical change, resulting from the varying operations of the plant, which had actually reduced gas temperatures below the natural dew point in parts of the airheater without this being shown on the recording instruments. After further investigation it was considered that the question of feed water controls and temperature did not have an appreciable bearing on the matter in view of the added fact that the boiler steamed continuously (but with reduced load) during the dark hours.

The following explanation was finally arrived at and was accepted by the station engineer who had assisted throughout the investigations with enthusiasm:—The large horizontal shelf in the ducting above the airheater collected heavy accumulations of ash and soot between soot blowing periods, and when any blower on the plant was being operated large quantities of this deposit would be disturbed and would fall into the airheater rotor. This would partially seal many of the gas passages in the rotor, and the metal forming these passages would not be heated up to the usual temperature before rotating into the cold air stream. During the period when the partially choked passages were in the cold air stream, the deposits would be blown out by the draught and the metal overcooled. This action being cumulative during successive revolutions of the rotor, the metal plates would be cooled sufficiently to cool, in turn, the reduced quantities of gas struggling through the partially sealed passages to below the dew point at that moment. Vapour condensation from the gases then occurred on the surfaces, more particularly when No. 7 blower was working, causing the corrosion and scaling observed and so restricting the normal draught. When No. 7 blower was operated the gas dew point was estimated at about 140° F.

To illustrate this matter further, the metal in the rotor is normally at about a mean between the gas inlet temperature and air outlet temperature at the top and a mean between the gas outlet temperature and the air inlet temperature at the bottom. Taking approximate gas temperatures of 400° F. and 200° F. and of air 60° F. and 260° F., the mean temperature of metal would be 330° F. at top and 130° F. at bottom.

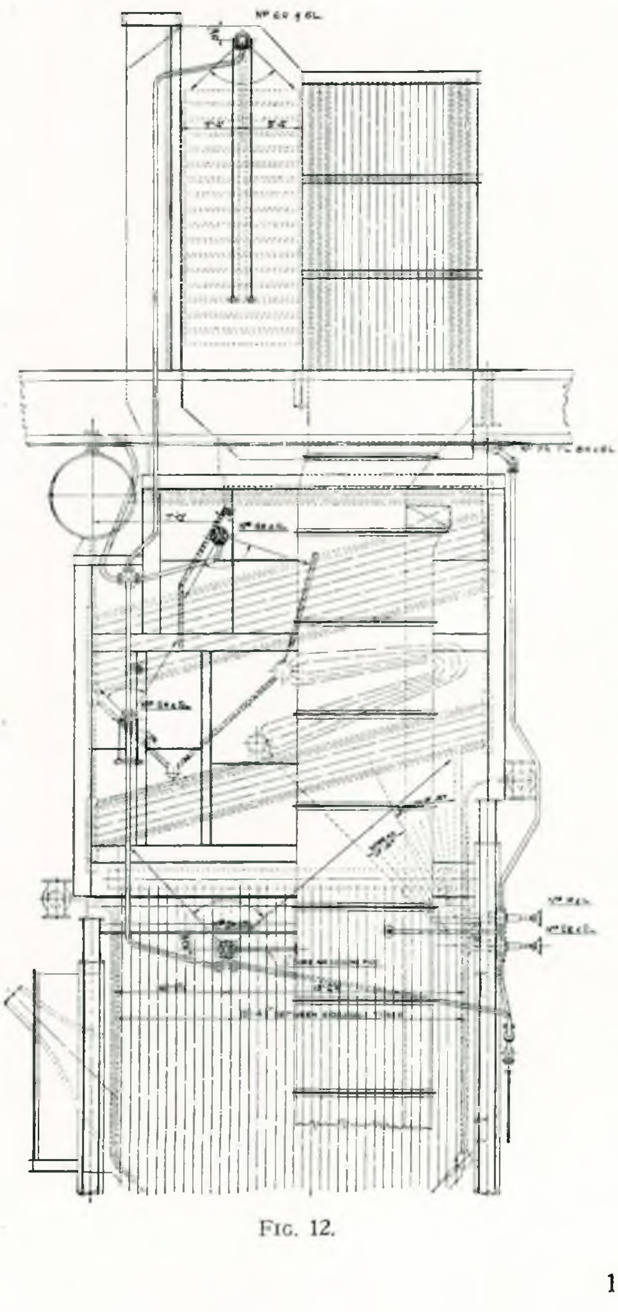


Fig. 12.

It was agreed that hoppers and chutes would be fitted under the horizontal shelf in the top duct, and openings made to prevent the large residual deposits forming. As nothing further has been heard of this job it is assumed that all is now satisfactory.

It is worth noting that airheater trouble of this character did not occur in the plant illustrated in Example "A" after the airheater blowers were suppressed, because all blowers blew only in the direction of the draught, and gravity did not allow any deposits blown into the rotor to remain there for an appreciable time. Probably (in Example "A") such deposits fell to the bottom of the casing and were ground down to smaller size by the motion of the rotor, so that when again lifted into the gas stream they could get through the fine passages; or perhaps they were carried by the motion of the rotor past the seals into the air duct, whence they would be blown clear.

Example "K"

This interesting example may be said to emphasise the practical value of air by-passes at critical periods on balanced-draught or closed-ashpit forced-draught jobs, by describing actual consequences resulting from their omission.

Fig. 12 shows one of three boilers installed at a north country power station which, prior to the Author's investigations, could only be kept steaming for five to ten days after which short period each boiler had, of necessity, to be taken off the range for hand-cleaning the fire-row tubes which became blocked with bird-nesting. The station engineers, on being informed that the trouble probably originated in the airheater, replied to the effect that they did not think this could be the reason as they could run this part for six weeks without having to hand-clean it!

On investigation, the condition of this plant proved it to be one of the two worst cases encountered in this country, being in many respects on a par with that described in connection with Example "F". Both economiser and airheater were seriously corroded, the former being thickly coated with scale from top to bottom. The more vulnerable tubes in the airheater were choked solid, whilst the rest were badly scaled. Very heavy corrosion had taken place on the gas side of the air inlet. On the air side movable dampers were fitted in place of fixed baffles, and these enabled the cold air to be short-circuited from the two top passes into the lower pass when raising steam. The gas by-pass damper was badly warped and could not be closed properly.

On recommendations by the Author's firm, steam soot blowers were installed as illustrated in the figure, and the gas by-pass damper was repaired and sealed shut. As a result the boiler gave no trouble for a working period of ten months. Certain of the airheater tubes, in positions out of the stream-line of gas flow, could not however be kept clear, but corrosion was limited to the bottom two rows of the economiser. The boiler had steamed, on an average, eighteen out of the twenty-four hours and, had continuous steaming been employed, the results would certainly have been better still.

On each of the several occasions during the period stated when the economiser was examined, the two bottom rows of tubes were found wet from end to end, although there was no indication of water leakage where the tubes fitted into their headers. This showed that either the flue-gases became saturated with vapour before leaving the economiser during the time taken in closing down the boiler, or extraneous steam or water had been admitted then or later into the gas passages.

When accounting for the wetness on the two bottom rows of tubes in the economiser, the probable causes to be considered were:—

(1) An abnormally high gas dew point occasioned by an inappreciable partial pressure of H_2SO_4 in the gases.

(2) The closed system of feed-water control causing large quantities of water at much lower tempera-

tures than 120° F. to pass through the economiser at a greatly increased weight ratio to the relatively small weight of flue-gases flowing when the boiler was being closed down. (The normal feed-water temperature was stated to be 120° F.).

(3) Condensation of the steam formed by the use of hydro-jets in breaking up slag at the bottom of the combustion chamber on shutting down the boiler.

In the Author's opinion the explanation was to be found in either (2) or (3), or both.

Example "L"

The illustration of the marine Scotch boiler (Fig. 13) is an actual arrangement as fitted in the "G" class standard ships during the War. It represents a typical closed-ashpit forced-draught boiler as used at sea for the last 25 years or so. Similar boilers, but without airheaters, have also been worked at sea for many years—chiefly under natural draught conditions. In the illustration, attention is drawn to the primary and secondary air valves, also to the ashpit door. By opening the latter the cold air may be short-circuited from the airheater and so passed direct from the stokehold to the ashpit and secondary air valve.

In better-class steamers, the water in these boilers is invariably heated, before any fires are lit, by the methods already mentioned; also, the completion of steam raising, and manœuvring in and out of harbours, is usually performed under natural draught on coal-fired boilers, whether there are fans or not.

Many years research regarding the maintenance of clean heating surfaces in this type of boiler has now firmly established that under the above conditions of operation:—

(1) There is no corrosion in the bore of the boiler smoke tubes.

(2) There is no corrosion in the bore of the airheater tubes, provided they are out of the way of rain descending the funnel.

(3) Effective steam soot blowers for cleaning the boiler tubes, clean the airheater tubes also.

On the other hand, observations show that when boilers are not heated up and circulated prior to lighting fires:—

(*a*) Corrosion occurs in smoke and airheater tubes, and on smoke tube superheaters, particularly where moisture dropping from the airheater tubes falls on elements and headers.

(*b*) Effective steam soot blowers on boilers may almost remove evidences of corrosion in the smoke tubes if the ash lodging in the tubes is sufficiently abrasive. When steam soot blowers are first operated on a boiler which has worked for some time without them, and without preheating of water before lighting fires, hard rust scales are blown like hailstones against the smoke-box doors and fall to the bottom of the boxes.

(*c*) Under such unfavourable conditions, separate blowers acting on the airheaters may improve the airheater efficiency to some extent, but cannot approach the conditions as under (2) and (3) or prevent the useful life of the airheater tubes being curtailed.

Higher than natural dew points, due to the presence of H_2SO_4 vapour in the gases when the boilers are under steam at sea, cannot be the explanation of the hard scale found in smoke and airheater tubes on Scotch boilers, as in vessels of the same fleet on the same service, burning similar coal, there is not a vestige of corrosion on the boilers of some of the vessels while there is heavy corrosion on others.

In the application of oil fuel to the type of boiler illustrated, designers have kept closely to the effective methods of protecting airheaters used with coal-fired boilers. Means are usually provided for raising steam under natural draught with small bore oil burners in order to ensure a high ratio of air to fuel and correspondingly low dew points, the cold air being short-circuited from the airheaters.

In view, however, of a case reported to the Author, in which very serious choking and corrosion of the airheater tubes took place on a ship where all the precautionary methods above described were standard routine, it would appear that the typical arrangement of airheater and ducts illustrated is not adequately equipped for full protection against vapour condensation under oil-firing. This may be explained as follows:—

When coal is burned, all fires are alight while a steamer is being manuœuvred in busy waterways; and when—if necessary—natural draught is changed to forced draught, or vice-versa, the distribution of flue-gas and air in the airheater is just about as uniform as when the vessel is at full speed.

On the other hand, when manœuvring an oil burning vessel, the burners have to be extinguished and re-lit as the demand for power varies, and it is not possible to extinguish or relight all the burners simultaneously. Also, the small bore oil sprayers (used in raising steam) are not in use, and probably the forced-draught fan is running idly when burners are extinguished in readiness for emergencies, i.e., manœuvring is under forced draught with all the air for combustion passing through the airheaters.

If all primary and secondary air valves are tight, the airheaters are kept warm by natural convection currents rising from the

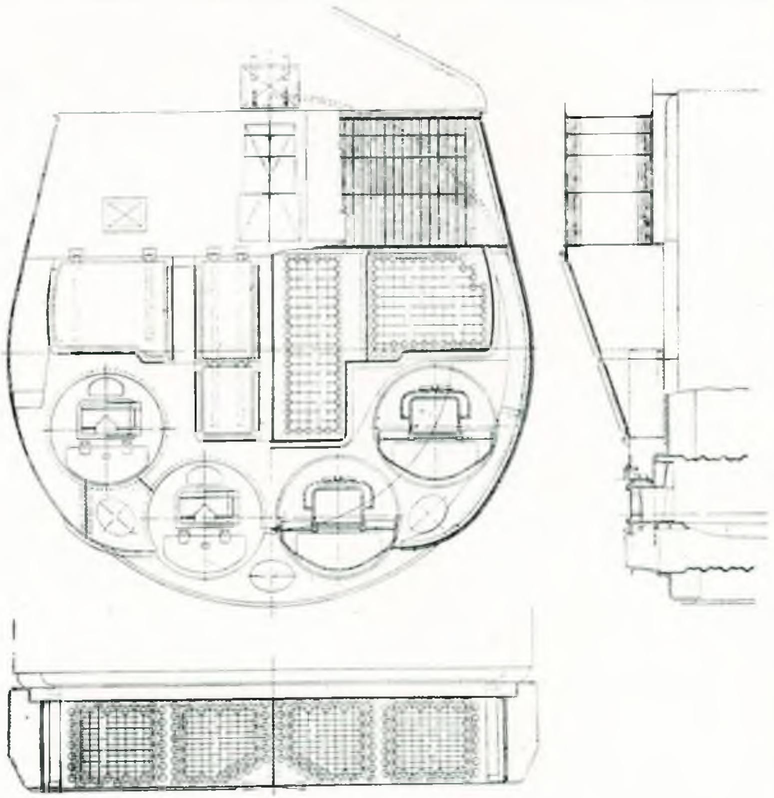


Fig. 13.

smoke-box, but in opening the valves on any one furnace, the fan drives the air through each side of the airheater and must overcool the heater tubes on the side of boiler on which the furnace valves are still closed. Before the burner is lit the air circulating through its particular furnace, nest of boiler tubes, smoke-box, and airheater nest, may (or may not) keep this latter warm enough to prevent vapour condensation from the first products of combustion; but the adjacent airheater nests must become overcooled unless the valves on their furnaces are also opened. For example, suppose the valves are closed on the furnace adjacent to that in which the first burner is lighted. Some gas will leak past the smoke-screen plates and will enter the adjacent overcooled airheater nest. The inside of the tubes must become wet—just as the windscreen of a motor car becomes wet inside during rainy or cold weather, or the glass chimney of an oil lamp on first lighting. This tube nest may be considered a separate airheater, from which gas is supposed to be by-passed, but through which some gas leaks, and is equivalent to the land plants described on which gas by-passes were used.

It is probable that such airheaters would be protected during manœuvring periods if the valves on all furnaces were left slightly open—whichever burners were alight or extinguished. Protection would also be possible by fitting dampers in the air casings at the sides, so that each burner could be lit (except the last) with no air flowing through the airheater tube nest directly above it. Airheaters on oil-burning Scotch boilers, in closed stokeholds or with induced draught only, could be protected during manœuvring periods by opening doors arranged in the air-trunks between airheaters and burners—as for many closed stokehold water-tube boiler installations.

All the above methods, however, seem complicated compared with fitting, at the outset, simple air by-pass ducts and dampers for use until the vessel is at full speed, clear of congested waters.

Examples "M" & "N"

The plants illustrated in Figs. 14 and 15 may, with advantage, be considered together. Fig. 14 shows an oil-fired factory plant working in London, and includes an arrangement for re-circulating hot air from the casings between the hot air outlet and oil burner, back to the forced-draught fan inlet. Fig. 15 represents a fairly recent (1929) high-class Merchant Marine boiler and, allowing for the gas flow being upward instead of downward through the airheater, the draught arrangement is the same as in Fig. 14.

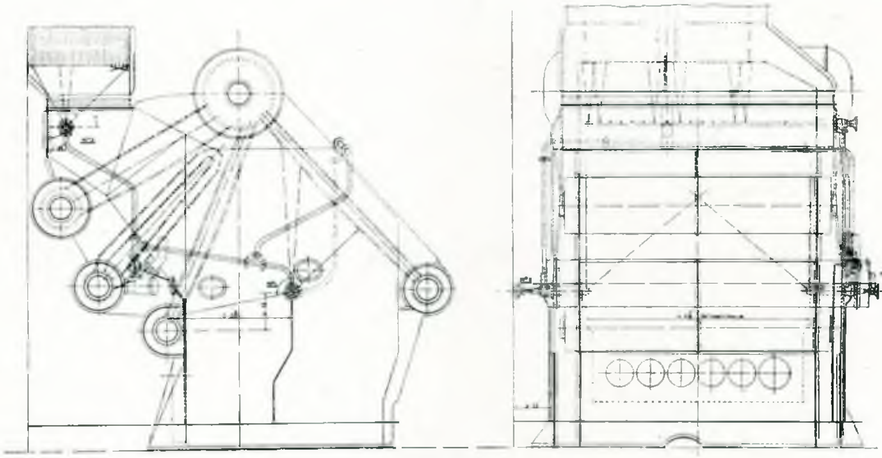


Fig. 15.

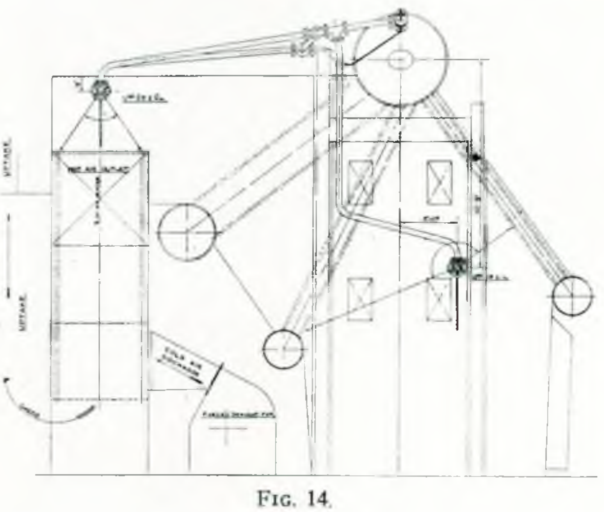


Fig. 14.

At first neither plant had means for preheating the boiler water before raising steam, but these were provided for in Fig. 15 immediately following the vessel's maiden voyage. Earlier marine plants of this type were generally similar, but in view of experience with coal-fired Scotch boilers, separate soot blowers for the airheaters were not installed until the vessels had been on service for some time. The necessity for soot blowers on such airheaters will be apparent when the following remarks are studied.

Prior to building the boilers shown in Fig. 15 there had been some choking trouble with airheaters which varied considerably in similar vessels on the same service. In some ships little hand-cleaning was required, whilst in others great difficulty was experienced with the airheaters. The choking occurred more particularly in the tubes around the air inlet, and also in those which rain could reach when falling down through the funnels and uptakes. On these vessels, when raising steam from cold water with the air for combustion passing through the airheaters, water dripped from the airheater tubes and the casings between the boilers, and airheaters became quite wet and remained so until the water in the boiler was heated.

Referring now to Fig. 14, steam was raised from cold water on this plant six times in the first 12 months, after which it was reported that all was satisfactory except that the lower 3 feet of the 13ft. long airheater tubes was covered with hard laminated scale to a thickness of about $\frac{3}{32}$in. The owners suggested that the foul and corroded airheater tubes were due to the steam from the airheater soot blowers, and that there could not be any other reason as the re-circulation of hot air maintained the air entering the heater at 130° F. when the boiler was steaming. The Author was invited to give his views and in discussion with the boilermakers later, it was ascertained that the plant had steamed for some time under similar conditions, but without the airheater blowers being operated, and that the scale found was three times as thick and extended practically to the top of the heater!

The marine plant (Fig. 15) was reported clean throughout after trials with the exception of the airheater tubes above the thick line shown on the illustration. It was suggested that the soot blowers had not been blowing on those particular tubes; but when it was demonstrated

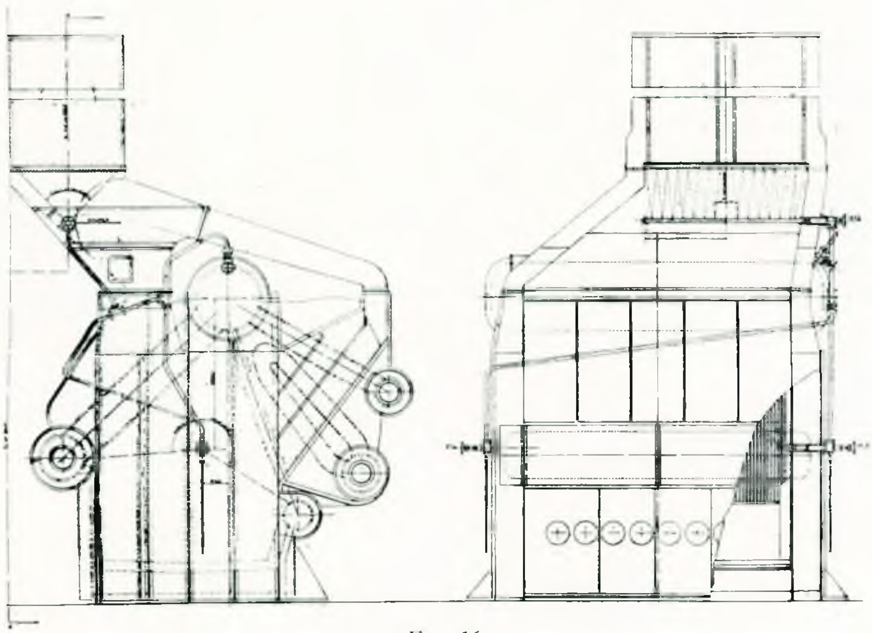


Fig. 16.

modern Atlantic liners — one British and the other foreign. The actual boiler illustrated shows one of the foreign vessel's boiler units.

In the British vessel there are eight of these boilers in groups of two abreast fore and aft. Means are provided for heating the boiler water prior to raising steam, and induced draught fans are installed to assist the forced draught at overload powers. After the vessel had been some time in service, the Author was requested to inspect the air-heaters which were not considered satisfactory following a long cruise on which only poor quality oil (which did not ignite readily) was available.

On inspection, all boilers and superheaters were found satisfactory. The air heaters of the extreme after pair of boilers were fairly clean; the next pair forward were nothing like so clean; the next pair forward were worse; and the extreme pair forward, the worst of all. Further information was to the effect that in the time available in port before sailing it was only possible to circulate boiler water to a temperature of about 150° F. in the forward units, rising to a maximum of about 220° F. in the after units, the boiler water "circulating" pumps being in an engine room abaft all boilers. From the positions of the worst tubes in the airheaters, and even allowing for the inferior fuel used on the last voyage, it was considered advisable not only to circulate boilers prior to igniting burners but to by-pass the cold air from the airheaters during lighting-up and

that they had, it was accepted that the conditions were beyond the capacity of steam soot blowers, and means were provided for preheating the boiler water prior to lighting burners when raising steam. Further reports are not available, but in view of later experiences it would be expected that the particular groups of tubes would be cleaner, but not perfectly clean.

Example "O"

Fig. 16 may be taken as representing the boilers in two

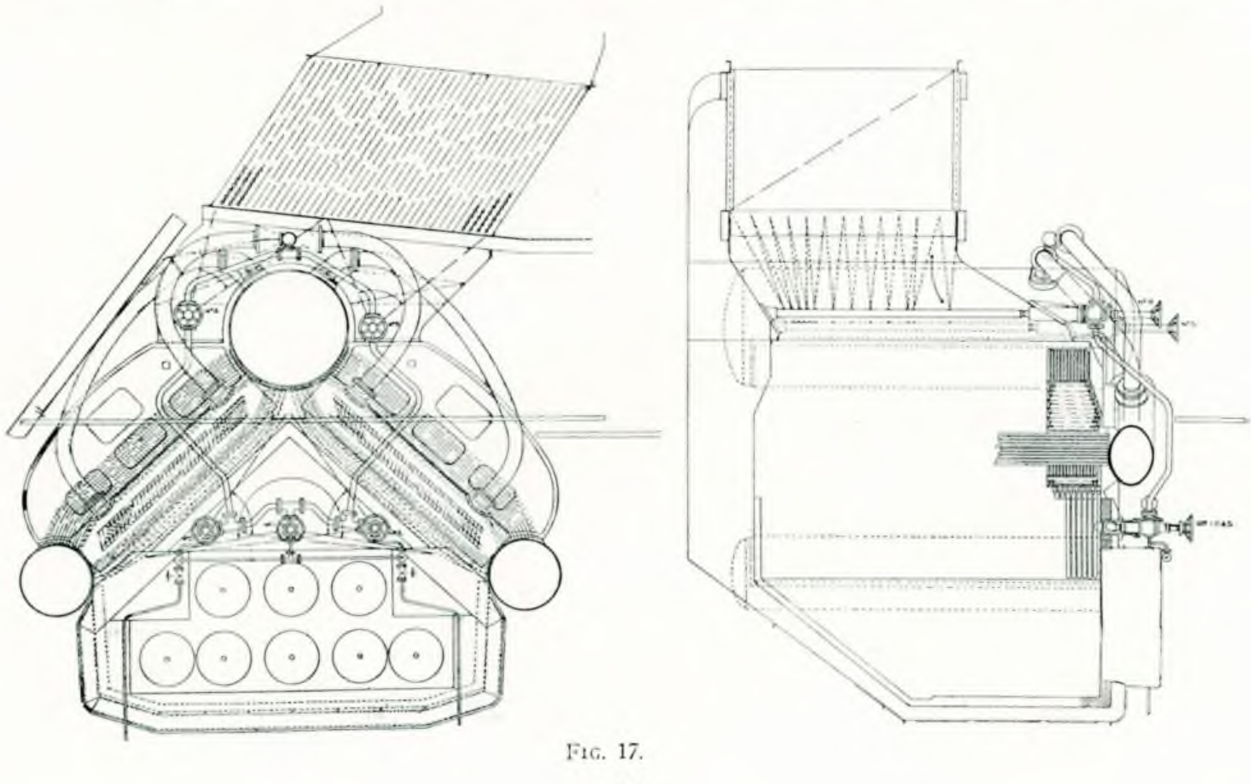


Fig. 17.

manœuvring periods, in line with the old-established practice with Scotch coal-fired boilers. This would simply mean providing, if not already provided, easily-operated doors on the air trunks between airheaters and oil burners, to admit air direct from stokehold to burners without it passing through the airheaters during the critical periods when natural or induced draught only would be applied as required.

In the foreign vessel there are forced and induced draught fans, and it was agreed by the builders and owners, following the Author's recommendations (which were supported by the boiler designers and the oil firing contractors) that doors, to permit of steam raising and manœuvring under natural or induced draught only, were *essential* for the protection of the airheaters. Preheating of boiler water prior to igniting burners was not agreed to.

Example " P "

Fig. 17 illustrates a modern naval boiler unit operated under forced-draught in a closed stokehold. The boiler water is not heated prior to igniting oil burners initially, but doors are provided for short-circuiting the cold air clear of the airheaters during critical periods.

Attention is drawn to the portable baffles for deflecting the gases to the front of these airheaters. Owing to the shape of the uptakes it was feared that, without the baffles, tubes at the front end of the airheaters might be *starved* and not get their fair share of the gases on account of the natural stream-line effect. Had this occurred, vapour-condensation and consequent corrosion seemed probable in these tubes during light steaming rates.

[After extensive trials of a warship equipped with boilers of this type, signs of corrosion *were* noted in the front tubes of the airheaters—as expected, but it is understood that there has been no recurrence of this slight trouble under service conditions.]

* * * * * * *

Perhaps the most fitting conclusion to these notes would be a reference to the main boiler equipment of the "Queen Mary"—the great ship towards which all eyes are now turned.

The boiler units installed in the "Queen Mary" are generally similar to Fig. 16, working under a closed-stokehold system of forced draught. In line with the latest practice outlined in this paper, it is understood that suitable doors are provided on the air casings for the purpose of short-circuiting the cold air from the airheaters during critical periods, and that there will also be means available for "circulating" the boiler water to a good heat before raising steam with the oil burners.

Discussion.

Mr. J. Hamilton Gibson, O.B.E., M.Eng. (Member of Council), opening the discussion, remarked that as one of the oldest Members of the Papers Committee he would just like to say that this was the kind of paper they often dreamt about, but seldom managed to get. There were plenty of papers to be had recording successes, but very few that gave accounts of troubles met with in everyday work and the means taken to overcome them. Only recently they were favoured with a remarkable paper dealing with shaft failures, etc. and the lessons to be learnt therefrom, and on discussing this with a well-known superintendent engineer the latter said that he might describe plenty of interesting breakdowns and repairs from his own experience, but for obvious reasons it simply could not be done. Mr. Parry, however, was not bound by any such restrictions and had presented them with some very valuable information which deserved careful study.

A perusal of the Author's paper and the dozen or more actual examples of boiler troubles and their remedies led one to the inevitable conclusion that most, if not all, such troubles could be avoided by the simple expedient of keeping all heating surfaces and gas passages *warm* and *dry*. Easier said than done, of course, and that was not the whole story. But it did mean this—that any normal deposits of soot and ash could then be readily dealt with and the steam generating surfaces maintained at maximum efficiency for indefinite periods. It was not necessary to blow all the stuff up the chimney; as shown in the examples, probably 95 per cent. of it could be trapped and removed by means of hoppers arranged in suitable positions on the plant. In that connection he might quote the case of a well-known ocean liner where the wing smokebox doors had frequently to be opened and cleared of deposit which had first accumulated in the horizontal uptakes and then cascaded down whenever the ship gave an extra heavy roll.

The primary source of trouble was clearly set out in the very first paragraph of example "A" in the appendix, viz. the mistaken policy of "divided responsibility". In these days no one would expect the makers of a superheater or an economiser to be responsible for their internal surfaces; it was recognised that the water and steam circulated round the whole system and what was good (or bad) for the boiler itself was also good (or bad) for every other part. But what happened in regard to the gas side? Makers of grates, economisers, airheaters, etc. were expected to guarantee that their special parts would always be maintained efficient and clean; in other words, that they would never bung up with ash and soot. "Certainly" they would say, "we will see that our particular part of the plant is keep in good condition", and in so doing it did not matter to them where the stuff went or how it might affect other parts of the system. He, the speaker, had seen steam soot blowers stuck right in the centre of an economiser stack; at first glance an ideal place—for the economiser—but as it happened the very worst place that could be chosen, for the adjacent parts were wetted by the steam jets, the normal draught was arrested, and tarry deposits induced in parts far remote that were very difficult to clean afterwards.

On the other hand, cases were sometimes met with where airheaters were deliberately allowed to soot up until they got beyond the capacity of the draught fans, and the plant had to be shut down for hand cleaning. That happened every five or six weeks, whereas, as might be seen in example "C", there was no reason why such plants should not carry on for *fifty* or ***sixty weeks,*** or even longer. Meanwhile, what was the effect of the partial choking of an airheater? Half-way down the first column of page 88 it was shown that the resultant restriction of the air supply might boost up the furnace temperature to nearly 4,000° F., at any rate considerably higher than the maximum fusing point of the ash as given on page 86, viz. 2,400° F. Consequently, molten ash welded itself on to the fire row of tubes and in a short time the boiler shut itself down or had to be taken off the range as described on page 88 (1). Then it was that the most powerful soot blowers were useless and as likely as not the unfortunate soot-blower manufacturer was blamed because he could not achieve the impossible. Incidentally, he might point out that in effect these blowers were carefully designed auxiliary engines which, when in operation, used high-pressure steam equivalent to 800 or even 1,200 i.h.p.

There were many questions he could put to the Author, but that would not be quite fair to listeners because he already knew the answers and it was better that they should propound their own queries. He might, however, mention two items only, because these were always cropping up in conversation and Mr. Parry might like to deal with them in his own way. (1) Why was saturated steam preferred to superheated steam for soot blowing? and (2) what were the objections to using compressed air for this purpose?

The paper, as it happened, made little or no reference to these points (it was, of course, impossible to cover the whole range of boiler operations), but he thought this might afford an opportunity for the Author to throw some further light on these essential matters.

Mr. J. Reid (Visitor) said that on page 88 the Author had introduced some very interesting figures in connection with furnace temperatures and fusible ash. The speaker suggested that these were academic rather than real figures and he strongly objected to an assumption, even though hypothetical, that "the coal burns without loss of heat by radiation before it is completely consumed". He might be misunderstanding the Author, but surely at this date it was a remarkable suggestion that even under laboratory conditions a bed of fuel on a grate should burn to transmit heat through the furnace into the water and do so without radiation.

So far as the speaker could figure it out the fire bed must transmit to the surface of the furnace and then to the water at least 30 to 50 per cent. of the total heat value in the fuel. The net result of such a hypothesis was that the Author's temperatures all became quite useless. The speaker knew that as far as Scotch boilers were concerned they were quite useless. He had a suspicion that the first temperature of 2,340° F., or even the second of 3,070° F., might be found if in certain phases of the combustion the temperature of the flame were taken by means of a thermo-couple, but certainly the general temperature of the furnace would not approach these figures. Such temperatures in Scotch boiler furnaces would simply represent failure, because a great deal of the heat generated must go into the water direct by radiation and the general temperature of the furnace should not exceed 2,000° F.

He had difficulty in following the Author's deductions as regards boiler efficiencies, whether or not they were intended to apply to water-tube or Scotch boilers of either the land or marine types. There were no such efficiencies in any kind of existing boiler, nor could they be anticipated for any boiler of the future.

He was interested in the Author's statement that 11½ to 12 per cent. was about as far as one wanted to look for CO_2 in even the best of modern land plants, for which higher efficiencies could be planned than for marine installations.

The speaker had come to the conclusion that it was far better to cut out airheaters. Alternatively, if by-passes were fitted, this conformed with what the Author admitted had been done in Scotch boilers for fifty years. The Scotch boiler in Fig. 13 had a by-pass arrangement which could be used in starting up and manœuvring.

The Author took the unction to himself that when by-passes were fitted in the system it was to prevent the blowers causing trouble. Actually, the reason by-passes were put in was that the airheater tended to close up and one had to "get on with it". The Author would admit that there had been a great deal of trouble at sea with so-called high-efficiency airheaters due to their closing up. No blower was going to move from a flat or corrugated sheet or tube, ash which was welded on to the surface. In this connection he had noted in the paper the expression "fly ash". A great deal of the material baked on to tubes was good coal dust, and in oil-burning plants a considerable amount of combustible baked on. That stuff could not be removed by any reasonable amount of soot blowing.

The speaker thought that the solution of a great many of these difficulties lay in the direction of a more thoughtful introduction of the fuel and air into the furnace, and a greater determination to get the highest possible furnace efficiencies, because, as everyone knew, no type of boiler could have a high general efficiency without a high furnace efficiency.

On the proposal of **Mr. A. F. C. Timpson, M.B.E.** (Member) a very cordial vote of thanks was accorded to the Author.

By Correspondence.

Mr. E. H. Gibson (Associate Member) wrote that, in placing on record so clearly and forcefully the plain facts of the case, Mr. Parry had done valuable service to all those engaged upon the design and operation of modern steam generating plant, and it was to be hoped that in future work full advantage would be taken of his unique experiences. That the finest boiler units were manufactured by British boilermakers was, of course, common knowledge; but it was beyond comprehension that more sound thought and ingenuity had not been displayed hitherto in allowing for the natural physical laws of flue gases at critical periods—laws which were well known, but were so often found to have been completely disregarded, with the inevitable dire results. The drive for higher overall efficiencies by increasing combustion temperatures, and the use of preheated air, had succeeded only in making matters worse, and it was high time that serious consideration was given to the maintenance of clean heating surfaces for prolonged periods.

For instance, was it not regrettable to find in 1936 that it was the practice at many prominent power stations to allow plate airheaters to fur up with soot (which could quite easily be cleared by carefully positioned soot blowers) and to compensate for the resultant draught loss by increasing the "pull" of the induced draught fans until these became overpowered in their efforts to maintain the normal draught conditions? Such practice was but the distorted outcome of many years of airheater trouble due to the failure on the part of designers to include the necessary protective measures, and to the wholesale use of badly-drained systems of poorly-designed soot blowers, many of which were arranged to blow against the draught, thus creating atrocious conditions.

In this latter connection the practice of certain airheater and economiser makers of supplying soot-cleaning appliances integral with their products was to be deplored—unless the makers were also prepared to supply additional casings or ducts in which to house their appliances far enough away from the nearest heating surfaces to ensure that no "wetting" could take place. When blowing an economiser or airheater, a mixing distance of several feet was needed, on account of the relatively low gas temperatures, in order to ensure that the blower steam had ample time to become well dried and mixed with the hot flue gases. It would be interesting to have Mr. Parry's views on that particular point.

In support of the mistaken method of plate airheater operation above mentioned, it was sometimes argued that so long as the difference of draught pressures in and out of the heater were maintained as the airheater fouled, no harm could ensue. Such an argument was, of course, absurd where soot blowers were already used on boilers and economisers (but not on airheaters). The running period of such a plant was limited to the time it took the airheater to get beyond the maximum capacity of the induced draught fans—usually but a few weeks—and during that short period the conditions throughout the gas passages became rapidly worse.

It was not uncommon to find cases in which 50 per cent. of the normal clear area through a plate airheater had become blocked by a soft flour-like deposit—accumulations of layer upon layer of fine grey soot adhering to the flat plate surfaces. Under and approaching such conditions, with the fan power increased to maintain normal draught readings, it naturally took the products of combustion all their time to be sucked through the narrowed passages quickly enough. Now it was clearly shown on page 87 of the paper that when soot blowing in the correct manner, the draught pressures were boosted up and there was an increase in the total volume of gases passing through the boiler. Obviously, therefore, the effect of soot blowing on a plant where the airheater was half choked was merely to "pack up" this excess air, gas and steam beneath the airheater whence the induced draught fan—already overloaded—was incapable of dealing with it for some considerable time. That, in turn, temporarily destroyed the draught so that the boiler soot blowers, instead of creating and maintaining a strong gale-like blast through the plant, simply created a back-pressure against which the velocity and momentum of their jets was dissipated, rendering the appliances ineffective—however powerful—and causing the dew point of the gases to approach that of pure steam (212° F.). Mr. Parry had brought out clearly how ebullition in the boiler diminished as the draught was destroyed, causing the water level to drop and relatively cool extra feed water to be pumped through the economiser. The gases trapped beneath the partially choked airheater remained in contact with the cooled economiser tubes long enough for intensive vapour condensation to take place, and thus the tubes became thoroughly wetted and attracted dust and soot to form hard rough scales, when dried later, which no steam blowing appliances could be expected to shift. Such vapour condensation would occur suddenly, in waves as it were, as the various soot blowers were operated and in the writer's opinion was a primary cause of an economiser trouble which was not fully understood.

It should always be borne in mind that an airheater, by its very construction, was a most powerful draught brake even when clean and, as the effectiveness of a soot blower system depended largely on creating an increased draught when in operation, the importance of keeping an airheater clean was self-evident. Means for effectively soot blowing the boiler, economiser and airheater should be one of the first considerations in every new plant, and on no account should any one part be neglected if long running periods (as in example "C") were hoped for.

His remarks related in detail to but one of the many instances where the physical conditions of the flue gases in a boiler had been ignored, but it was hoped that they would serve to emphasise the fact that unless more attention was given henceforth to ensuring clear gas passages and complete freedom from vapour condensation by the means already proved, and outlined in Mr. Parry's valuable paper, further progressive development in steam boiler efficiency would be frustrated instead of encouraged.

Mr. Crawford W. Hume (Messrs. James Howden & Co., Ltd.) wrote that the Author seemed to be specially interested in the type of soot blower fitted to the Howden-Ljungstrom rotary heater and from his statements one would be led to believe that this type of heater was continuously choking up or continuously being washed with hot water and soda and that in all successful cases no soot blowers were fitted or operated. It was quite clear that Mr. Parry had been in contact with these plants for brief periods only and that his memory had failed him, as many of his statements with regard to the preheaters were either exaggerated or incorrect

The writer would encroach on too much space if he were to recount the details of the examples "A", "G", "H" and "J", which referred to plants fitted with Howden-Ljungstrom preheaters. He would like, however, to analyse a few of the Author's statements.

The Author had stated with regard to plant "A" that the soot blowers were "suppressed". The difficulties experienced with this plant necessitated a conference between Mr. Parry, some engineers of the writer's Company, and the owners of the plant. Mr. Parry at once suggested that all the trouble in keeping the boiler clean was due to the counter-draught soot blower on the air preheater. The actual facts were that previous Ljungstrom preheaters delivered to this station had kept clean without any soot blowing and that the use of the soot blowers had therefore been discontinued. When starting up the preheaters in connection with the five boilers referred to by Mr. Parry it was therefore decided not to connect the soot blowers at all. They had consequently never been in operation when the troubles to which Mr. Parry referred were encountered. How could this be reconciled with the Author's remarks about the steam consumption of the soot blowers fitted to this particular plant or to his ridiculous remarks about the washing with hot water twice every eight hours? It seemed that the Author in his enthusiasm to prove his theories relied too much on the credulity of his audience.

While the writer had no doubt that the Author had had a wide experience in dealing with soot blowing problems in boilers, his further remarks about the washing of the heating surface on rotary airheaters with hot water and soda only showed the limited nature of his experience with these airheaters. If the conditions were generally as he stated, how could there have been put in service throughout the world during the last decade some 1,500 of these rotary air preheaters, and how could the rate of supply of these be still increasing? The writer believed that he was correct in saying that in not more than ten out of all these preheaters had any other type of soot blower than that incorporated in the standard design been fitted. It was the very fact that the Ljungstrom preheater was so easy to keep clean that had led to the ever increasing popularity which it enjoyed.

Mr. W. Yorath Lewis wrote that the Author was to be congratulated on the ambitious and "high-brow" title he had given his paper, as well as upon its contents and especially upon the Appendix. The former—because the latter showed that none of the modern water-tube boilers could work beyond a few hours without the help of several good soot blowers rightly applied. The "high-brows" then might well become "knit-brows".

The steam raising community, both ashore and afloat, would gratefully welcome the Author's contribution (1) because he clearly indicated as a result of his extensive experience how costly sooting up and corrosion troubles could be largely mitigated and in certain cases entirely overcome, and (2) because he warned them that some such remedies might be even worse than the disease.

First impressions from a perusal of the paper emphasised that continual effort had been and was still necessary to combat the difficulties which were seen to be caused by the faulty design of some up-to-date water-tube boilers. Further consideration made it obvious that if sufficient attention was given to the disposition of the drums, heating surfaces, gas passages and flues, the necessity for such elaborate soot blowing apparatus would be greatly minimized—in fact soot blowers might then become a refinement instead of the absolute essential that they now were, even for the still moderate average efficiency which their oft repeated use ensured. There remained however the danger of increasing corrosion troubles by soot blowers of incorrect design and application, owing to their liability to wet the heating surfaces, especially if, as was occasionally the case, their extensive piping connections were inadequately drained.

On examining the several examples referenced "A" to "P" in the Appendix, one could not fail to be struck by two facts—(1) the large number of soot blowers required ranging from 6 to 16 and averaging about 10 per boiler, and (2) the amazing extent of the piping and valves necessitated to enable modern water-tube boilers to work at all, to say nothing of working efficiently. These were costly initial accessories, involving increased maintenance charges, which, when neglected, meant still heavier upkeep expenses, as for instance those due to corrosion and the heat losses resulting from leaky valves and joints.

It would appear that the boilers which had large tubes and a plurality of drums and/or headers required the largest number of soot blowers, whereas the fewest were required for the small tube boiler having only one top drum—its two or three bottom drums being merely unnecessary relics of those bad feed-water days of long ago. The Author in his italicised opening remarks implied that such bottom drums were no longer essential as sludge traps, since modern methods ensured the perfection of boiler feed water. In the Lewis single-drum boiler, which the writer had recently introduced, advantage was taken of that attainment internally, whilst externally sooting and corrosion troubles were reduced to insignificance, because every one of the Author's points had been given due attention in its design.

There was so much of value to steam users tucked into this paper and its appendix, that it might be permitted to epitomize several of its salient points by the following comparison with a water-tube boiler characterized by great simplicity, such as the one just mentioned. That boiler followed the Admiralty type shown in Example "P", but instead of the bottom drums, it had water walls, and when oil fired it also had curtain tubes. These greatly augmented its proportion of radiant heating surface, with the advantages mentioned in the paper on pages 92 and 93. Its much reduced water content, coupled with its enhanced circulation, facilitated and accelerated initial warming up (see *b*, *c* and *a* on page 88) without preheating by steam, which was a lamentable necessity in several of the examples, and one which was intolerable to Continental and naval engineers.

Another advantage arising from the elimination of bottom drums was that the gas speed could

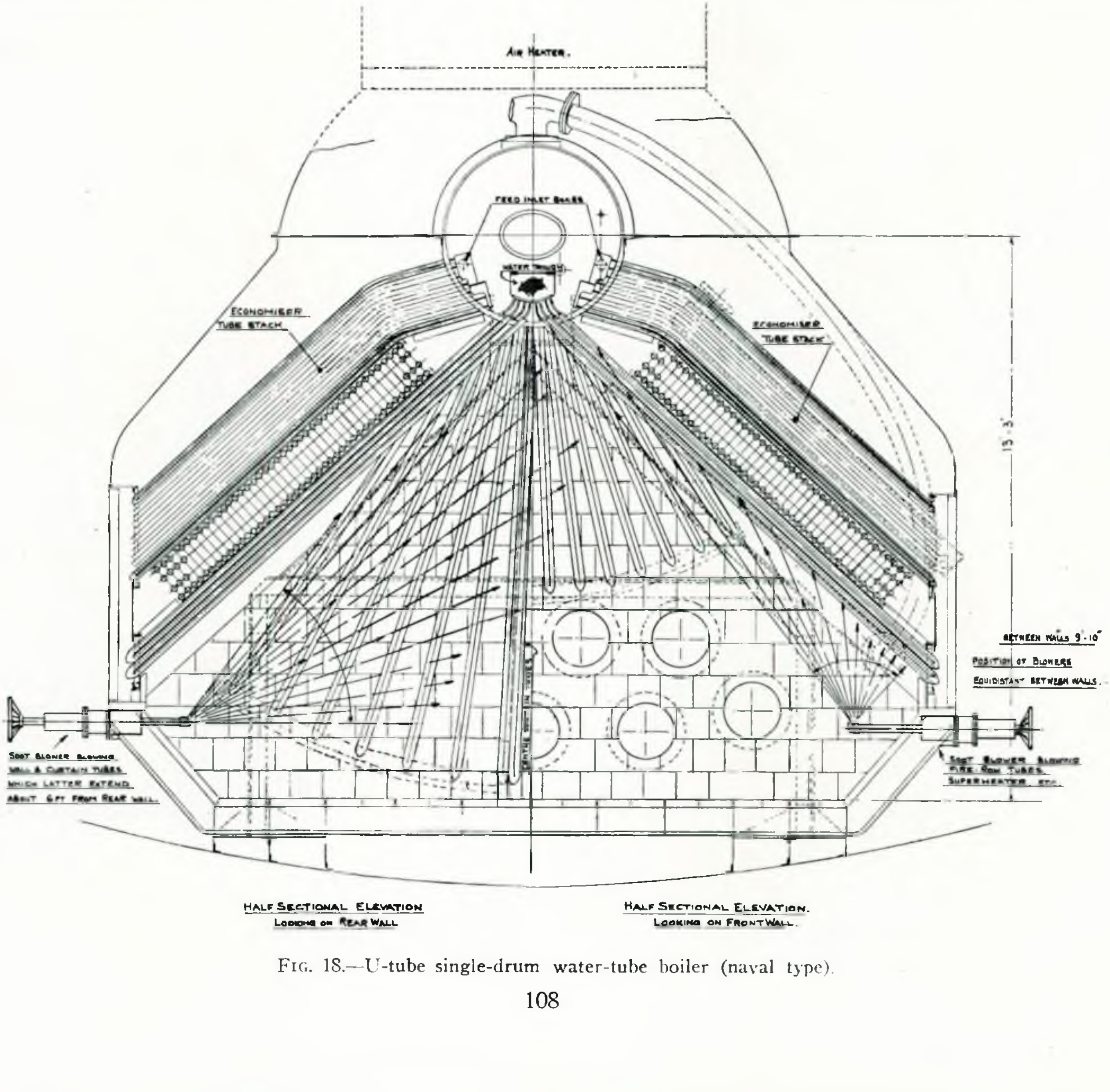


FIG. 18.—U-tube single-drum water-tube boiler (naval type).

be kept constant throughout the tube bundle, a feature sadly lacking in several of the examples shown in the Appendix. This was accomplished by reducing both the length of the tubes and their number towards the gas exit. Thereby the several right angle turns and baffles in the gas flow, as for instance in such examples as "C", "E", "F", "G", "H" and "J" were obviated, and so of course were the extra soot blowers necessitated.

The Author on page 87 dwelt forcibly on the superiority of soot blowing in the direction of the gas flow, and one was bound to agree with him that it was better to do so than to blow in the opposite direction, which he condemned in the next but one paragraph. In the intervening sentence however, he referred very briefly to soot blowing in the direction of the tube length, perhaps because, with bottom drums always in the way, he had never been able to experiment with soot blowing along the length of the tubes. There might be some advantage in this, as he admitted that the combustion was not affected thereby and presumably that the resulting increase of dew point, specific heat and exit temperature would be relatively of no importance. Certainly the large amount of steam, which one of the speakers had referred to as being equivalent to the rate of some hundreds of horse power, might be reduced by this method. The component of the flow so directed would be more truly in the direction of the gas flow and without so much loss of kinetic energy, as when blowing across the tubes the steam jet hit the first and second rows of staggered tubes. The scouring action should be superior for the same or less amount of steam, since it would attack the stuff to be removed lengthways with a vigorous and turbulent sweeping effect, thence carrying it onwards and upwards at increased velocity. The Author's successful experience in removing pulverized fuel slag from fin-tube walls of square combustion chambers by means of his famous rotatable blowers seemed to confirm this, but his considered views on the matter would be of general interest.

The remarks on page 89 regarding feed heating were of special interest in respect of his single-drum "U" tube boiler. The diagram on page 86 showed that whatever the fuel or air ratio, in no case was the dew point above 130° F. Therefore neither internal nor external corrosion trouble would arise if de-aerated feed water at 175° F. was delivered direct to the rear tubes. The efficiency of the boiler would thereby be enhanced by making its rear tubes into a feed water heater or economizer, or in fact a steaming economizer in the case of the first rows beyond the superheater. In boilers having bottom drums, and utilizing their rear tubes as downcomers for circulating water to their fire row tubes, the incoming feed had to be mixed with the water in the drum and it quickly attained boiler steam temperature, whereby the advantage of low temperature in reducing the mean temperature difference between gas and tube wall was lost. Whereas in the three drum boiler the proportion of heating work done by the tubes beyond the superheater was only about 12 per cent. in his boiler it could be increased to 20 per cent. There was no need therefore to contemplate the return of exterior economizers in either marine or land practice, an air heater being sufficient even if the firing was by mechanical stokers which required much lower air temperatures than fuel oil or pulverized coal.

Other points raised by the Author regarding difficulties with the closed feed system were met in his boiler but he need not further enlarge upon these. It sufficed to say that not only was weight saved by the elimination of bottom drums and water, but also by minimizing the weight of feed water, heaters and accessories.

The accompanying drawing (Fig. 18) of his single-drum boiler illustrated its main features in respect of the points dealt with in the Author's most interesting and instructive paper.

The Author's Reply to the Discussion.

In replying to the various contributors to the discussion the Author desired first of all to pass on the congratulations of one contributor on the choice of the title to the Papers and Transactions Committee, who had suggested the title. Mr. Hamilton Gibson's remarks to the effect that this was the kind of paper the Papers Committee liked to have, were very encouraging and if his two questions were framed, as they appeared to be, to bring the paper nearer to the required standard then the Author would be amply rewarded if his reply had that effect.

Dealing now with the first question of saturated versus superheated steam for soot blowers, he would say that it was immaterial whether saturated or superheated steam was used provided that the necessary care was taken in designing the pipe arrangement for complete drainage before and during operation. Saturated steam was preferable generally because a position could always be chosen for the master valve, either on the boiler steam drum or on a branch on the main saturated steam pipe, between which and the boiler water level no residual water could lodge. It would then be impossible for a boiler attendant, even if he ignored instructions and operated the blowers when the boilers were under banked fires, to blow condensed water into the boiler gas passages. There was less objection to using superheated steam when the superheater was self-draining as in Figs. 3, 6, 7, 8 and 9, but it must be borne in mind that drainage was not controlled by the soot blower designer but by the operator controlling the superheater drains. Any superheater would fill with water when the boiler was not steaming unless suitably drained. Consider Figs. 3 and 16—land and marine boilers respectively: in each case saturated steam was used with complete success. Then consider Fig. 15 where the blowers used superheated steam, also with complete success.

In the early days of water tube boilers in the British merchant service, some engineers, in attempting to clean boilers, mistakenly thought that it would be economical to use the residual heat energy in the boilers when oil burners were extinguished at the end of a voyage, and then operated the blowers. Under such conditions the superheater in Fig. 15 became a condenser through which the steam passed on its way to the blowers, and certainly more water than steam would issue through the nozzles.

Superheated steam was preferred by the owners for these boilers to ensure that their superheaters would not be short-circuited and overheated during soot blower operations. Although there had been no report of any such trouble with the boilers shown in Fig. 16, or with any land boilers by the same makers over many years, it must be acknowledged that an unnecessarily large saturated steam consumption by blowers might cause overheating of superheaters. The manufacturers of the superheaters in Example A had informed the Author that actually they had observed evidences of overheating. This could only have been due to excessive steam consumption of air heater blowers before these were suppressed. There had been no such evidence in regard to the superheaters in Example C.

It was worthy of note that the soot blowers in Figs. 3, 4, 9, 10, 11, 12, 13, and 16 all used saturated steam, and that no vapour condensation troubles had occurred in these plants.

Condensation troubles in the boiler shown in Fig. 8 had been cured by re-arranging the blower pipes using superheated steam so as to drain them properly, by providing additional blowers using *saturated* steam, and by suppressing certain blowers which blew against the boiler draught.

The troubles mentioned in connection with Figs. 10 and 11 were partly cured by suppressing the air heater soot blowers using superheated steam. Referring to Fig. 12, a whole set of blowers using superheated steam, some blowing against the draught, were removed from the installation and replaced by the set shown using saturated steam.

It should be noted that soot blowers taking steam from the superheater must start their operation with saturated steam in any case, and if they blew against the draught the steam supply must be wet, as under such conditions the gas was blown back from the superheater, which thus became a cooler or "condenser".

It would therefore be realised that the demand for superheated steam for soot blowers had, in many cases, been merely a pious hope for a miraculous cure for the effects of bad drainage and of blowing against the draught.

In reply to Mr. Hamilton Gibson's second question, there were three great objections to compressed air for soot blowing, viz. (1) its economic waste, (2) its futility, and (3) the harm it did to the boiler plant.

Referring to Fig. 12, the Author happened to know that a turbo-air compressor bought and used for soot blowing for four somewhat similar boilers cost £5,500 exclusive of erection. This was in addition to the total cost of the soot blowers, which, of course, would be considerably less than the figure stated. The momentum of the air jets would be about two-thirds that of steam jets. Compressed air was not being used through certain of the blowers, which now used steam, and it was significant that air was not to be used on later boilers to be installed in the same power station. Presumably someone hoped that compressed air would miraculously prevent a repetition of the ill effects (of faulty design and badly-arranged steam soot blowers using superheated steam) that occurred with the plant shown in Example "K" before the Author was called in to deal with the trouble.

Compressed air as used in soot blowing must go through a similar cycle of operation to that in the old cold air refrigerating machine, with which the Author presumed the older generation of marine engineers were familiar, so that he need not describe the cycle of operations. It would be sufficient to point out that, in the absence of a costly re-heating apparatus, the resulting air jet might be as cold as *minus* 100° to 150° F. Was such a low temperature suitable for blowing into hot boiler passes? Even navvies using compressed-air drills found it necessary to wear thick leather aprons to protect them from the intensely cold exhaust air and water mixture that was ejected. He thought that any engineer proposing to use compressed air for boiler cleaning would soon find himself "on the beach"—and serve him right!

Obviously then compressed air for soot blowing, as a remedy for boiler fouling and corrosion, was a delusion and a snare and actually aggravated the troubles, not to mention causing leaky steam and water joints at tube ends and internal connections.

In reply to Mr. J. Reid, the Author would refer him to the synopsis explaining the scope and purpose of the paper, and the assumptions on which the estimated rises in temperature during combustion were based.

As to his criticism of the temperatures, they had hypothetical indicator diagrams and he did not see why they should not have hypothetical temperatures. He would accept Mr. Reid's figures for the general temperature of the combustion chamber, but an insulated combustion chamber would give the figures in the paper. (The Author and Mr. Reid here exchanged views on the validity of taking the temperatures quoted in the paper for purposes of discussion).

He would point out that the paper referred to other than Scotch boilers, and it was a matter of common observation that, in refractory lined furnaces where the fuel was burned in positions remote from water cooled surfaces, common refractories did not stand up to the high temperatures resulting from a low ratio of actual to theoretical air for combustion.

High-class brick refractories would, it was claimed, stand up to a temperature of 3,000° F. and those of which the base was carborundum, would probably stand temperatures approaching 4,000° F.

When high-class brick refractories were actually seen in a state of flux, and combined in the form of stalactites and looked like pig-iron when cold, there should be no difficulty in accepting the stated temperatures.

In describing the CO_2 graph on the screen the Author stated that about 14 per cent. CO_2 was about as high as was thought worth while in modern coal burning land plants—not 11½ to 12 per cent. as mentioned by Mr. Reid.

As regards air heaters it was not clear whether Mr. Reid had in mind gas or air by-passes, and the Author would refer him again to the paper and the Appendix as to his own views on the matter.

He regretted that, in spite of his plea for correct operation of air heaters, so that these could appreciably increase boiler efficiencies without giving trouble to the engineers, Mr. Reid had come to the conclusion that it might be better to cut out air heaters altogether.

The Author agreed with Mr. Reid that air-heaters were not worth the trouble they had caused, but the paper showed that they could be preserved. The most difficult air-heaters he had experienced had been kept clean for long periods by following the methods he suggested.

He also agreed that the Scotch boiler had a sort of by-pass air arrangement. The air-heater could be short-circuited by the natural draught. However, with oil fuel, first one burner and then another was lighted. It would be found difficult, however, completely to by-pass air from a Scotch boiler air heater. In manœuvring a ship under forced draught the fan was idling, and if the valves were leaking there was air going through the air heater on each side and the tubes became very cool.

The Scotch boilers in the "Queen Mary" would not be used in manœuvring, and there would not be the frequent lighting-up and putting out of the burners. If the Author were a superintendent engineer he would, in the case of Scotch boilers, either have an air by-pass or work under induced air draught only.

Referring to Fig. 17, that was the first occasion to the Author's knowledge, and it was at his request, that air by-passes were fitted with Howden air-heaters. There had been many more fitted since then, and he had in hand at the moment plans for boilers at two electric power stations in this country and one or two abroad, where this air by-pass would be installed. It would cut out 99 per cent. of the trouble; therefore, he saw no necessity for eliminating air-heaters from marine installations.

Mr. E. H. Gibson's observations were mainly with reference to plate airheater fouling by soot and were particularly applicable to the airheater described in plant "E" of the Appendix. The Author congratulated him on his knowledge of the subject and agreed that the type of airheater fouling he described was undoubtedly a direct cause of extensive economiser fouling and scaling. In connection with plant "E", it might be added that, in accordance with the erroneous views of the plate airheater makers, this airheater was (as far as he knew) still being operated unsatisfactorily, whereas the perfect results obtained on exactly similar airheaters in plants "B" and "C" followed operation on the lines advocated in the paper.

With regard to the point raised concerning the positioning of airheater soot blowers with reference to the relatively low flue gas temperatures obtaining at this point in the gas stream—he would point out that, during expansion through the soot blower nozzles, the steam condensed to some extent as its heat energy was converted into kinetic energy. The percentage of moisture present in the steam leaving the nozzles was, of course, less when pure superheated steam was used for soot blowing than in the case of saturated steam, but it was important to note that in both cases the temperature of the wet steam at the nozzles was about 212° F. The resultant moisture content at the nozzles could be controlled within limits by throttling the steam supply to the nozzle pipe.

In the mixing of the soot blower steam with the products of combustion, however, the kinetic energy of the steam was to a great extent dissipated and a reconversion into heat took place. Thus the moisture tended to vanish as the velocity of the steam and entrained flue gases fell off. Sufficient distance had, of course, to be left in order that the moisture which could not be dried up by the reconversion of kinetic energy of the steam would be dried by the heat of the flue gases before the blast reached the nearest heating surfaces. Thus a hot, dry, powerful scouring agency was created and the tubes or plates could be safely swept clean from time to time without fear of wetting. It was, however, very important that airheater soot blowers (if fitted) should only be used when the temperature of the flue gases approaching the airheater was normal—say 350/400° F. or over.

Mr. Crawford W. Hume's remarks were likely to mislead the unwary, and the Author could only assume that, in writing them, he had lost sight of the main object of the paper which was, of course, to get to the root of the various fouling and corrosion troubles connected with boilers, economisers and airheaters, and by frank discussion to show how these could be partly if not wholly overcome.

The Author hastened to re-affirm that the facts in connection with example "A" were as stated in the Appendix. Mr. Hume was, however, quite correct in his statement that the previous Ljungstrom airheaters installed at the same power station had kept clean without any soot blowing. It was to *these* soot blowers (not those on plant "A") that steam pipes were never connected. Later it was realised that the above airheaters could never have remained so clean had the airheater soot blowers been in use, and it was this discovery, together with satisfying the owners of the plant and the superheater company that the steam consumption of the airheater soot blowers was at the rate of nearly 1,000lb. weight per minute, thus starving the superheater (as described in the reply to Mr. Hamilton Gibson), that led to the suppression of the airheater soot blowers on the new plant "A".

With reference to the estimated consumption of the airheater soot blowers, the airheater engineers had given this as 600lb. weight per minute for plant "A". Sometime previously, however, the Author had been informed by a director of the same firm that the steam consumption of the airheater blowers on plant "J" was at the rate of 400lb. weight per minute. As the steam pressure on plant "J" was only half that of plant "A" and the steam supply orifices to the soot blowers were the same size in each case, it would appear that the airheater Company's calculations were somewhat in error—for if the 400lb. weight per minute for plant "J" was correct (and there was no reason to doubt this) the 600lb. weight per minute given for plant "A" should have been at least 800lb. weight. It was interesting to note that a good design of airheater soot blower need use no more than 200lb. weight per minute's operation. Prior to discontinuing the use of the airheater soot blowers on plant "A" the guaranteed gas exit temperature of 240° F. could not be maintained and rose to about 315° F., owing to the steady fouling of the boiler and economiser heating surface. The suppression of the soot blowers in question produced an "unbelievable improvement"—words which spoke for themselves.

It would almost appear that Mr. Hume had taken the reference to the plant "A" airheater being "washed with hot water twice every eight hours" too literally. The airheaters were, of course, "washed" by the soot blowers which were placed so near to the heating surfaces and used such an exorbitant quantity of steam that a washing effect was produced automatically as explained in the example.

Following the first month's suppression of the airheater soot blowers on plant "A", the airheater engineers (together with the Author) inspected the plant, and these gentlemen were so impressed by the improvement generally that one of them went so far as to ask the Author for his views in regard to some heavy corrosion that had been occurring in the airheater rotor in plant "J". At that time there was not sufficient information available to comply with this request, but Mr. Hume was welcome to the results of the later investigations described in connection with plant "J". It was understood that the plant "J" rotor became so badly corroded as to require replacement after twelve months' service, and there was no reason to doubt the word of the station engineer regarding the periodical washing of this airheater. The Author actually witnessed the washing of the plant "H" airheater in September, 1933 and was informed that this occurred about every three months. Space did not permit adding to that list, but sufficient had been said to confirm that washing was resorted to in cases where choking and corrosion troubles had been experienced, due to the mal-operation of rotary and other airheaters, and it was useless to attempt to disguise the fact.

Fortunately, perhaps, for all concerned, boiler owners were now realising that they could run their plants more efficiently without the advice of the airheater makers regarding their operation and, in fairness to Mr. Hume, it must be added that this also applied to plate and tubular airheater manufacturers.

Mr. Hume asked why had 1,500 of the rotary type airheaters been put into service during the last decade, and why was the rate of supply increasing? In the Author's opinion the reasons for this were (1) the continued refusal in the past of plate and tubular airheater makers to face the facts in regard to the weak points in their plant, (2) their short-sighted policy in condemning cold air by-passes and good airheater soot blowers and allowing their airheaters to foul and choke up in about half the time taken to choke a mismanaged rotary heater and (3) the fact that, unfortunately, commercial guarantees were in many cases more powerful in securing orders than sound engineering knowledge and the application thereof. One need go no further than read Examples "F" and "G" to explain the past commercial success of the rotary airheater. As a matter of interest, the makers of the boilers illustrated in Examples "F", "G" and "K" had accepted the basic principles outlined in this paper in regard to a large plant now being erected in Lancashire and if, as it was hoped, this powerful commercial concern now proposed to adopt these principles in future work, it would be interesting to see how long it would take them to recover their tubular airheater market, which was at the present time almost lost to the rotary airheater for the reasons stated.

The Author warmly appreciated the kind remarks in Mr. W. Yorath's Lewis's contribution, but with regard to his survey of the advantages and disadvantages of modern multi-drum marine water-tube boilers, he must disagree with the view that the lower water drums of these boilers were "unnecessary relics" of the past. He granted that up-to-date methods of treating boiler feed water had done and were doing a great deal towards eliminating corrosion and sludge troubles on the water side of steam boiler heating surfaces, but condensers were still not perfect and, even to-day, there were occasional failures of condenser tubes and tube packings which applied presumably to both Naval and merchant services. Then there was always the possibility of an emergency to be considered—especially in the case of warships—and, as it was not inconceivable that at some time or other it might be urgently required to fill up the boilers with river or sea water and to steam away quickly in answer to a sudden call, the lower water drums appeared necessary if only as an additional factor of safety.

In comparing the Lewis type of marine boiler shown in Fig. 18 with the standard marine water-tube boiler, it seemed to the Author that the former would prove the more difficult of the two in service to protect from sweating and corrosion troubles on the gas side of the heating surfaces. It was obvious, of course, that this boiler would suffer less from a single raising of steam from cold water; but on the other hand the U-tubes and the water therein would certainly cool down much more rapidly than straight through drum-to-drum tubes, when, for instance, the oil burners were being intermittently extinguished and re-lit during manœuvring periods. In consequence, the boiler, and airheater (if fitted), would be prone to greater trouble from this cause unless very carefully handled.

It was true that the de-aeration of feed water eliminated to a great extent internal corrosion of economiser tubes and drums, and there seemed to be no reason why an economiser should not be embodied in the boiler proper as indicated. This had already been done on the Continent and probably also in some land stations in this country. Economiser design was, however, outside the scope of this paper.

With regard to the query as to the advantage to be gained by soot-blowing in a direction parallel to the boiler tubes, the Author would refer him to Figs. 4, 7 and 11 in the Appendix. It would be noted that, where possible, this was done—but it was of the utmost importance to arrange that the soot blower nozzles were sufficiently distant from the nearest heating surface acted upon to obviate the risk of erosion. He agreed that less steam would be required to clean boiler tubes when soot-blowing in line with them, and Mr. Lewis must also agree that less tube heating surface would be required to generate a given quantity of steam if the gases also flowed parallel with the tubes, for a more uniform gas temperature could then be obtained around the circumference of each and every tube in the stack. As, however, Mr. Lewis was constrained to follow the practice of other boilermakers in so far as his gas flow was at right-angles to the length of the tubes, he must permit the same latitude as other boilermakers allowed the soot blower manufacturer in choosing the best positions for his cleaning appliances. There was no reason why soot blower positions similar to those illustrated in Figs. 14, 15 and 16 should not clean this boiler as efficiently as they cleaned the boilers in those examples.

Mr. Lewis's statement that the preliminary heating up of boiler water before fires or burners were lit "is intolerable to Continental and Naval engineers" surely referred more to the conditions of years ago. To-day, land station engineers throughout the world were finding out that this pre-heating of the water paid them handsomely in eliminating fouling and corrosion on the gas side of their heating surfaces and it might safely be said that, slowly but surely, the measure was being adopted as standard practice in all better class work. To the Author's knowledge, in many Continental power stations the boilers were filled initially with hot water, and in no circumstances was that water allowed to cool until it was finally required to shut down the plant. With regard to Naval practice—it was true that the engineer officers responsible had not yet considered it worth while to complicate their present steam-raising routine by including preheating of the boiler water. It would have been absurd, however, to conclude from this that they did not fully appreciate the true value of this measure, and it could only be said that the many advantages to be gained thereby (including a longer useful life of the boilers themselves) had, of necessity, to be sacrificed to other more urgent considerations peculiar to the warship.

The proven fact remained, however, that in first-class merchant work where multi-drum water-tube boilers were the rule, preheating of the boiler water before burners were ignited afforded the only sure protection against choking deposits and corrosion on the heating surfaces. Sound practice and trouble-free operation of steam boilers must always go hand in hand.

INSTITUTE NOTES.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday April 6th, 1936.

Members.

Joseph Chester Jackson Askew, 65, Beverley Road, Monkseaton, Northumberland.

Joseph Henry Brownbill, Shanghai Power Company, P.O. Box No. 404, Shanghai, China.

Richard Henry Campbell, 3rd Engineer, R.M.S. "Remuera", New Zealand Shipping Co., King George V. Dock, E.16.

William Dowling, c/o Messrs. The Hain Steamship Co., 24, St. Mary Axe, E.C.3.

Roland William Garreau, Boiler Office, 40/1A, Free School Street, Calcutta, India.

Ernest Charles Hatcher, Instow, Woodside Road, Northwood, Middlesex.

Cyril George Lister, 3, Glenby Avenue, Great Crosby, Liverpool, 23.

John Forrest Ramsay, B.I. Engineers' Club, P.O. Box 296, Calcutta, India.

William Henry Revill, 31, Lyonmeade, Canons Park, Stanmore, Middlesex.

William Arthur Richmond, 18, Kings Bench Street, Hull.

John Leslie Couch Rogers, Mayville, Upper West Cross Lane, Swansea.

Thomas Carmichael Rolland, 29, Manor Road, Ruislip, Middlesex.

John Oscar Sproul, 18, Caebryn Avenue, Sketty, Glam.

Joseph Sutherland Struthers, 4, Panmure Road, Sydenham Hill, S.E.26.

Frank Elmes Warren, 3, Church Hill, Honiton, Devon.

Associates.

Thomas Walker Grainger, 101, Deerpark Road, Belfast.

Herbert Sidney Kessick, Bank Chambers, 13, Kirkdale, Sydenham, S.E.26.

Edward John Loader, c/o Wilson, Sons & Co., Ltd., Caixa Postal, 751, Rio de Janeiro, Brazil.

William Alfred McClurg, The Square, Crossgar, Belfast.

Student.

William Upton, 9, Ingle Road, Chatham, Kent.

Transfer from Associate to Associate Member.

Douglas Tagg, B.Sc., Dacre House, Alma Place, North Shields.

Transfer from Student to Associate.

John Henderson Simpson, B.Sc., 31, Brighton Street, Barrow-in-Furness.

ADDITIONS TO THE LIBRARY.

Purchased.

Notes on the Grants to Research Workers and Students. H.M. Stationery Office, 2d. net.

Reports of the Progress of Applied Chemistry, Vol. XX, 1935, issued by the Society of Chemical Industry.

The Mercantile Navy List and Maritime Directory for 1936. H.M. Stationery Office, 25s. net.

Directory of Shipowners, Shipbuilders and Marine Engineers, 1936. The Directory Publishing Co., Ltd., 20s. net.

King's Regulations and A.I. Amendments (K.R. 2/36). H.M. Stationery Office, 3d. net.

British Shipping (Continuance of Subsidy) Bill. H.M. Stationery Office, 1d. net.

Presented by the Sea-Action Committee of The Institution of Civil Engineers.

"Deterioration of Structures of Timber, Metal, and Concrete Exposed to the Action of Sea-Water". Edited by S. M. Dixon, M.A., and H. J. Grose, M.C., B.Sc. Published by H.M. Stationery Office, 12s. 6d. net.

The problem of protecting structures against deterioration in sea water has been exhaustively studied by a Committee of the Institution of Civil Engineers for over 15 years. During that time, observations have been made in several parts of the world on the action which sea water has exerted upon a wide variety of structural materials. Since 1920, fourteen progress Reports have been published by His Majesty's Stationery Office for the Department of Scientific and Industrial Research.

The present volume constitutes a general survey of the problem as a whole based upon the work already undertaken. The four main sections of the Report are:—Preservation of timber; corrosion of steel and iron; protection of steel and iron by means of paint and other preservatives; and deterioration of reinforced concrete.

The book is illustrated by numerous photographic plates, diagrams and statistical tables, and is fully indexed.

Presented by the Publishers.

"Informal Discussion on Modern Methods of Indicating High-Speed Engines". The Diesel Engine Users Association.

Proceedings of The Institution of Mechanical Engineers, Vol. 130, 1935, containing the following papers:—

- "Aerodynamical Research and Hydraulic Practice", by Fage.
- "Recent Developments in Hydraulic Couplings" by Sinclair.
- "Progress in Design and Application of the Lysholm-Smith Torque Converter, with special reference to the Development in England", by Haworth and Lysholm.
- "Voith Turbo Transmission", by Hahn.
- "Mechanical Handling as Applied to Industry", by Lister.
- "Noise", by Hutchinson.

Transactions of the Institution of Engineers-in-Charge, Vol. 40, 1935, containing the following papers:—

- "The Principles and Practice of Drying in Industry", by Knowles.
- "Modern Electrical Equipment for Industrial Purposes", by Mortimer.
- "Communication, Protection and Supervisory Control Systems for Electric Power Networks", by Smart.
- "Modern Laundry Machinery", by Mitchell.
- "Elevating, and Conveying Machinery", by Marriott.
- Debate: That the use of Machinery in our Industrial and Social Life is productive of Unemployment.
- "Boiler Water Problems", by Merry.
- "Home Office Requirements in the Factory, and Legislation relating Thereto", by Williams.

"Machine Drawing for Students", by F. J. Pryer, B.Sc. Sir Isaac Pitman & Sons, Ltd., 141pp., copiously illustrated, 7s. 6d. net.

Since the declared object of this book is that of assisting the training of the engineer rather than the making of a draughtsman, a good deal of possible criticism is automatically disarmed. Any charge of undue specialisation, for example, is converted into a compliment, though one may still question the Author's objection to the use of sectioned isometric views. The inclusion of a chapter on freehand sketching is an unusual feature and deserves full praise, since the importance of this branch of drawing to the engineer *qua* engineer can hardly be over-estimated.

Where the book deals with the general principles of projection, developments, etc., the standard is admirable. The various illustrations are carefully chosen and the text describes the constructions step by step in a most painstaking manner.

British Standards Institution practice is followed throughout, though a reference might have been made to the standard American method of projection; even in this country there are firms who prefer this method.

A point of criticism arises, as it does in almost every textbook of drawing, over the comparative remoteness of the text from the drawing plates referred to. For example, the text on page 50 refers to illustrations on pages 78-79; whilst exercises 80-1 on page 79 cover the nine pages 71-9 and refer to no fewer than twenty-two drawing plates. The intention is excellent, but the effort to include it in book form seems to lead to confusion. We hasten to repeat that this criticism may be applied to almost any book on drawing.

Another unusual section is that dealing with limits and fits, which explains most clearly much of the subject matter of the British Standards Institution reports; there are, however, two rather important misprints, i.e. page 58 has "B" hole for "U" hole and page 59 has 4in. instead of ¼in. Whilst on the subject of misprints, we might mention one in the preface where "their plates" should be "thin plates", and another on page 98 where "wire draws" should be one word.

The chapter on riveted joints, with its special references to the particular problems arising in the case of thin plates and hollow rivets, is excellent; considerable attention is paid to the basic principles of design as well as the drawing aspect.

Reference has already been made to the section on developments. Both this and the allied one on bending allowances are most carefully carried out; the text is full and, combined with the excellent examples and illustrations, gives a complete course in a complex subject.

In conclusion, this book can be strongly commended for its general standard. Within the obvious limitations of its declared object it is first-class, and even outside that field it would be found of great value to all engaged in the teaching or study of engineering draughtsmanship in general. It contains several features not usually included in books of its type and the descriptive matter is thorough and painstaking.

"Planning Your Career", edited by C. Leslie Wood. London Express Newspapers, Ltd.

Organisation of industry and the professions has developed enormously since our fathers started work as boys. In those days dear old Samuel Smiles' "Self Help" and books like "Men Who Have Made Themselves" were the usual birthday present or school-leaving prize given to serious-minded youth. Good sentiment, perhaps, but not very practical except in so far as they often served to inspire boys with the idea that "what others have done can, and shall, be done by me", and sharpened their perception in recognising and seizing every opportunity for advancement as it appeared. Admirable enough in one way, though rather fortuitous in practice and hardly fair to the great majority of young folk who were thrown on the labour market at an early age before they had time to think of what they would prefer to do for a living.

Some sort of authoritative guide for parents and guardians, to say nothing of the young people themselves, has been long overdue and therefore Mr. Leslie Wood's book "Planning your Career" is both opportune and welcome. The sub-title gives a useful synopsis of its contents:—*"A comprehensive guide to vocational selection, the mode and cost of training for, and entry into, more than thirty of the chief professions and callings open to young people of ambition"*. A wide range is covered in the 575 pages, and the gentler sex is not forgotten as may be seen in the chapters devoted to dress designing, beauty culture, nursing and secretarial work.

The army, the navy, the church, banking, accountancy, law, police, medicine, dentistry, agriculture and insurance are subjects that leap to the eye in glancing through the book, each one being dealt with completely and conscientiously as indicated in the sub-title quoted above.

Naturally the writer concentrated on engineering and its allied vocations. Under mechanical engineering the reader will find all that is required to be known as to the ways and means of entering that profession, there being cross-references to locomotive and marine engineering as special branches of the art. Aeronautical, automobile, and electrical engineering are dealt with in separate chapters.

Each and every chapter is introduced by a few words of advice and encouragement from a man or woman well-known and distinguished in that particular line. Thus the President of the Institution of Mechanical Engineers, Capt. Haviland, Sir Herbert Austin, and Mr. Alexander Russell write the foreword respectively for each of the engineering subjects cited, the pages immediately following going fully into the question of preliminary study, scope of examinations, terms of apprenticeship, prospects, rates of pay, etc.

It will be realised from these short notes that the book supplies a long-felt want, and anybody who may be responsible for launching a young man or woman on a suitable career will find this volume an invaluable guide in forming a right decision.

"Mercury-Arc Current Converters", by H. Rissik, B.Sc. Sir Isaac Pitman & Sons, Ltd. 424pp. illus., 21s. net.

This book, although somewhat more than "an introduction to the theory of vapour-arc discharge devices and to the study of rectification phenomena", is not too specialised or mathematical in treatment. It has been specially written to form a basis of study for students in universities and technical schools who are confronted for the first time with the entirely fresh set of problems that the operation of this new converting plant presents.

An introduction by Captain J. M. Donaldson is particularly interesting and helpful in showing the reasons for, and lines of development during recent years of, the mercury-arc rectifier.

After a short introductory chapter dealing with the historical evolution of the mercury-arc rectifier, and a chapter on the physical principles underlying its operation, a considerable portion of the book is devoted to rectifier-circuit theory, where a method of diagrammatic presentation and analysis, developed by the Author, presents a more simple and generally acceptable treatment of the rectifier problem than is usually met with. An exceptionally well illustrated and explanatory chapter on modern practice in the construction of both glass-bulb and steel-tank rectifier equipments completes the first part of the book.

Subsequent chapters deal with the principles underlying the control of arc-discharge devices, with applications of grid-controlled rectifiers, the mercury-arc invertor and the mercury-arc cycloconverter. Final chapters deal with the generation of harmonics by the mercury-arc rectifier and the bearing this has on the power factor problem, whilst the chapter on the calculation of rectifier circuit data deals with the principal design requirements of a typical steel-tank rectifier unit for traction duty, and a multiple-unit glass-bulb rectifier installation for lighting and power supply.

Throughout the book practical applications are widely illustrated, and almost the whole of the last hundred pages of the book deal with the design, equipment and operation of recent typical British rectifier installations for railway service, municipal lighting, power and traction, etc. The descriptions, illustrations and diagrams of connections in this last chapter are particularly praiseworthy.

The above review only gives a bare conception of the scope of the book, which is particularly comprehensive, detailed, and clear throughout concerning apparatus, information respecting the theory, operation and peculiarities of which is still somewhat scattered and otherwise not readily accessible.

The general production of the volume is excellent and the book is one which we have no hesitation in recommending, not only to students but to all engineers concerned with the subject of the theory and application of mercury-arc converters and devices, perhaps more generally defined by the Author's title "Mercury-Arc Current Converters".

"Thermodynamics for Engineers", by Sir J. A. Ewing, K.C.B. Cambridge University Press, 2nd edition, 389pp., illus., 21s. net.

Sir Alfred Ewing was engaged upon the revision of this book, originally published in 1920, until shortly before his death last year, and he entrusted its final revision and passage through the press to Mr. A. Egerton. The work comprises twelve chapters and an appendix containing abbreviated steam tables based on the latest 1934 International Steam Table Conference values, with pressures up to 3,200lb. per sq. inch.

The first six chapters deal with elementary thermodynamic principles and the properties of fluids, and their application to the theory of the steam engine, jets and turbines, refrigeration and the internal combustion engine. The chapter on the internal combustion engine is somewhat brief, the theory of the cyclic action being disposed of in a matter of ten pages, and the Diesel engine (including in this term all compression-ignition types) within the compass of a single article. The formula for the ideal efficiency of the true Diesel cycle, in terms of the two specific heats, is not given, but as modern compression-ignition engines do not operate on this cycle, its omission is probably justified. The simple formula for the constant-volume cycle is the only one given, and it is pointed out that, because of the rise of specific heat with temperature, this is an unreasonably high standard to apply to any actual performance. The remainder of this chapter is devoted to a discussion of the various phenomena of the process of explosive combustion.

Chapter VII is on the molecular theory of gases, and there follow two chapters on general thermodynamic relations and their application to particular fluids. These chapters are mathematical, but their introduction late in the book after fundamental ideas have been clearly grasped, should render them less difficult to the engineer of limited mathematical ability. The final chapters deal with supersaturation phenomena, gas mixtures, and thermo-electric effects.

The subject matter is presented with that conciseness and clarity characteristic of all Sir Alfred's writings. The student preparing for an engineering degree or the examination for Associate Membership of The Institute will in general require more exercise work than is provided in this book. He will, nevertheless, find it a most useful addition to his library, and it can be confidently recommended to the practising engineer who wishes to refresh his knowledge of basic principles without having to wade through masses of inessential detail.

"The Theory of Emulsions and Their Technical Treatment" (3rd edition), by W. Clayton, D.Sc., F.I.C. J. & A. Churchill, Ltd., 458pp., 91 illus., 25s. net.

This volume is a much enlarged edition of Dr. Clayton's well-known treatise on emulsions. Although only seven years have passed since the publication of the second edition, the growth of scientific knowledge and the extraordinary increase in the technical and industrial applications of this branch of colloid chemistry has created an imperative need for an up-to-date textbook on the subject. This Dr. Clayton has given us in a form which makes readable and interesting much material which, like an unemulsified fat, would without such expert treatment be difficult to assimilate.

The author deserves particular commendation for the excellent way, not frequently encountered in books on this subject, in which he has combined a sufficient, but no more than sufficient, account of the theoretical aspects of colloidal phenomena with an ample description of the numerous applications of these phenomena to industry. It would, of course, be impossible here to enumerate even a small proportion of these applications but mention of such aspects as biological processes, textile emulsions, dairy products, fungicides, petroleum, road asphalt and tar emulsions, muds, foams and the manufacture and destruction of emulsions indicates the Author's wide knowledge of the practical side of the subject. The account given of the structure of emulsions, well illustrated by diagrams and photo-micrographs, is a model of clarity, while the sections of particular interest to marine engineers will be those dealing with the de-oiling of condenser and bilge water, the emulsifying of wet oils and the reversal of this operation.

Equally high praise may be given to the general production of the book, which is amply illustrated, to the excellent and up-to-date bibliography and to the well constructed indexes. The whole constitutes a volume deserving the highest recommendation.

JUNIOR SECTION.

Developments in the Machinery Installations of Lifeboats of The Royal National Lifeboat Institution.

A paper on the above subject was read by Mr. A. C. Butcher (Member) at a meeting of the Junior Section held in the Lecture Hall of The Institute on Thursday evening, 19th March. Mr. E. W. Cranston (Associate) occupied the chair.

The paper gave a general idea of the evolution and trend in development of the machinery of motor lifeboats as constructed and operated by The Royal National Lifeboat Institution. Fundamentals and basic technicalities were not generally entered upon, the nature of the paper on the whole being descriptive, and the Author hoped that it would be of use to those engaged in the light marine industry by suggesting some points of useful application to other craft.

A particularly useful discussion, participated in by several of the senior members present, followed. That the special value of the paper was appreciated by those present was indicated by a unanimous request that it be published in the Transactions. It is hoped that this course will be possible in a later issue of the Transactions.

On the proposal of Mr. T. R. Thomas (Chairman of Council) a very cordial vote of thanks was accorded to Mr. Butcher.

ABSTRACTS.

The Council are indebted to the respective Journals for permission to reprint the following abstracts and for the loan of the various blocks.

Russian Timber-carrying Motorships.

"Shipbuilding and Shipping Record", February 27th. 1936.

We illustrate on this and subsequent pages the first of three motorships in course of construction at the Amsterdam yard of the Netherland Shipbuilding Company for the Russian mercantile fleet. This is the "Walerii Meshlauk". She is a complete breakaway from the traditional lumber carrier and a visit to her which we made recently indicates how an established ship type can be taken and interpreted when really clear thought is given to the present and future requirements of transport. Although the "Walerii Meshlauk" is intended for carrying general cargo and bulk cargoes as well as timber cargoes, she is essentially a specialist in the latter work and her design is based upon a patented design of the Netherland Shipbuilding Company known as the Amsterdam type which was originally evolved with the idea of handling wood from Northern European ports to the works of one of the greatest timber importers in Holland, the N.V. Bruynzeel's Schaverig at Zaandam, who specialise in the making of doors, window frames, and so on, for houses.

These works need a constant supply of timber, and at peak order periods it is necessary that the cargoes should be unloaded at the maximum possible speed so that the ships can turn around quickly for a further load. Research showed that considerable improvement could be made on the more stereotyped kind of timber carrier such as is regularly produced in Northern countries, but the patented design needed for its success the shipping of wood in what may be termed as squared-off packets, which could be loaded and unloaded with the minimum of time owing to their convenience and shape, and a maximum advantage of stowage owing to the fact that the whole of the hold space would be occupied.

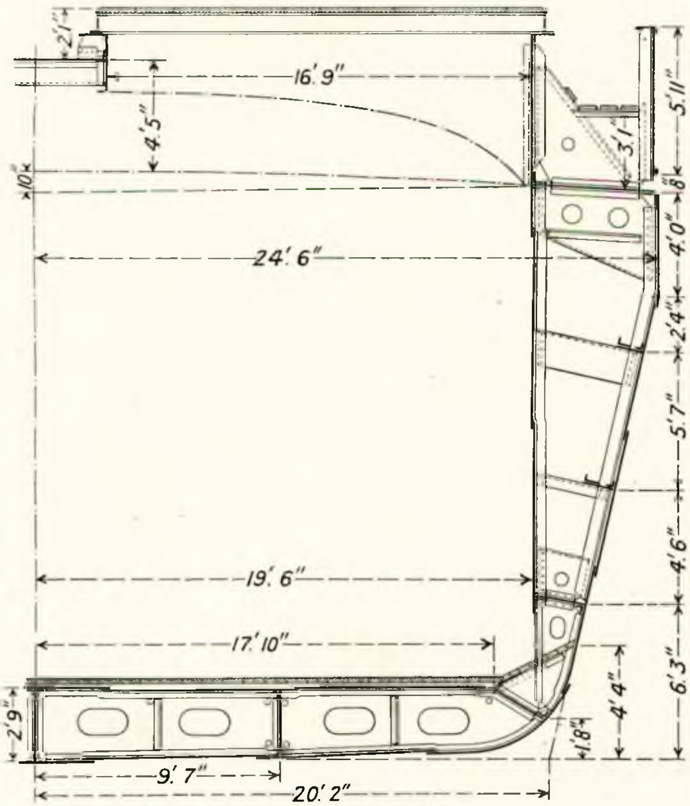
The original Amsterdam design visualised lattice masts with swinging horizontal derricks along which baulks travelled in a horizontal direction. All these were electrically controlled and, furthermore, were distant controlled, thanks to the medium used for operation, so that the man in charge could be at the side of the ship if necessary when the timber was being lifted out.

The original Amsterdam type had a length of 258ft., a beam of 43ft. 6in., a depth of 22ft. 8in., and a draught to summer freeboard of 18ft. 6in. Her gross tonnage was designed to be 2,085 and her net tonnage 1,100, the deadweight being 3,250 tons. She carried 755 standards below deck and 535 above deck, the proportion of deadweight to standards being 2·51 and net tonnage to standards 0·855. Her service speed was to have been 10 knots and her horsepower 900. The water ballast in percentage of deadweight was 26·8 and the consumption of oil per day was to have been about 3·2 tons for all purposes.

The "Walerii Meshlauk" is based upon this design, and the following facts stand out as unusual :—

(1) The cargo hold is as nearly as possible box-shaped, avoiding all corners and knuckles except at the forward end. This is accomplished, as the cross section shows, by a clever arrangement of ballast tanks. The hatches are arranged in pairs and goal-post masts have taken the place of the lattice structure of the original Amsterdam type. To have goal post masts is not necessarily an advantage, since it means two obstructions to a hold otherwise clear except for centre line girders. It does enable, however, the length of derrick suitable for loading from alongside to be cut down.

(2) The whole of the hatch structure and even the hatchways themselves contribute greatly to the strength of the ship.



Section amidships of timber carriers.

(3) All the accommodation, together with the machinery, is arranged aft. Considerable thought has been given to this. The standard of equipment is such that gyro compasses, echo sounders, Barr & Stroud range-finders, submarine telephone systems and internal telephones are all part of the navigational equipments of the ships. The standard of luxury for officers and crew is exceptionally high for a ship of this type.

(4) The main engine is remarkable for its compactness in the fore and aft sense. This is due to the fact that a special rotary blower is arranged at bottom platform level underneath the engine-room floor plates on the port side aft.

(5) Considerable flexibility of operation with the engine is possible due to the interposition of a Vulcan hydraulic clutch between the engine and the propeller, the emptying and filling of this clutch being controlled from the main control platform. This serves the dual purpose of taking any shock which may be caused through the propeller striking ice when she is navigating among ice floes, and also it allows very slow running of the propeller to take place, the main engine turning at its usual rated speed of 135 revolutions, whilst the propeller itself can be operated at as low as 30 r.p.m.

(6) The compactness of layout of engine-room is evidenced by the fact that all the pumps are of rotary type, electrically operated, and along the forward bulkhead. These are powerful and enable the ship to be trimmed very rapidly.

(7) The forward end is characterised by raking stem and rising forefoot. This is ice-strengthened, frame spacing in this part of the ship being about 1ft.

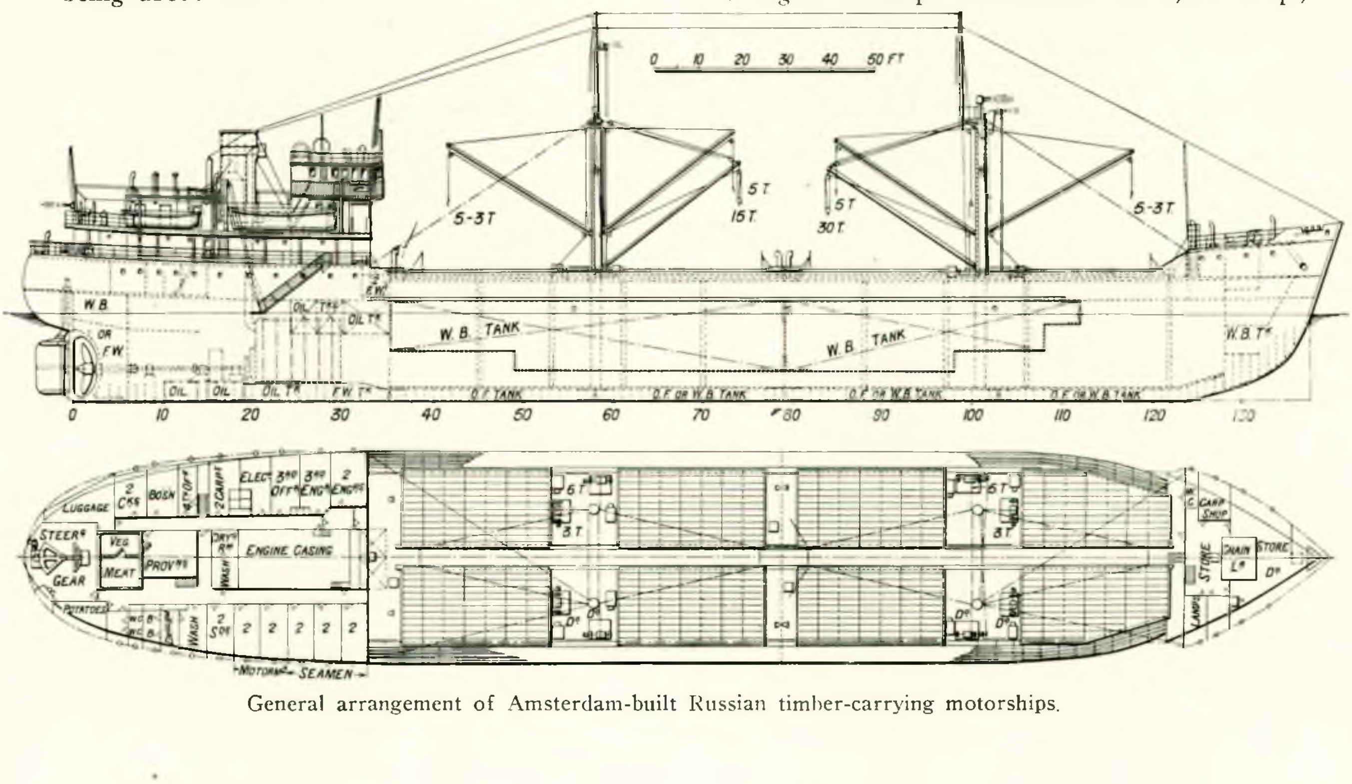
Particulars of the "Walerii Meshlauk" are:—

Length, o.a.	92·00m. (302ft.)	
Length, b.p.	86·30m. (283ft.)	
Breadth on deck	14·90m. (49ft.)	
Breadth on base line	12·30m. (40ft. 6in.)	
Depth	6·90m. (22ft. 8in.)	
Draught, loaded:—		
Summer wood trade...	5·93m.	19ft. 6in.
Winter wood trade	5·93m.	
Summer general cargo	5·93m.	
Carrying capacity wood trade ...	3,400 tons	
Deadweight	3,635 tons	
Bale capacity	175,000 cubic ft.	
Capacity fuel oil tanks...	165 tons	
Capacity lubricating oil tanks ...	25 tons	
Capacity of holds, 852 standards ...	2,260 tons	
Deck cargo, 428 standards	1,140 tons	
Tonnage	2,850 gross; 1,461 net	

All the crew are accommodated in the poop and in the deckhouses above. In view of the low temperatures in the North European regions, which will be visited by the vessels, all accommodation is insulated with cork. In all accommodation a temperature of 17° C. can be maintained when the temperature in the open air is 20° C. below zero.

Besides an oil-burning range an electric oven for bread baking has been erected in the galley. Close to the galley there is a provision storeroom and two cooling rooms, one for meat and one for other foodstuffs. The CO_2 refrigerating installation for the cooling of these spaces is installed in the engine-room.

The propelling machinery consists of a direct-reversing six-cylinder, two-stroke cycle, single-acting Stork Diesel engine, having cylinders 540mm. bore and 900mm. stroke. Running at 135 r.p.m. the engine develops a maximum of 1,675 b.h.p.,



General arrangement of Amsterdam-built Russian timber-carrying motorships.

which gives a speed of 11 knots, a speed which was easily reached on the trials. The main engine and all auxiliary Diesel engines were supplied by Machinefabriek Gbrs. Stork & Co. N.V. Hengelo (O.) and installed by N.V. Verschure & Co.'s Scheepswerf & Machinefabriek, Amsterdam. The auxiliary machinery includes fuel pumps, scavenging air pumps, cooling water and lubricating oil pumps; also fire, ballast, bilge, and sanitary pumps. A Clarkson oil-fired boiler of the standard wide water space design is installed in each vessel. Each boiler is 5ft. 6in. in diameter and 12ft. 6in. in height. The working pressure is 120lb. per sq. in.

The Steamship "Hopestar".

"The Engineer", March 6th, 1936.

Built by Swan, Hunter & Wigham Richardson, for the Wallsend Shipping Company, Ltd., the steamship "Hopestar" of the shelter deck type, with raked stem and cruiser stern, ran successful trials on Wednesday, February 26th. With a length between perpendiculars of 410ft., a breadth moulded of 57ft. 3in., a depth of 38ft., a draught of 26ft., and deadweight of 9,800 tons, the ship has been constructed to Lloyd's 100 A 1 class. It has clear holds for carrying large machinery, and is also designed for carrying grain. On many parts of the structure electric welding was adopted, with the object of saving weight. Bulkheads, machinery casings, deck-houses, bunkers, auxiliary engine seats, etc., are completely welded, whilst the tank top and decks have welded seams and butts, which give reduced weight without loss of strength.

Model tests were carried out at the National Physical Laboratory to obtain the most efficient form of hull possible for the required carrying capacity and other items such as a streamlined rudder with special fairing plates to reduce resistance and assist high propulsive efficiency. Seven water-tight bulkheads divide the hull into five large holds, and one deep tank, situated immediately aft the engine-room. Large hatches served by the latest type of steam windlass and derricks provide for the rapid handling of cargo. With the exception of the feed water tank, all the double bottom tanks are arranged for water ballast; also the fore and aft peaks and deep tank. Bunkers are constructed for carrying coal, and there is a reserve bunker in the No. 2A hold; also in the 'tween decks abreast of the machinery casings.

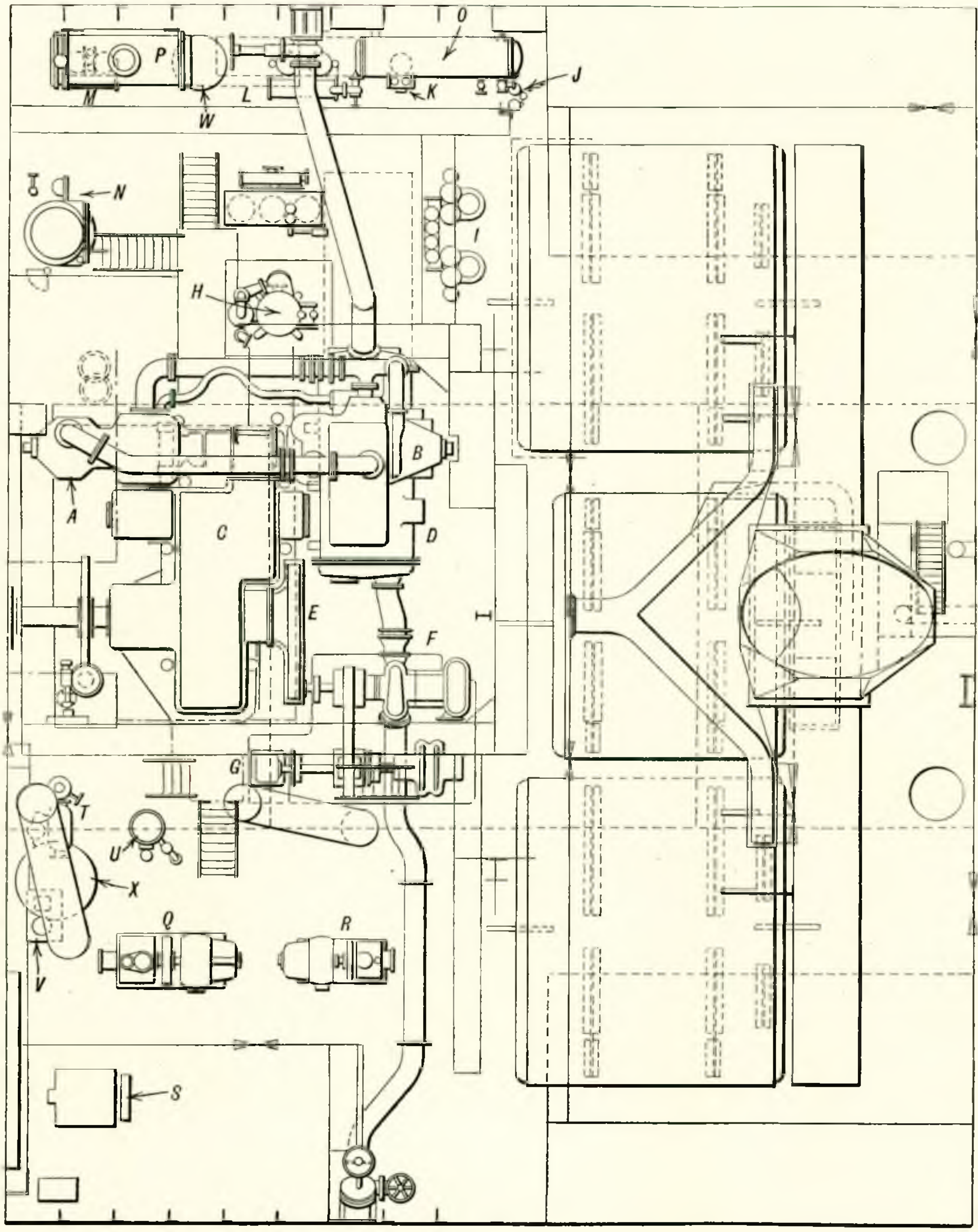
Accommodation for the captain and officers is provided in steel deck-houses forward of amidships, whilst engineers' accommodation is in deck-houses abreast of the machinery casings on the shelter deck. The crew's accommodation, situated aft, conforms with the latest Board of Trade regulations. It is divided into two groups of cabins for seamen and firemen. There are cabins with two berths in a single tier and separate mess-rooms are provided for seamen and firemen. Steam heating and electric lighting are fitted throughout the accommodation, and there is a refrigerated store chamber for ship's use.

As regards the main machinery, it will be recalled that some months ago the Parsons Marine Steam Turbine Company constructed a demonstration geared turbine set, considered to be particularly suitable for the propulsion of cargo vessels of about 2,000 h.p.* Exhaustive trials carried out independently led to satisfactory and encouraging results. This set of machinery has been installed in the "Hopestar", which is proceeding on service to demonstrate the further possibilities of the turbine. It is considered that the new design will prove attractive to owners of pure cargo class tonnage who are searching for the most economical form of propulsion. Although cargo vessels of low horse-power have not been fitted with turbines on an extensive scale, this latest propelling unit, which is not really revolutionary or new in principle, is expected to have a wide field of application. Although it is a simplified unit, it has the inherent characteristics of the marine turbine used in the development of over 6,000,000 h.p. of the world's mercantile tonnage. Simple construction and operation, high efficiency, low upkeep, reduced weight, and low fuel consumption are claimed for the equipment.

Whilst first cost has hitherto been an obstacle against the turbine's adoption on cargo vessels, the cost of this simplified unit has been brought well within the region of that of good-class reciprocating machinery. The "Hopestar" unit comprises one high-pressure and one low-pressure turbine working in series and connected by flexible couplings to the opposite ends of a single high-speed pinion. For astern running, high and low-pressure turbines are incorporated in the casings of the respective high and low-pressure ahead turbines. The high-speed pinion gears with a primary wheel mounted on the secondary pinion shaft, which gears in turn with the secondary wheel keyed to the main gear wheel shaft. All gearing is of the single helical type, and to take up the unbalanced load due to the axial thrust of the gearing thrust blocks are provided for each pinion. The main thrust shaft is formed by an extension of the gear wheel shaft, the thrust block housing being incorporated in the gear case base, thus providing a very rigid attachment. The turbines and main condenser are mounted on the gear case, thus allowing the alignment of the entire unit to be carried out in a single operation.

Manufactured by the Wallsend Slipway and Engineering Company, Ltd., the steam generating plant consists of two main multitubular Scotch type boilers, with an outside diameter of 14ft. 6in. and a mean length of 12ft. 3in., the total heating surface of both boilers amounting to 4,306ft. Three "Deighton" corrugated section furnaces with withdrawable back ends on the Gourley-Stephen principle are fitted to each boiler, each giving a total

*See Mr. S. S. Cook's paper, Vol. XLVI, Part 11, page 277 of Institute TRANSACTIONS.



A.—H.P. turbine.
B.—L.P. turbine.
C.—Gearing.
D.—Main condenser.
E.—Chain drive.
F.—Auxiliary unit.
G.—Thermal engine.
H.—Air pump.
I.—Feed pump (main).
J.—Feed pump (harbour).
K.—General service pump.
L.—Ballast pump.
M.—Auxiliary condenser circulating pump.
N.—Evaporator.
O.—Feed heaters.
P.—Auxiliary condenser.
Q.—12-kW. dynamo.
R.—5-kW. dynamo.
S.—Refrigerating machinery.
T.—Stand-by lubricating oil pump.
U.—Lubricating oil cooler.
V.—Lubricating oil purifier.
W.—Auxiliary condenser drain tank.
X.—Lubricating oil tank.

Arrangement of machinery.

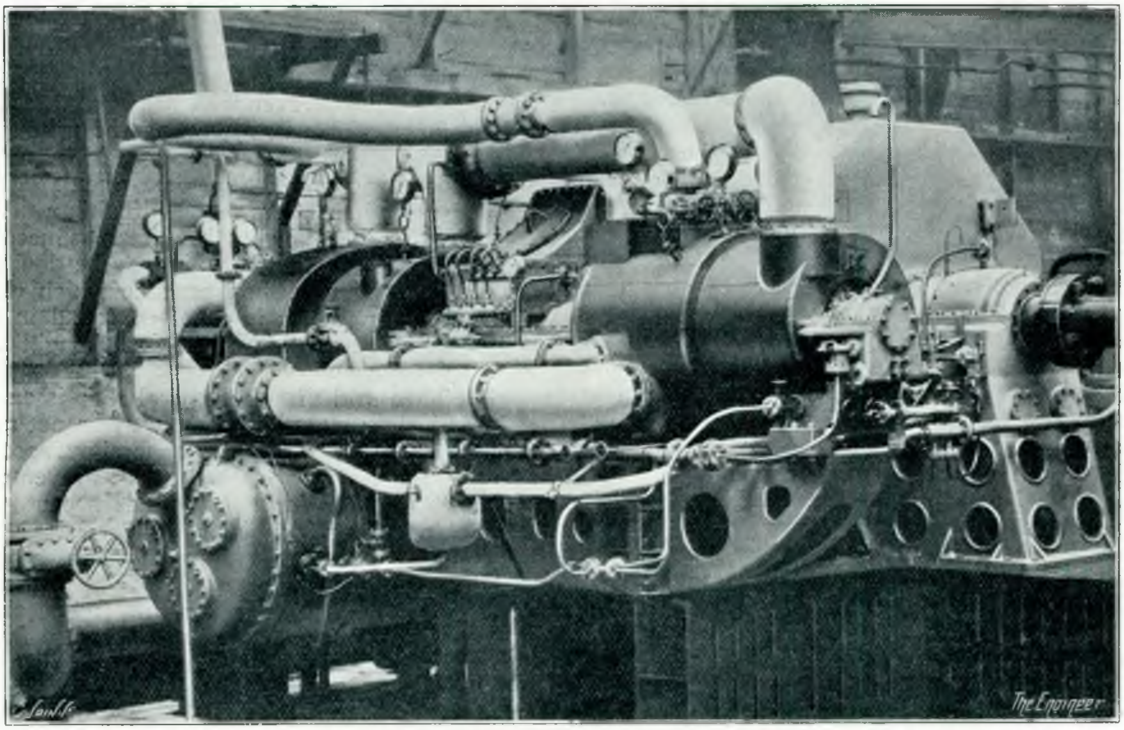
grate area of 118 square feet. The working boiler pressure is 285lb. per square inch. Combustion type superheaters, made by the North-Eastern Marine Engineering Company, raise the steam temperature to 750° Fah., an unusual feature of the superheaters being that the elements are fitted in all three combustion chambers, a scheme made possible by arranging a circulating connection to the superheater elements from the donkey boiler steam range for use when lighting up the main boilers. Under stand-by conditions or when the steam is on the main boilers only and none is being supplied to the turbine unit, the steam from the superheater outlet is led to a de-superheater made by the Superheater Company, and having its elements suspended between the nests of smoke tubes. After de-superheating the steam is led to the auxiliary range or to the auxiliary condenser.

Forced draught equipment for the main boilers was supplied by James Howden & Co. Each boiler smoke-box outlet leads into a tubular type preheater, arranged for three air passes. The forced draught fan is a James Howden double inlet high-efficiency unit, driven by an engine. Collins improved fire-bars, having a length of 5ft. 6in. and giving a total grate area of 118 square feet, are provided in the main boiler furnaces. A Diamond soot blower in the back of each combustion chamber is arranged so that both the superheater elements and smoke tubes are cleaned in one operation.

The auxiliary boiler supplying steam for harbour use, auxiliary purposes and to the main boiler superheaters when lighting up works at a pressure of 120lb. per square inch, and supplies saturated steam only. Its outside diameter is 12ft. 6in., and its mean length 10ft. 9in. It is fitted with two corrugated furnaces. The total heating surface is 1,495 square feet, and the grate area 39½ square feet. The boiler is placed abreast of the main boilers, and is arranged for working with forced draught, the tubular air preheater being of the single-flow type. A Crompton self-tipping ash hoist is installed in the stoke-hold.

The auxiliary machinery in the engine-room consists of a Drysdale auxiliary unit comprising a main circulating pump, forced lubrication pump, bilge pump, sanitary pump, and oil cooler circulating pump. The unit is operated by a chain and friction clutch drive from the main turbine unit or, alternatively, by a high-speed reciprocating steam engine and friction clutch, which are only used when working in or out of port or when steaming during foggy or stormy weather. There is also a monotype air pump with a vacuum augmenter, a pair of independent feed pumps, a stand-by forced lubrication pump, a primary and secondary feed-water heater, and an evaporator capable of producing 20 tons of fresh water per twenty-four hours. These units were manufactured by G. and J. Weir, Ltd. The general service pump, ballast pump, harbour feed pump, auxiliary condenser circulating pump, and gravity feed filter are of Carruthers' manufacture. For reconditioning the lubricating oil there is a motor-driven Vickcen oil purifier with a capacity of 90 gallons per hour. In the auxiliary exhaust range there is a Holden and Brooke "dual" oil separator.

The steam generating plant and its installation has been under the supervision of Wilson and Burletson, of Newcastle-on-Tyne, and it fully complies with Lloyd's rules and regulations.



Main propelling machinery of s.s. "Hopestar".

The General Shop.

"The Engineer", February 7th, 1936.

Amongst the many things which occupy the mind of the practical works manager there is perhaps none pleasanter than the devising of methods of carrying out exceptional work with existing equipment. It calls for the exercise of the mechanical engineering imagination, and for a display of ingenuity which is denied to those whose output is exactly fitted to the equipment and the equipment to the output. The manager of the specialised shops lacks these pleasures, and even the tool-room on which such work now-a-days devolves has little more to do, in all save a very small proportion of cases, than make gauges by standardised methods, devise cams, or work out the best form, duty, and order of use of cutting tools. They flourish in the atmosphere of the general shop, and are often found blooming in repair yards and on repair jobs. We recall an example which occurred in foreign waters during a certain Balkan war. The work involved the re-turning of the forward journals of the two main turbines of a destroyer. Usually the rotors and shafts would have been lifted and put in the lathe. As an alternative the shafts would have been barred slowly round by hand or, as in many a reciprocating repair job at sea, by fitting up a donkey or winch engine to provide power. In this case a young and ingenious mechanical engineer—how well and truly the name fits such work—revolved the turbines slowly under their own astern steam and turned the journals so true that on examination later the correction necessary was found to be hardly appreciable. Some of our readers will remember the late Mr. W. H. Morley, of Cole, Marchent and Morley, one of the cleverest mechanical engineers of his day. We visited him once at Bradford, when he was busy on the construction of an engine whose dimensions were far outside the capacity of his plant and well recall the admiration and pleasure aroused by the devices and makeshifts he employed to accomplish the work. Such cases are not rare. It has been said that the amateur mechanic is a man who achieves with inappropriate means what the professional hardly dares to attempt with specialised equipment. But just as the amateur has to be a good mechanical engineer within his limitations, so the professional mechanical engineer remains at heart an amateur in the pleasure he derives from calls made upon his ingenuity and resourcefulness in the prosecution of his work.

It is because the "general" shop offers such opportunities of this kind that it was at one time regarded as the best training ground for mechanical engineers. Fortunately, many such works remain and young men who desire to become "mechanical" engineers rather than "production" engineers might do worse than seek them out for the serving of their time. Many are rough and ready; the proportion of modern to old tools is small, and it is only by experience that the user learns where the best spots on the lathe bed are and what parts of the lead screw are to be avoided when screw cutting. Often the men are like the machines. Rather rough, but exceedingly knowledgeable in the arts and crafts of the wheelwright. Intermediate between these and specialised shops there are hundreds of factories up and down the country in which a surprising variety of work is undertaken and in which modern high production conditions are absent. They are, as we say, admirable training grounds for the genuine mechanical engineer. They are, morever, a very valuable asset to the industry. In the early days of any novel mechanical invention it is in a quite unsuitable condition for the specialised shop. It goes, therefore, to the general shop, where the initial stages in its development may be undertaken. No new mechanical invention is perfect from the moment it leaves the drawing board. It always reveals some defects, either in design or operation. An enormous amount of very valuable experience is there for the observer who has eyes to see, and who, perhaps assists in correcting the primary defects. This is a form of training which is valued by engineers who served their time when specialised production methods were much rarer than they are now. No doubt a new type of man is needed to meet the new conditions, but it may be doubted if the real love of workshop practice which characterises older engineers is so often found in those of the present generation whose first thought has to be organisation and output.

We have said that the general shop is an asset to the industry; we might add that it is not an uneconomical one. The fact that general purpose tools take the place of specialised tools prevents any machine being idle for long periods because work of the kind for which it is designed is lacking. Moreover, it is generally found that many of the machines are elderly, if not old. They have been written off long ago; there are no standing charges on them, but in the hands of men who are familiar with their little idiosyncrasies they are still capable of good work. The buildings too, the offices, and the organisation are generally out of date; but cheap. For these and other reasons such works are often able to put in quotations much lower than those presented by firms burdened with high "overheads". A serious drawback to such works is that with few assets and small reserves they rely very greatly upon the personal zeal of one or two men. They have very little momentum and often enough seem to carry-on rather by the grace of God than their own endeavours. They are, no doubt, destined to diminish with the continual spread of modern production methods, but some of them will always be needed, and unless the apprenticeship system is as doomed as a recent discussion at the Junior Institution seemed to indicate, then it is to be hoped that a sufficient number of general shops will always remain as the training ground for your true mechanical engineer.

The Name "Mauretania".

"The Engineer", February 7th, 1936.

It has been decided by the Southampton-Isle of Wight Steam Packet Company to change the name of its 365-ton paddle steamer "Queen" to "Mauretania". This change is being made to oblige the Cunard White Star Line in order to preserve the name "Mauretania", should that company want it for another ship in the future.

Marchese Marconi.

"The Engineer", February 7th, 1936.

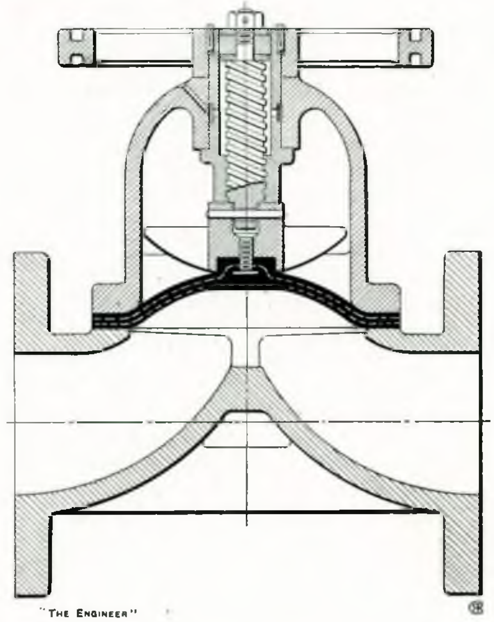
Sunday, February 2nd, was the fortieth anniversary of the day on which Marchese Marconi arrived in England with his crude apparatus to demonstrate to the G.P.O. and other Government Departments the possibility of communication without the aid of wires. In June of 1896 he lodged his application for the first British patent for wireless telegraphy, and in July of that year gave his first demonstration before Sir William Preece, then Chief Engineer of the G.P.O. This was over a distance of 100 yards, but subsequent experiments on Salisbury Plain, on the Bristol Channel, and elsewhere showed possibilities of communication over much greater distances. Within a year of his coming to England Marchese Marconi had proved that distances up to 10 miles could be covered. During the following year this distance was doubled, and within five years the Atlantic had been spanned by the transmission of "S" signals from Poldhu in Cornwall to St. John's, Newfoundland. From these beginnings modern wireless developments, including broadcasting and the possibility of television have emerged.

The Saunders Valve.

"The Engineer", March 27th, 1936.

A simple form of stop valve, which has already been briefly referred to in our Patents columns, and is now being manufactured in this country, is illustrated by the accompanying drawing. This valve was originally devised to reduce the leakage of air from the compressed air lines of the gold mines in South Africa, and has since then been adapted to various other purposes. It involves the familiar principle of separating the fluid controlled from the working mechanism by means of a diaphragm, and provides an easy flow for the fluid, so that back pressure is reduced to a minimum.

As will be seen from the drawing, the body of the valve is swept up towards the centre to form a weir reaching well above the centre of the bore. Between the body and the bonnet, above, there is clamped a rubber diaphragm, which can be forced down on to the weir by a screw-operated "compressor". This compressor is provided with feathers which distribute the pressure over the surface of the diaphragm when it is pressed down into the closed position, while other feathers support it in the opened position. The hand wheel is connected with the operating nut by a sleeve and the screw is always enclosed in this sleeve, so that it is protected from injury.



Saunders valve.

It will be noticed that in closing the valve the diaphragm has to be pushed down against the full working pressure, so these valves are generally confined to pressures of about 250lb. per sq. in. or less, but they will hold tight with temperatures up to 140° C. when handling practically all kinds of fluids. The materials of construction of the body and diaphragm are naturally chosen to resist any corrosive action of the fluid, but the moving parts are immune from such action. The head lost by the fluid in passing through the valve is little more than that through a gate valve and is much less than that of a globe valve. The valve is made in many sizes up to 6in. in bore.

The Dead Sea as a Source of Chemicals.

"The Engineer", March 27th, 1936.

The Dead Sea was described as "one of the most striking phenomena on the globe" in a paper read on March 6th by Mr. M. A. Novomeysky before the Institution of Chemical Engineers. Mr. Novomeysky pointed out that with its average level some 1,300ft. below the Mediterranean sea level, and with a depth of another 1,300ft., the Dead Sea is the lowest point on the world's land surface. How the Dead Sea became so saturated with valuable mineral salts—so saturated with them that it is impossible to sink in its waters—has been a matter of conjecture for many years. The sea fills part of a great rift in the earth's surface, and is a natural reservoir without outlet. From the river Jordan and from the Judean Hills, by way of subterranean springs, it receives 8,800,000 cubic metres of water every day. Its only method of discharge to make way for such a huge intake is by the rapid evaporation of the water under the glowing oppressive heat and the almost continual winds which rapidly disperse the vapours in the eight rainless months. The Dead Sea has been a matter of investigation for centuries, and during the last 100 years there have been expeditions to its shores from England, America, France, and Germany. These investigations have now revealed how the evaporation of the waters has left behind a vast storehouse of chemicals. Salts of potash, magnesium, and calcium are brought into the sea by the waters of the Jordan, and bromine comes in from the hot springs of Herod's Bath that have been known from Roman times. It was calculated recently that although the Dead Sea is only about 47 miles long with a width of 9 miles, it contains some 40,000,000,000 metric tons of valuable salts in solution. One of the most valuable, although in lesser quantity than others, is muriate of potash, of which more than 2,000 million tons are thought to be present. Mr. Novomeysky explained how the recovery of these valuable salts has developed into a substantial industry in Palestine, 25,000 to 30,000 tons of potash now being produced annually, with scope for expansion to 100,000 tons a year. More than 1,000 tons of bromine are being produced annually at present. Only one raw material, said Mr. Novomeysky, needs to be imported—fuel oil. The other raw materials—the sun, the Dead Sea, and the fresh water from the Jordan—are all available on the spot.

Colloidal Fuel.

"Engineering", February 28th, 1936.

The paper on the subject of "Colloidal Fuel", read by Dr. A. B. Manning and Mr. R. A. A. Taylor, both of the Fuel Research Board's staff, before the Institution of Chemical Engineers, on February 21st last, carries the theoretical conception of this type of fuel a stage nearer to complete understanding. At this meeting and at others, there has been opposition to the name "Colloidal Fuel", partly on the ground that the coal, at all events, is not ground to that degree of fineness which would entitle it to the designation "colloidal"; at the same time, to judge from the present researches, a suitable oil for the suspension of coal appears to have a gel structure under certain conditions. The alternative name of oil-coal fuel is favoured in many quarters. "Coal-oil" is to be avoided because it gives the impression of referring to an oil derived from coal.

The authors pointed out that the principal advantage of this mixed fuel was that it could be handled in the same way as oil, but that the price of coal per therm is only about half that of oil per therm, so that the mixture has the ease of handling associated with oil, and at a lower cost. The size of particle of the coal in an oil-coal fuel ranges from 1μ or 2μ to 65μ. The 65μ size appears to be that generally favoured on account of cost of grinding, and roughly corresponds to 100 per cent. through 100 I.M.M. mesh, and 85 per cent. through 200 mesh, i.e., to that now used for pulverised-fuel firing. The prospects of oil-coal fuel coming into commercial use depend on the consideration of whether it is technically and economically sound. The authors state in their paper that "no information seems to be available publicly on the behaviour or prospects of the fuel in Diesel engines"; it was stated in the discussion, however, by Mr. Hamilton Martin, that he had used colloidal fuel in an 80-h.p. Diesel engine successfully. It was found that the fuel burnt more easily than oil or brown-coal dust, and that it ignited at some 23 atmospheres pressure, as compared with 30 atmospheres to 45 atmospheres for other Diesel fuels. This observation of the combustion of the fuel under pressure is interesting when contrasted with the authors' observation that in boilers the two constituents burn more or less independently, the oil first, and then the coal, so that it is necessary to provide sufficient space for the complete combustion of the slower-burning solid particles before the flame impinges on the boiler tubes. A formula has been derived by the authors for calculating the economics of the system, showing that the cost of colloidal fuel works out at about 0·99*d.* per therm, as compared with oil at 1·13*d.*, taking account of all such items as the cost of mixing and grinding, freightage, and so forth.

The principal contribution to the subject made by the authors is upon the theoretical side, and concerns primarily the physical condition of the oil. The authors have followed up the Cunard Steamship Company's work, which showed that some fuel oils, especially those produced by cracking, form stable suspensions of pulverised coal, of the size described as economically producible, without the use of a stabiliser. The properties of oils which are suitable for this purpose have been investigated. With one exception, the origin of which was unknown, all oils found to be suitable were cracked oils. It is found that suitable oils correspond to Iranian oil with sodium stearate addition. They do not appear to possess a clearly-defined gel structure, but they "show a type of structure resembling a gel" at low velocity gradients. The viscosity increases as the rate of shear decreases. When any given particle of coal starts to fall through oil it has a very small initial velocity. When many particles are closely packed together, the initial rate of fall is still less; for example, a single particle of coal passing through a 240-mesh B.S. screen will fall through oil at the rate of 0·00167 cm. per second, but with a 40 per cent. concentration of coal in the oil, the rate of fall is only 0·00003 cm. per second. At these rates of fall a suitable oil behaves as if it were gelantinous, and the coal is unable to move. When such an oil-coal mixture is stirred—as when it is pumped—it behaves as if the oil were quite fluid and the gel structure had disappeared, but in the course of a few hours the gel structure is re-formed. It was suggested that this loss of "dilute gel structure" upon agitation might prevent the use of oil-coal mixtures at sea where the fluid would rarely be at rest. Apparently the more frequently the oil is agitated, the longer is each succeeding period before the dilute gel structure is re-established.

Finally, attention may be directed to the experimental methods employed. Measurement of the rate of settling of an oil coal suspension is difficult and laborious. The authors have devised an ingenious apparatus consisting essentially of a glass tube holding the suspension, fitted up as a compound pendulum that will oscillate upon knife edges carried upon agate surfaces. From the period of oscillation of the pendulum, the centre of gravity of the mixture can be calculated, and from that the average settlement per particle. The rate of settlement is not proportional to the period of the pendulum. The more rapid fall during the first day or two with the suitable oil is by reason of the time taken to establish the dilute gel structure. Measurement of the time taken for re-formation of the dilute gel structure is determined as follows: the oil is vigorously stirred, or perferably heated, and then introduced to a convenient level in a capilliary U-tube, which, with its contents, is stored in a constant-temperature bath. The level of the oil in one limb is displaced about 1in. by applying a pressure, and then the time taken to flow back some three-quarters of this distance is measured. The level is then again displaced, and the oil is left a period before another observation of the time of flowing back.

Boiler Explosion Inquiries.

"Engineering", February 7th, 1936.

In accordance with the Boiler Explosions Acts, 1882 and 1890, inquiries have been conducted by Board of Trade officials into a number of explosions. Reports of the investigations have been published recently, and of some of these we give brief summaries below.

Explosion in s.s. "El Uruguayo".—Though the explosion of a cast-iron boiler stop valve in s.s. "El Uruguayo" on February 27th, 1935, which is the subject of Report No. 3266, was caused by water hammer, the circumstances were somewhat unusual, as the accident was directly due to a mistake made in assembling an exactly similar valve on another boiler. The "El Uruguayo", of the Furness-Withy Line, has six single-ended cylindrical boilers working at 200lb. per square inch, the boilers being disposed two on the centre line of the ship, two on the port side and two on the starboard side. Each pair of boilers has a common steam main leading to an isolating chest with three valves. In December, 1934, all six boiler stop valves were opened up for survey, five of them being dealt with by the ship's engineers and the sixth, the one which led to the trouble, being done by shore fitters. Each stop valve was of the "screw lift" type, the screwed spindle working in a threaded brass bush in a steel bridge piece fixed on two pillars. The bush had a plain cylindrical body, and a flange on the under side to take the thrust, while it was prevented from turning by three $\frac{3}{8}$in. screwed dowel pins on the upper side. When the shore fitters closed up the stop valve on the after starboard boiler they replaced the bridge upside down, thus rendering the flange on the bush useless and causing the upward thrust to be taken by the dowel pins. On the day of the accident all main stop valves were shut, but the port after and starboard after boilers were in use for auxiliary purposes. The ship was in Brocklebank Dock, Liverpool, and the fifth engineer was told off to examine the isolating chest on the main steam pipe system. Finding this hot, he proceeded to tighten the main stop valves on the two boilers in use, but found that on screwing down the spindle of the valve on the after starboard boiler it became quite slack. Not being satisfied, he went to report to the second engineer, but before he had reached the deck he heard a "clicking" sound and then the roar of escaping steam. Fires were drawn as soon as possible and examination showed that the main stop valve chest on the forward port boiler had fractured, while the spindle of that on the after starboard boiler had been forced upwards about an inch. The steam had thus gained admittance to the main steam pipes and water lying in that to the port boilers had been set in motion, giving rise to hammer action. There was no question that the wrongly assembled valve was the initial cause of the accident, but as to the lay-out of the pipe system, the Engineer Surveyor-in-Chief remarks "the pipes were ranged on a plane parallel with the keel, and although isolating valves were fitted by means of which the system could be separated into three sections, the pipes were not fully safeguarded against the risk of water hammer to which pipes so ranged on board ship are very susceptible, particularly in relation to the stop valves of any boilers not in use while other boilers are under steam", and "further, the explosion might have been avoided had the valve chest been made of material better adapted than cast-iron to resist shock". The explosion resulted in no personal injuries, although four men at work in the empty boilers had an alarming experience. Subsequent to the accident, bushes threaded externally were fitted in the bridges of all the main stop valves, while improvements were made in the draining system.

Explosion from a Niclausse Boiler.—Report No. 3270 deals with an accident to a Niclausse water-tube boiler which occurred on February 23rd, 1935, at the Willans Works, Rugby, of Messrs. The English Electric Company, Limited. Though between thirty and forty years ago many ships in the principal navies were fitted with Niclausse boilers, the type was not adopted widely in H.M. ships, and it is probable that comparatively few were used in land stations in this country. The particular boiler at Rugby, the report says, was one of six at the works, and the order for it was placed with Messrs. Willans and Robinson, Limited, Thames Ditton, Surrey, on January 21st, 1896. The old firm of Messrs. Humphrys and Tennant, Deptford, were the licensees for the manufacture of Niclausse boilers, and the boilers at Rugby, we presume, were made either at Deptford or obtained from France. One of the chief features of the boiler, which was perfected by M. Niclausse in the 'nineties of last century, was the use of double tubes as invented by E. Field in 1862, but whereas Field suspended the tubes vertically from a tube plate, M. Niclausse placed his tubes at an inclination of about 10 deg. with the horizontal, fitting the front ends into headers and supporting the back closed ends in a "spectacle plate". The boiler was well described in 1898 by Leslie Robertson in his translation of M. Bertin's work on marine boilers, and the sketches contained in this work are practically identical with those appended to the Board of Trade report. The boiler at Rugby, which had safety valves lifting at 180lb. per square inch, had a steam drum 3ft. 7½in. internal diameter and 8ft. 5in. long, from which hung vertically nine malleable cast-iron headers, each of which carried 18 generating tubes 4in. in diameter. M. Niclausse in his design included a "sleeve" or "lantern end" on each tube which fitted into the header with two slightly coned joints. The coned surfaces had to be kept in good condition, and when a tube was put into place it was common practice to drive it home with light blows from a lead hammer. As the ends of the tubes were about equal in diameter, there was practically no tendency for a tube to be forced out of place by the steam pressure, but on the front of the headers were studs and nuts for securing dogs or cross-bars, one dog serving for two tubes. When everything was in good condition there was practically no stress on these dogs and studs, but if a tube fractured across the sleeve or lantern end, then the dog prevented the loose end from being blown outwards. At Rugby one of the lanterns fractured, the stud holding the cross-bar was defective, the end cap with the inner tube was projected across the stokehold, a great volume of steam escaped, and one man received injuries from which he afterwards died. As regards the breaking of the lantern, this may possibly be traced to the method employed for removing the tubes. A special tool is supplied for withdrawing the tubes, but at Rugby, so the report says, "the process had frequently to be assisted by hammer blows on the closed ends of the tubes at the back of the boiler". This hammering was certainly never intended by M. Niclausse, and in ships where boilers were back to back it was not possible. As regards the other fittings, the report says, "The security of the cross-bars to the studs was, in general, very unsatisfactory. . . . In one further instance the stud thread at the tip was so completely worn that the nut had no security and fell off when it was touched", while the maintenance staff "had not visualised any circumstances whereby the load due to the boiler pressure on the cap might be transferred to the cross-bar stud and nut". Since the accident the firm has decided to scrap three of the Niclausse boilers and adjust the working pressure of the remaining three to 80lb. per square inch. The Niclausse boiler as fitted in warships had excellent steaming qualities, but though it has been superseded by other types, it is of interest to learn that boilers of the type nearly forty years old are still at work on shore.

Steering Gears for Ships.

"The Engineer", March 20th, 1936.

The report of the Special Committee appointed by the President of the Board of Trade to consider in the interests of safety of life at sea the types of steering gear fitted in the steamships "Usworth" and "Blairgowrie", which were lost at sea in December, 1934, and February, 1935, has now been issued. The main steering gear in each vessel was of the rod and chain type, which, the report states, is the most common in cargo vessels. After examining the evidence, the Committee came to the conclusion that the rod and chain steering gear was reliable when properly designed and fitted and kept in repair. Certain safeguards, however, were, in its opinion, necessary. The main recommendations of the Committee are:—An annual survey of the rod and chain and auxiliary steering gears; rod and chain steering gear should be inspected every three months; a steering gear register should be kept in the ship to include a record of the periodic overhauling while on voyage, of breakdowns and repairs, and of official inspections; all new chain should be subjected to proof and breaking tests; and a set of spares should be carried; rod and chain gear should be effectively protected from damage by deck cargo; and the auxiliary gear should be rigged and operated every six months and at the annual survey of steering gear. In the case of new ships it is recommended that a detailed plan of the rod and chain and auxiliary steering gears should be approved by the inspecting authority, by whom the gears should also be surveyed during construction.

The Fire on the "Potsdam'.

"The Engineer", March 20th, 1936.

When the North German Lloyd Far East liner "Potsdam" anchored in Cowes Roads on Thursday morning, March 12th, it became possible to obtain further information concerning the fire in the engine-room which took place about 3 a.m. on Wednesday morning when the ship was off Worthing and was heading down the Channel. We record this fire on account of its technical interest, and because we were in the ship as a member of a small party of British engineers representing shipping and shipbuilding interests which had been invited by the owners to inspect the Benson boiler installation and the electrical propelling machinery. The fire was caused by the fracturing near the nipple of a screwed connection of a 13mm. diameter copper pipe, on the end of the port high-pressure turbine which carried lubricating oil at a pressure of about 6 atmospheres for operating the relay governor gear. While the crack was not sufficient to stop the flow and shut down the turbine, it sprayed with oil the hot end of the turbine, at which the steam was entering at 450° Cent. The oil ignited at once and the fire immediately spread to the electrical resistances connected with the control board which were arranged immediately above the port turbine. The insulation was seriously damaged by the fire, and by the water used to extinguish it. Immediately the alarm was raised the emergency generator sets were started up, and the fire was fought by the chief engineer and his staff, many of them in smoke helmets, and was brought under control and extinguished. The next day the undamaged starboard turbine unit was connected to the two main propelling motors, and with a temporary steering arrangement, operated by telephone from the bridge, in the steering gear compartment, the ship was able to proceed to Cowes at about half speed, and later returned for repairs to her home port. Before leaving the ship the British party waited upon Commander Arndt and Chief Engineer Baumann, and expressed to them their warm appreciation of the efficient manner in which the accident was dealt with and their congratulations on the discipline maintained in the hours of danger by the officers, crew, and passengers.

Diesel-electric Propulsion with Alternating Current.

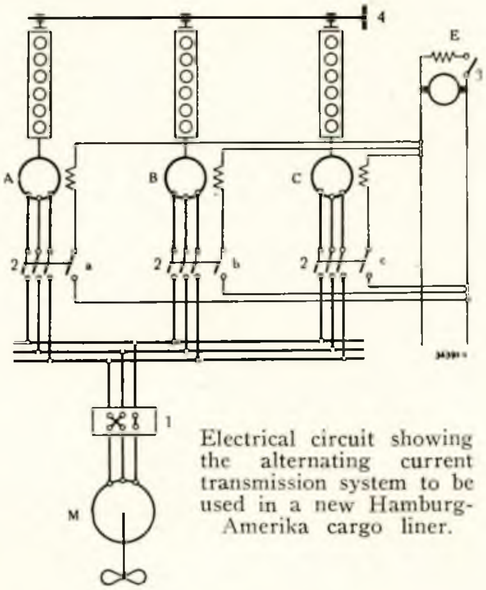
"The Motor Ship", April, 1936.

It was recorded recently in "The Motor Ship" that the new Hamburg-Amerika cargo liner now under construction, which is to be propelled on the Diesel-electric system, would be the first ship of this class to have alternating current electric transmission. The system to be employed is, in principle, that which was described in "The Motor Ship" of May, 1932.

The power is to be supplied from three Diesel-engined generators running at 250 r.p.m. and delivered to a single propelling motor operating at 125 r.p.m. for the normal speed of the ship. The variation of speed is obtained partly by switching in or out one or more generating sets, and partly by reducing the speed of the alternators. The system is shown diagrammatically in the illustration. The engine-speed control is indicated at (4), and this acts upon the throttle of the three engines simultaneously. They are all adjusted on the governor together and at no load the three units run at the same speed. The three engines can likewise be started together, and the alternators are excited from a single dynamo coupled to a Diesel engine. There is no variation of excitation, except that it is temporarily increased each time an alternator is brought under load.

Assuming that the order telegraphed is "slow ahead", the reversing switch (1) is closed, the three Diesel engines having already been started up before this operation is carried out.

Next, the generator switch, or circuit breaker (2a), is closed, and after this the exciter switch; the excitation is thus momentarily strengthened. Current then flows to the propelling motor to the full extent of the output of one engine, as set by the governor.



Electrical circuit showing the alternating current transmission system to be used in a new Hamburg-Amerika cargo liner.

If it is now required to go full speed ahead, the exciter switch (3) is opened; the load is thus taken off the generator (A) and the speed increases until it equals that of the sets (B) and (C). The generator switches (2b) and (2c) are then closed, the excitation switch is again closed for increased temporary excitation, and the three generators run in synchronism and supply the full power to the propelling motor.

If it is desired to go full speed astern, the Diesel engine speed is reduced to about 40 per cent., the exciter switch (3) is opened, the direction switch (1) is changed over to astern, and the exciter switch (3) then closed. The speeds of all three Diesel engines can then be increased simultaneously to the extent desired.

Stiffened Boiler Furnaces.

"Shipbuilding and Shipping Record", February 13th, 1936.

There are a number of patented designs of furnaces for use in the familiar return tube type of marine boiler in all of which the idea is to obtain a certain measure of stiffening as compared with the plain cylindrical furnace. The importance of such stiffening is indicated in a report just issued of an inquiry held under the Boiler Explosion Acts into an explosion on a coasting steamer which resulted in the death of the second engineer. It appears that the cause of the explosion was the wasted condition of the starboard combustion chamber bottom plate. The boiler was constructed in 1902, and originally angle bar stiffeners were fitted to the underside of each furnace. In 1927 these angle bars were removed in order to effect repairs and were not replaced. It would appear as though the removal of these stiffeners led to an undue amount of working of the plates which, as is generally the case where molecular friction occurs, resulted in rapid corrosion or wasting of the material and ultimate failure. The Board of Trade surveyor in his report stated that while he did not consider the owner's superintendent engineer guilty of wilful neglect of duty, he failed to appreciate the consequences which might ensue from his action in failing to replace the angle bar stiffeners and he was ordered to pay £10 towards the cost of the inquiry. The assistant superintendent engineer was also held guilty to the same extent because he was at fault in assuming that the wastage was only confined to a small place whereas it was general.

Liner Wear.

"The Marine Engineer", December, 1935.

A useful addition to the knowledge which has already accumulated on the subject of liner wear has been presented in the form of a paper entitled "Undue Cylinder Wear in Internal-combustion and Steam Engines", by Mr. Horace J. Young, which he read before the Institution of Automobile Engineers recently. As a point of departure, the author emphasised the unchanging position of wear in any reciprocating engine as always facing the first free ring at its topmost reach to the combustion zone, and alluded to the series of corrugations which may be found by the successive gumming-up of the rings solid with the piston, beginning with the uppermost. Each trench or corrugation faces a piston ring, a phenomenon which is fairly common in Diesel practice, as many of our readers will be aware.

In speaking of materials for cylinder liners, the author referred primarily to sand-cast irons without after-treatment, the characteristics of which he had studied all his life. He criticised the supposed connection between irons which were close-grained or hard, and had good wearing properties, and stressed the bad wearing effects of ferritic irons. Every case of "mysterious" failure to wear satisfactorily coming before him had proved to be one where less than all-pearlitic iron existed. Sulphur, on the other hand, assists the property to wear well, and the suggestion of a research aiming at the production of high-sulphur iron without the disadvantages ordinarily associated with sulphur deserves practical support.

Mr. Young's observations on oil-film retaining properties of irons will be studied closely. Properly made cast irons, he asserted, have been made to wear as satisfactorily as any other liner material known to date, though they are neither hard nor non-corrosive. He explained this by saying that their power to resist wear rests upon their ability to avoid having to do so. "In other words, they behave as bearing metals".

Manufacture a material which will retain oil film, and wear is reduced to a minimum. Where oil film breaks down heavy wear takes place, which often represents the state of affairs on the cylinder walls at the top of the stroke. That is why, as the author points out, exceedingly hard materials provide one means of alleviating the effect.

The comments of the author on the effects of heating and cooling of materials are interesting, particularly his suspicion of laboratory tests, where the materials are kept at a temperature different from that to which they are usually subjected. Also his remarks on corrosion follow opinions on this important subject which he has expressed on a previous occasion. In this connection the desirability of keeping the lubricating oil thoroughly clean may be mentioned.

The common factors affecting wear in both steam and internal-combustion engines may also be noticed, which, we believe, have not always been generally realized or accepted in the past. The paper comprises a valuable addition to the subject with which it deals.

Experiments with Piston Rings.

"Shipbuilding and Shipping Record", February 27th, 1936.

In the endeavour to investigate the many problems which have presented themselves during the service operation of the marine Diesel engine, many notable researches have been made during the course of which apparatus has been designed to simulate in the laboratory the conditions occurring when the engine is actually running. The experiments of Dr. Sass into the flow of scavenging air in the two-stroke cycle engine may be recalled as an illustration of this. Of a similar nature were the experiments into the effect of piston rings which were described by Engineer-Commander C. J. Hawkes and Mr. G. F. Hardy, in a paper entitled "Friction of Piston Rings", read at a recent meeting of the North-East Coast Institution of Engineers and Shipbuilders. The authors described the model cylinder, 6in. in diameter, in which they could obtain piston speeds ranging from 0·06 to 11ft. per second, measuring not only the friction of the rings but also the gas leakage when subjected to steady air pressures up to 90lb. per sq. in. The apparatus was also designed so that the experiments could be carried out at different temperatures. The authors realised, of course, the limitations of such experiments and the large number of variables which must be envisaged if results comparable with those of an actual engine are to be obtained, but their tests show that the rate of supply of lubricant has an appreciable effect on the results, while the air leaking past the rings was greater than could be accounted for by the ring gaps alone.

Dry-ice Refrigeration.

"Shipbuilding and Shipping Record", February 6th, 1936.

On vessels of small and medium tonnage for the carriage of provisions for officers and crew as well as for small perishable cargoes, the ice box is not infrequently employed as an alternative to the small refrigerating machine. We have already drawn attention to the possibility of using solid carbon dioxide, or dry ice to give it its trade name, instead of ordinary ice, that is frozen water, and the use of the former substance is apparently being successfully developed. In a recent issue of the trade journal devoted to the activities of the producers of dry ice, an account is given of the transport between San Francisco and Philadelphia of a cargo of 800 cases of eggs, each case containing 30 dozens. The storage chamber in which the cargo was carried was equipped with an air conditioning plant by means of which both the temperature and the humidity of the air were automatically controlled. The refrigeration was carried out by means of dry ice, and the system employed was such that during a voyage of 21 days' duration, which included the passage through the Panama Canal, the temperature was maintained at an average value of 36·4° F., average relative humidity 89 per cent., and average concentration of CO_2 gas 10 per cent. Charts taken from the recording instruments indicate the uniformity of the conditions throughout the voyage during which, it may be noted, only one charging with dry ice was required.

Manufactured Weather in the Tropics.

By C. A. Middleton Smith, M.Sc., M.I.Mech.E.
(Taikoo Professor of Engineering in the University of Hong Kong).

"The Engineer", February 14th, 1936.

Unless the reader has experienced the mental and physical reactions of the combined effects of the excessive heat and humidity in the Tropics upon the human mechanism, he will be unable to appreciate the enormous advantages of a manufactured atmosphere.

This almost latest application of engineering science for the benefit of human health and efficiency must, in time, have a profound effect upon the development of the large areas of the earth which lie within the tropical zone. For a manufactured atmosphere increases human efficiency.

During recent months the writer has been making a few practical experiments on the subject. Although the results obtained are not yet sufficient to provide much accurate scientific data, they are quite enough to confirm, by personal experience, the theoretical studies which convinced him that this subject is well worthy of close commercial investigation by British firms manufacturing refrigerating machinery. And it is with the primary object of stimulating an interest in Britain in an engineering development that is, at present, in its infancy that this matter is discussed. For the British Flag flies over many thousands of square miles that are in the Tropics. And the Empire can be made more productive by an increase in the application of science to local problems.

It is a truism that where the banana grows there the natives are, and apparently always have been, less energetic, and therefore less civilised, than residents in colder regions. It is, of course, true that there is not much incentive to store or even to cultivate food, or to provide protection against the weather in a climate where Nature allows edible vegetation to flourish almost without attention, and where the inhabitants require but little covering. But that is not the whole of the story. For the Englishman is at work in the Tropics, and he does not easily resign himself to local conditions.

When the white man arrives near the Equator, he is appalled by the sights which spell out inefficiency in letters of fire that burn into his brain. Especially affected is the white man who has had an engineering training. He knows enough about health and sanitation to realise, at a glance, that ignorance on these subjects is affecting adversely the lives of the natives.

Steeped in the traditions of efficiency, the energetic British engineer attempts to reform the conditions that appal him. The religious reformer has, perhaps, a less exhausting task. But whatever their mission may be, white men in the Tropics soon feel the effects of the enervating climate, and in the popular magazine stories, that fascinate city typists, the rapid deterioration in the morale of the white man in these regions, which is vividly described, has a foundation of truth.

It can, however, be accepted as fact that the majority of our countrymen remain true to the "home" type, even although we must acknowledge that their tempers are easily upset when the heat and humidity is something which those who dwell only in England have never experienced. In the course of time it does have a lethargic effect both upon body and mind.

Human Efficiency.

There have been many definitions of the engineer, but it is not claiming too much to suggest that one great result of the collective endeavours of members of the profession has been to increase human efficiency.

It is because the conquest of the enervating climate of the Tropics must increase human efficiency that an appeal is made to engineers to become interested in the subject of manufactured weather for offices and homes in the Tropics.

After many years of investigation it has been possible to install a small air-conditioning plant in my office in the Hong Kong University. It has been at work for about six hours a day during the last week, and the benefits obtained from it and the low cost of operation, have convinced me that when residents in a humid climate begin to realise these facts, there will be quite as much demand for these air-conditioning machines as there now is for the comparatively new apparatus called household refrigerators.

Incidentally, it may be mentioned that this small apparatus now in use in the University is fitted inside a cover of appearance rather like a gramophone or wireless cabinet. The outside dimensions of this cover are 39in. by 26in. and 27in. high.

The machine makes no more noise than does an ordinary fan; indeed, it is probably the exit air through the grating in the top of the cover and the fan that cause the purring sound, which is not at all irritating to a mental worker.

It is only during recent years that small household refrigerating machines have been in use. Formerly, we preserved the food that otherwise would soon become unfit for consumption in the unsatisfactory—even unhealthy—wooden ice-box. Now we use a motor-driven tiny compressor with cold coils in a sheet iron cabinet.

In the usual type of household refrigerating machine there is no water circulation, for it is unnecessary when the heat carrier is SO_2. Water cooling is employed in my small air-conditioning plant, in which the heat carrier is called "Freezon". This water circulation may, or may not, be an advantage. My own experience is that it is an advantage, as the hot water obtained is supplied to students in an adjoining laboratory, and it helps them to "clean up" after handling machinery in their experiments.

Some Interesting Figures.

The plant was installed in a small room of about 175 square feet floor area and 18ft. in height. It was switched on at 8.30 a.m. on April 17th when the atmospheric temperature was 72° Fah. and the humidity 91 per cent. At 10.15 a.m. the room temperature was 69·5° Fah. and the humidity was 86 per cent. Not only had the temperature of the room fallen, but the machine condensed 12·88lb. of water from the atmosphere in six hours.

The temperature of the room steadily fell until it reached 67·1° Fah., and the humidity remained practically constant at 86 per cent. If the humidity figure remains constant as the temperature falls, the number of grains of water per cubic foot of air falls with the temperature. The main use of the machine is to condense the water vapour.

The mean temperature of the atmosphere outside during the test was 75° Fah., and the mean humidity was 85 per cent.

The total cost of the energy consumed during the test of six hours, at 5c. local currency per unit, was 25c. Although our local silver dollar fluctuates with the price of silver, we may reckon it at 2s. to the dollar, or, say, at about 1d. per hour for the electrical energy consumed.

The figures obtained concerning cooling water were surprising. It will be remembered that the heat carried away by this water is not only the equivalent of the work done, but also includes the heat abstracted in cooling and condensing the refrigerant. It does not, of course, include the energy consumed by the fan; but that was only 40 Watts.

We used 3·45lb. of circulating water per minute during the six hours of test. The cooling water was raised 37·6° Fah. in temperature—that is to say, 130 British thermal units per minute were carried away by the cooling water.

If we subtract from the heat carried away by the cooling water the equivalent in heat units of the electrical energy recorded by the Wattmeter used by the machine, we have an idea of the heat abstracted by the heat carrier. This gave an (overall) coefficient of performance at 1·64. As the energy recorded by the Wattmeter includes that used in a small transformer, used to step down from 200 volts to 100 volts, and that used by the fan, the actual coefficient of performance of the machine was 1·9.

The figures were obtained when the room was unoccupied, except during the short period at the end of each two hours when readings were taken.

Although no figures are available for the initial cost of the machine, if we remember the price of household refrigerators for preserving food, it is reasonable to suppose that they can be supplied in Hong Kong for some price less than £100.

The Ideal Conditions.

These few tests have been made under general conditions of climate that are by no means the worst experienced in this part of the world. For although Hong Kong has a very delightful winter, those who have lived both in Hong Kong and Singapore tell us that there are days during the summer months in Hong Kong when the climate is far worse than anything experienced in Singapore.

It is therefore fairly certain that if we wish to manufacture an atmosphere with temperature and humidity that is within what experiments in America call "the comfort zone", the ordinary sized living-room will require a larger machine.

The Ideal Climate.

Experiments on animals subjected to different degrees of temperature and humidity, in order to observe the degree of exhaustion produced under different conditions of atmospheric temperature and humidity, have been made. The following results are taken from "Mind and Work", by Dr. Charles Myers. He states that with a temperature of 69° Fah. and 52 per cent. humidity the work done was at a maximum, and records it as 100. It was found that with a temperature of 75° Fah. and humidity 70 per cent. the figure for work done was 85, and with a temperature of 91° Fah. and humidity 90 per cent. the figure was 76.

Those figures may be applicable for men doing manual work, but the writer is convinced by general observation of many hundreds of Chinese students, European commercial men and colleagues, and the record of his own endeavours in the ideal winter conditions and the distressing summer climate of Hong Kong, that a much greater loss in efficiency takes place when mental effort is considered.

Those who have had the experience of living in a submarine, submerged for several hours in tropical waters, explain that the time factor is important. If they are submerged daily for twelve hours, and on the surface at night, the lethargy is much worse after ten days than after two or three days on duty.

It is, unfortunately, not easy to devise a system of measuring mental effort. That employed by Dr. Haldane, F.R.S., and others, for measuring the variations in physical work under different climatic conditions, seems to be fairly reliable. But the human brain is a much more complicated mechanism than the muscular apparatus of animals or men. So curious are the emotional reactions of individuals that "what is one man's meat is another man's poison". That is true, not only of food, but of endeavours to produce happiness, and, therefore, useful mental work. It is certain that the human intellect does fall off in efficiency in a hot and humid climate, even if we cannot record the decline in a percentage value.

A most noticeable result of excessive heat and humidity is revealed in the recuperative effect of sleep. It is a common complaint in Hong Kong during the summer months amongst Europeans that either they sleep only in snatches or that they wake up feeling weary and exhausted. Asiatics are generally speaking so unobservant and inaccurate in their statements that it is difficult to be sure of their reactions in this matter, but the climate certainly does affect them. Their *tempo* slows up perceptibly in the summer, and a great deal of their daylight leisure is used up in the endeavour to sleep. An air-conditioned bedroom in the Tropics must produce more restful sleep than one with a hot and humid atmosphere.

The House in the Tropics.

A study of this subject compels us to visualise houses of the future in these hot and humid climates, as something entirely different in design from those in use to-day. For it is now a characteristic of dwellings for Europeans and the better-class Asiatics that large areas of windows, easily opened, are included in the design. The idea is that the benefit of any summer breeze can be obtained in the spacious rooms.

Unfortunately, these large window areas admit sunshine, and therefore heat, when closed. When opened they often provide comparatively little relief unless there is a strong breeze, which seldom happens when heat and humidity is excessive. We may therefore imagine the house of the future with steel-framed windows of dimensions designed only to give sufficient daylight.

There is, of course, nothing novel about a cooled and dried atmosphere; that has been provided for several years in certain industrial undertakings. It is now being introduced in large commercial buildings in the Tropics. In Hong Kong a well-known British firm is installing an air-conditioning plant for the largest building in the colony, viz., the head office of the Hong Kong and Shanghai Bank. Incidentally, this splendid structure is said to be the first building in the world in which the whole of the steel frames is of high-tensile chromador steel. The air-conditioning plant, with the necessary circulating pumps for cooling water, is equipped with electric motors totalling about 450 e.h.p.

What is new is the evolution of small refrigerating plants for preserving food and for air-conditioning rooms. That is the problem upon which one or more British engineering firms might concentrate. It is, of course, a matter of producing apparatus as compact and as economical as possible. It will be a great stimulus to enterprise in the Tropics when the problem in solved, so that these machines can be considered as an essential fitting in the homes of professional men.

BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examinations for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

Name.	Grade.	Port of Examination.
For week ended 30th January, 1936 :—		
Johnston, Laurence	2.C.	Newcastle
Measor, Lancelot N. ...	2.C.	,,
Richardson, James	2.C.	,,
Shieff, Solomon	2.C.	,,
Cutlack, Valentine N. ...	2.C.	London
Marr, Donald	2.C.M.	,,
Miller, Alexander	2.C.	Liverpool
Verity, Claude H.	2.C.	,,
Ewing, William	2.C.	Glasgow
Lawson, Kenneth A. ...	2.C.	,,
Commins, Albert E. ...	2.C.M.	,,
Boylan, John F.	2.C.	Dublin
For week ended 6th February, 1936 :—		
Brennan, William E. ...	1.C.M.	Newcastle
Lynn, Norman	1.C.M.	,,
Slocomb, Jacques W. ...	1.C.M.	,,
Palmer, Kenneth	1.C.	London
Robjohns, John L	1.C.	,,
Wilson, Reginald A. ...	1.C.	,,
James, Donald K.	1.C.	Liverpool
Shepherd, Robert J. ...	1.C.	,,
Smyth, John C.	1.C.M.	,,
Adamson, Samuel S. ...	1.C.	Glasgow
Cameron, James	1.C.	,,
Gillanders, Joshua D. ...	1.C.	,,
Pringle, James	1.C.	,,
Urquhart, Francis	1.C.	,,
Wilson, John	1.C.	,,
Yardley, William	1.C.	,,
Carter, George L.	1.C.M.	,,
Davidson, John	1.C.M.	,,

Name.	Grade.	Port of Examination.
McKee, Stanley R.	1.C.M.E.	Liverpool
Docherty, John	1.C.M.E.	Glasgow
Staveley, John A.	1.C.M.E.	"
Whiteside, Harold N. E. ...	1.C.M.E.	London
Leach, Ben E.	1.C.M.E.	"
Jones, Frank T.	1.C.M.E.	"
Evans, Edgar C.	1.C.M.E.	"
Anderson, John H.	1.C.M.E.	"
Cowe, Henry A.	1.C.M.E.	Newcastle
For week ended 13th February, 1936:—		
Davies, Clement J.	2.C.	Cardiff
Fifield, William J.	2.C.	"
Jones, Evans J.	2.C.	"
Miller, James W.	2.C.	"
Rees, Richard H.	2.C.	"
Salter, John J.	2.C.	"
Clarke, James	2.C.	Glasgow
Hardie, George P.	2.C.	"
Paterson, John McD. ...	2.C.	"
Wilson, Alexander Mc. M....	2.C.	"
Hall, Thomas	2.C.M.	"
Ainslie, George H.	2.C.	Newcastle
Newton, Wilfred M. ...	2.C.	"
Hanson, Robert C.	2.C.M.	"
Lane, Harry	2.C.M.	"
Williams, Owen M.	2.C.	London
Brown, James Mc. A. ...	2.C.	Liverpool
Keady, Herbert L.	2.C.M.	"
For week ended 20th February, 1936:—		
Lloyd, Frederick C.... ...	1.C.	Cardiff
McBride, Alexander ...	1.C.	Glasgow
Parkhill, William	1.C.	"
Stuart, Ronald	1.C.	"
Mackenzie, Archibald ...	1.C.M.	"
Kumaran, Karinchet K. ...	1.C.	Liverpool
Salisbury, George	1.C.	"
Hubbard, John A.	1.C.M.	"
Moir, George	1.C.M.	"
Young, Richard	1.C.M.	"
Roberts, James J.	1.C.	London
Staff, Walter F. H.	1.C.	"
Walburn, Douglas R. ...	1.C.	"
Kirby, Kenneth G.	1.C.M.	"
LePla, Frederic R.	1.C.M.	"
Ridley, Harold	1.C.	Newcastle
Stewart, William T. ...	1.C.	"
Rogers, John L. C.	1.C.M.E.	Cardiff
Pape, Guy	1.C.M.E.	Glasgow
For week ended 27th February, 1936:—		
Jack, Arthur S.	2.C.	Newcastle
Lisle, Matthew S.	2.C.	"
Darnell, John R.	2.C.M.	"
Wood, William E.	2.C.M.	"
Wood, Thomas C.	2.C.	London
Searles, Herbert S.	2.C.M.	"
Keady, Ernest	2.C.	Liverpool
Morris, Patrick C.	2.C.	"
Rylance, Richard H. ...	2.C.	"
Leyland, Edward N. ...	2.C.M.	"
Wallace, Henry	2.C.M.	Glasgow
For week ended 5th March, 1936:—		
Couper, James K.	1.C.	Glasgow
Duncan, William	1.C.	"
Kerr, John	1.C.	"
Moore, Gordon	1.C.	Liverpool
Powis, Arthur N.	1.C.	"
White, Andrew P.	1.C.	"
Barron, John S.	1.C.	London
Ennew, George T.	1.C.	"

Name.	Grade.	Port of Examination.
Hill, William C.	1.C.	London
Coates, Kenneth S.	1.C.	Newcastle
Howey, James F.	1.C.	"
Simpson, Alfred C.	1.C.	"
Bulmer, James B.	1.C.M.	"
Ogle, George T.	1.C.M.E.	"
Cocks, Henry	1.C.M.E.	"
Jordan, Herbert J.	1.C.M.E.	London
Walburn, Douglas R. ...	1.C.M.E.	"
Robson, George B.	1.C.M.E.	Newcastle
For week ended 12th March, 1936:—		
Gracey, William	2.C.	Cardiff
Prichard, Trevor R. ...	2.C.	"
Thomas, James M.	2.C.	"
Harbottle, John H.	2.C.	Liverpool
Whieldon, Leonard	2.C.	"
Cormack, Daniel J. F. ...	2.C.	Glasgow
Craig, Daniel H.	2.C.	"
Hannah, Hugh	2.C.	"
McNeill, Duncan G.... ...	2.C.M.	"
Watt, John	2.C.M.	"
Handcock, James H. ...	2.C.	London
Woods, Edwin F. J. ...	2.C.	"
Driscoll, Arthur J.	2.C.M.	"
Caie, Ian S.	2.C.	Newcastle
Gibson, John G.	2.C.	"
Lowes, Edward D. P. ...	2.C.	"
Mackenzie, Fred. A. ...	2.C.	"
Wharton, Norman	2.C.	"
Grieves, Edwin	2.C.M.	"
Lugton, George W.	2.C.M.	"
Robertson, Arthur T. ...	2.C.M.	"
Russell, Charles S.	Ex.1.C.	Glasgow
Smith, James W.	Ex.1.C.	London
Wills, Alfred J.	Ex.1.C.	"
Adams, Maurice	Ex.1.C.	Newcastle
Elliott, Henry H.	Ex.1.C.	"
For week ended 19th March, 1936:—		
Dolling, Hector F. H. ...	1.C.	London
Strachan, James	1.C.	"
Varley, Leslie L.	1.C.	"
Stannard, Gordon J. ...	1.C.M.	"
Vickerstaff, Herbert ...	1.C.M.	"
Kenna, Cecil J.	1.C.	Liverpool
Probert, Charles E. ...	1.C.	"
Robertson, Bertie H. ...	1.C.	"
Walters, John McK. ...	1.C.	"
Wilson, John W.	1.C.M.	"
Graham, Edward P. ...	1.C.	Newcastle
Heddle, Austin T.	1.C.	"
Hunton, Cecil	1.C.	"
Robinson, Arthur L. ...	1.C.	"
Warnaby, Harry	1.C.	"
Potts, Thomas D.	1.C.M.	Newcastle
Mander, John H.	1.C.	Cardiff
Rees, Robert L.	1.C.	"
Edgar, Norman V.	1.C.	Glasgow
Ferguson, James C. ...	1.C.	"
Gallagher, Henry	1.C.	"
Laing, William F.	1.C.	"
Purden, Harry W.	1.C.	"
Russell, Lewis	1.C.	"
Young, Robert S.	1.C.M.	"
Welch, John R. C.	1.C.M.E.	Cardiff
Fulton, James W.	1.C.M.E.	London
Arthur, George C.	1.C.M.E.	Cardiff
Strong, Charles E. W. G....	1.C.M.E.	London
Anderson, Francis C. ...	1.C.M.E.	"
Archibald, Alexander W. ...	1.C.S.E.	Glasgow
Valentine, David W. ...	1.C.S.E.	"
Vogt, Edward T.	1.C.M.E.	"
Muir, Robert	1.C.M.E.	"

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President: The Hon. ALEXANDER SHAW.

Recent Developments in Marine Refrigeration.

READ

By J. D. FARMER

On Tuesday, April 7th, 1936, at 6 p.m.

CHAIRMAN: Mr. H. S. HUMPHREYS (Chairman of Council).

Synopsis.

THE paper deals with the changes in the design and application of refrigerating appliances to ships which have taken place during the eight years since the last paper on refrigeration was given before The Institute in 1928.

In the past few years the greater variety of cargoes carried and the more exacting requirements of carriage have caused shipowners to modify the equipment of their existing ships and in new tonnage to provide installations of a more elaborate and flexible nature than those fitted previously.

The paper deals chiefly with the application rather than the production of cold, and gives illustrations and descriptions of various systems which are being fitted into modern refrigerated tonnage, including details of the components such as fans, aircoolers and brine systems which go to make the complete equipment. Details are given of various experiments carried out by the Government Research Station at Ditton, Kent, and the effect which the results of these experiments have on the question of ships' equipment is discussed.

A description is given of the use of small automatic refrigerating machines in large passenger liners, cargo vessels and trawlers.

The final portion of the paper deals with the new application of air conditioning to the public rooms of passenger liners trading in hot climates.

The last paper dealing with Refrigeration given before this Institute was that by Mr. A. Greenfield in December, 1928. Since that time we have passed through the most severe slump in the shipowning and shipbuilding industries that has ever occurred.

Despite the depression in new building, however, the art of marine refrigeration was kept alive technically by modifications to existing vessels, chiefly due to the demand for improved methods of carrying fruit and cheese in vessels originally designed for frozen produce, meat, butter and the like.

In the period of eight years since Mr. Greenfield's paper the developments which have taken place in marine refrigerating installations for the carriage of perishable produce have been not so much in the methods of producing cold as in the methods of application of cold to the refrigerated spaces.

In the three years since the revival in the building of refrigerated tonnage most of the new construction has been for the Australian and New

Zealand trade. The South African trade has also received new ships but these are built essentially for the carriage of fruit only. It is in the vessels for Australia and New Zealand that most of the interesting new developments in the application of refrigeration have taken place, owing to the wider variations of temperature and general conditions in these trades. In order fully to appreciate what has happened in these few years it is as well to look back to the earliest days of marine refrigeration, the days of the cold air machine.

The first refrigerated cargoes were carried by means of the cold air machine, in which air brought to a very low temperature by adiabatic expansion in a cylinder was allowed to blow straight into the refrigerated compartments. The volume of air pumped by the machine was very small but at a very low temperature, resulting in uneven temperatures throughout the body of the cargo, which in early days was not of great matter. Somewhat later, fans were introduced, giving something like six to eight changes per hour, the cold air from the machine being injected into the fan stream. There is one famous liner running to-day which successfully carries refrigerated cargoes between the Antipodes and this country with a plant working on this principle.

The cold air machine, however, was cumbersome and had a very poor yield of refrigeration for its power consumption. The year 1887 saw the introduction of the CO_2 compression machine, also about this time the ammonia compression machine made its appearance in ships, each of these proving to be a considerable advance in efficiency and mechanical design over the cold air machine.

The cooling effect of the compression machine cannot be applied directly to the cold chambers as can that of the cold air machine, as the refrigerant must be contained in a closed cycle, generally consisting of pipes.

About the year 1900 two types of plant were being developed side by side by rival organisations, the CO_2 plant of Halls of Dartford, which distributed its cold by cooling brine which was circulated through pipe grids placed on the overheading and walls of the refrigerated chambers, and the ammonia machine developed by Linde and by Haslams of Derby, which in most cases distributed its cold by the forced circulation of air over a battery of pipes containing expanding ammonia.

Gradually the CO_2 machine displaced the ammonia machine owing to the regulations which limited the housing of the ammonia machine, and the pipe grid system with brine circulation displaced the forced air pipe battery system until, from say 1910 to 1925, the CO_2 and brine grid type of equipment was virtually standardised for all large refrigerated ships whose chief purpose was the carriage of frozen and chilled meats and other produce of a dead nature. This class of cargo is shipped in a pre-cooled condition and requires from the refrigerating equipment only a limited amount of heat removal for levelling up the temperature and the removal of such heat as may enter through the insulated skin of the compartments. For this latter purpose grids on the internal skin of the insulation are naturally ideal.

About 1900-1905 saw the commencement of the banana trade from the West Indies to this country and in this trade the first really serious attempt was made to develop the air-cooled ship as a definite combination of CO_2 machines and forced air circulation over batteries, with sufficient air and sufficient refrigerating power to cool a complete cargo of fruit loaded at about 80° F. to its carrying temperature in a few days. These special banana vessels, however, were not suitable for the carriage of frozen produce or any fruits requiring temperatures very close to freezing, as their batteries were not of the type to carry much frost without becoming quickly so heavily coated as to impede seriously the flow of air.

About this time too, in fact slightly before, the White Star Line had in their Australian trade developed ships fitted with full grid cooling on overheading and sides of the spaces, to which equipment was added batteries of brine pipes and forced air circulation by centrifugal fans for the carriage of non-precooled fruits. In the Australian trade various other shipowners have developed systems of refrigeration by which the ordinary form of grid cooling can be utilised for the purpose of fruit and cheese carriage with forced air circulation, such as the well-known screened grid system. This system has been generally in vogue since about 1920, when it was introduced primarily for the carriage of cheese. Later it was more fully developed for the carriage of fruit and, as remarked before, during the shipbuilding slump which occurred after 1929 a large number of modifications were made to existing refrigerated ships, which modifications consisted chiefly of improvements in air systems to make them more suitable for the carriage of fruit and cheese.

Until 1925 however, except for the special banana vessels, most marine refrigerated tonnage was designed primarily for the carriage of frozen and chilled meat cargoes and these vessels carried occasional cargoes of fruit, cheese and chilled eggs, which they dealt with in a manner which was considered satisfactory at the time but which in the light of modern scientific requirements (which may or may not be commercially necessary) would hardly be reckoned entirely satisfactory to-day.

About 1925 fruit carriage started to make great strides. The trade with the West Coast of the U.S.A. started with air cooled ships equipped with brine batteries, centrifugal fans and CO_2 compressors. The South American fruit trade, involving the export of bananas from Santos, and also oranges and grape fruit, sprang up alongside the chilled meat trade which had been operating from this continent for many years. Finally, the South African Government took steps to organise the growing and export of many types of fruits which their country is able to produce.

In all the new fruit carrying tonnage which came into being after 1925, air cooling by batteries was the requirement of the scientific advisers engaged by the shippers employing the tonnage. Thus the South African Government Authorities definitely laid down requirements for the equipment of ships engaged on this trade both as to insulation and method of cooling. The shipowners engaged in the South American trade, whose vessels were originally constructed for the carriage of chilled meat by grid cooled chambers only, modified the equipment of their ships so as to provide spaces equipped with batteries and fans for fruit carriage; the South African shipping companies re-equipped all their existing vessels with batteries and fans, and the Australian shipowners modified a great deal of the equipment in their existing grid cooled chambers so as to provide, for the carriage of fruit and cheese, air circulation of such increased power as to give more even temperatures and quicker cooling than had been possible with the original equipment.

A survey of the various means of applying refrigeration to the spaces of insulated vessels over the whole history of marine refrigeration may be epitomised in a few words as follows:—

(1) The original air cooling by means of the cold air machine.

(2) The displacement of the cold air machine by the CO_2 or ammonia compression machine, the former distributing its cold by grids and brine and the latter by direct expansion batteries and fans, followed by the gradual disappearance of the ammonia machine with its batteries.

(3) The gradual increase of the fruit trade demanding some form of mechanical air circulation in conjunction with grid cooling.

(4) Grid cooled ships with fans and batteries or screened side grids, in which ships, except for small overlapping of each system, both grid cooling and air cooling, each appeared as complete independent equipments.

(5) Finally, it appears that we are rapidly approaching the reinstatement of the air cooled ship in place of the grid cooled ship due to the fact that it has not been found possible to make the meat and frozen produce equipment carry fruit entirely satisfactorily, but there is every reason to expect that we can design an air equipment which will carry meat equally successfully.

Thus at the moment the modern refrigerated ship is being designed with most of its spaces primarily air cooled, each compartment having its own separate equipment. In the opinion of the Author there is no reason why air cooling, properly applied, should not answer every call made upon it for the carriage of any type of perishable produce. There is one requirement, however, that rules out, at any rate for the moment, the possibility of equipping a space intended for frozen produce with air cooling on the accepted open cycle as the only means of cooling. This is the necessity of providing some form of cooling which can be operative while hatches are open for loading.

As there are definite objections to loading a space with forced air circulation in operation the practice at present is to put grids on the roof of the space to keep the temperatures under some degree of control while hatches are open. According to our present ideas, therefore, the modern refrigerated compartment is one which is primarily cooled by air circulation, the units consisting of a brine pipe battery and a fan, the air being distributed by trunks which can be arranged in a number of different ways, added to which there is a limited number of brine grids placed on the roof.

Let us take now the various components which make up the complete equipment.

Fans.

This item is placed first because in the Author's opinion it is primarily the improvement in fans which has rendered possible the application of air cooling to general refrigeration on the scale we see to-day. About eight years ago the first high efficiency propeller fan made its appearance in this country. Before that time centrifugal cased fans had been fitted almost exclusively, as the propeller fans of the day were possessed of low efficiency and were not capable of producing the static pressures required for air cooling systems installed, namely, static pressures of 1½ to 2 inches of water.

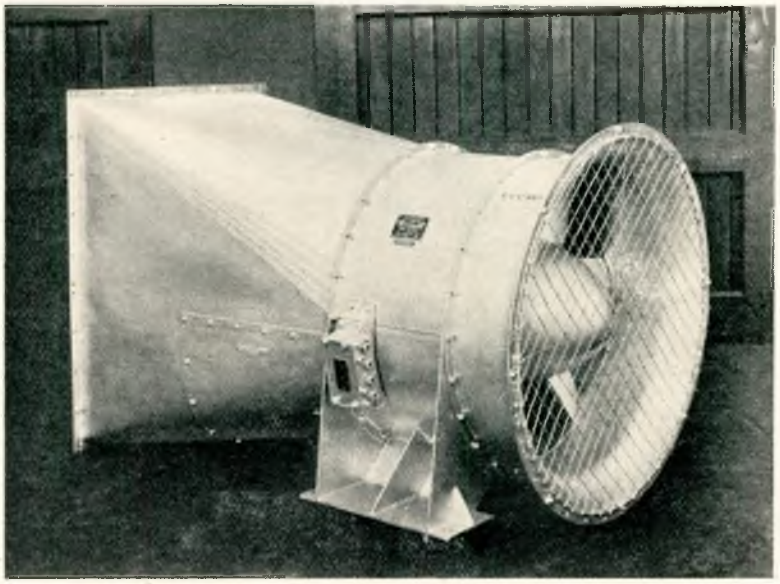


Fig. 1.—Typical modern propeller fan.

In about 1928 the Author's firm came into contact with a clever inventor who offered to produce a propeller fan giving an efficiency of 70 to 75 per cent. based on its static water gauge. As the average centrifugal fan outfit fitted in refrigeration systems had an overall installed efficiency of about 40 per cent. it seemed that this new fan would have the effect of reducing the power consumed by about half. This point of power consumption is of the utmost importance in a closed refrigeration cycle, for when a shaft or an electric cable enters the insulated envelope of a refrigerated space all the power, be it mechanical or electrical, conveyed by the shaft or cable is converted into heat which can only find its way out through the refrigerating machine. Thus, not only has the shipowner to pay for the production of power to drive the fan but also he has to pay for the removal of that power by way of the refrigerating plant.

An order was placed with its inventor for one of these propeller fans on the understanding that if it fulfilled his claims it would be paid for, otherwise not. The first fan amply proved the claims made for it and was duly installed as an experimental unit in a ship, where it has given complete satisfaction ever since.

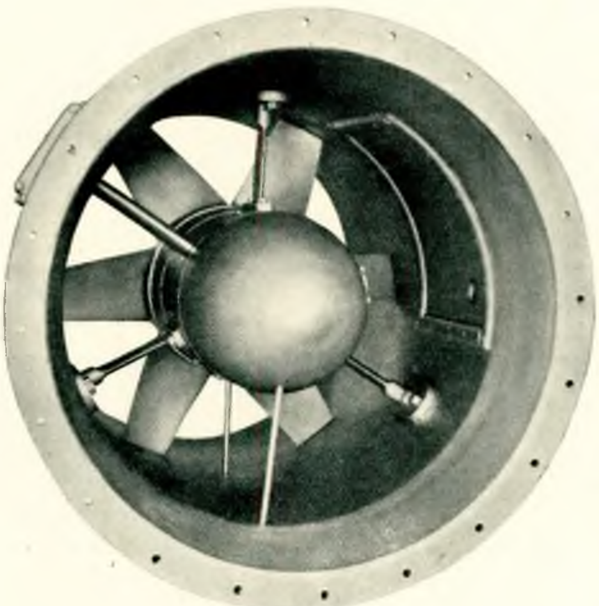


Fig. 2.—End view of fan shown in Fig. 1.

There are now three well-known makers marketing high efficiency aerofoil section propeller fans which have found numerous applications on ships for purposes other than refrigeration, such as engine-room ventilation and forced draught. Thus, by reason of its shape, which renders it easily adaptable to many designs of air systems, its low power consumption and its reversibility, the "streamline" propeller fan (to give it the present accepted title) has rendered possible the application of air cooling in refrigerated spaces to a degree which would not have been possible without it.

Fig. 1 shows a typical modern propeller fan with multi-blade propeller cast in corrosion-resisting aluminium alloy. The motor is inside with the propeller directly attached and is contained in streamline aluminium fairings. Fig. 2 shows an end view of the same type of fan; note the streamlined motor casing.

Fig. 3 shows a photograph and make-up drawing of a special type of fan for use in cases where it is necessary to have the motor outside the refrigerated chamber as, for instance, with compartments intended for the carriage of chilled beef in CO_2 gas.

Fig. 4 shows another type of fan with external motor designed so that the whole unit may be withdrawn from its location. The large flange bolts directly to the deck or bulkhead and the shaft passes through a gas and watertight gland. This fan has been accepted by the Board of Trade as suitable for mounting in watertight bulkheads or decks.

All the fans shown above are available for vertical or horizontal mounting.

Fig. 5 shows a fan for vertical air flow arranged to bolt straight to the deck which has been designed especially for use in an air system where the fan draws its supply from either side below and delivers to a trunk overhead.

The class of fan shown in these illustrations gives an efficiency of 65 per cent. to 75 per cent. based on the static water gauge produced, and the examples shown are those most commonly found in marine refrigeration to-day. Generally this class of fan is fitted with motors possessed of variable speeds by shunt regulation and also reversible rotation. In reverse this class of propeller gives about 60 per cent. to 70 per cent. of the volume in the normal direction, the water gauge falling in proportion to the square of the volume.

Air Batteries.

The design of air cooling batteries has received a great deal of attention in recent years. The earliest forms of pipe batteries using either direct expansion ammonia or brine consisted of long pipe grids laid parallel to the air flow. These were inefficient by reason of the poor heat transfer coefficient given by the air flowing along the pipe. Furthermore, when used in conditions at which frost formed this type of battery became rapidly frosted up at the air entry end where, by reason of the pipe bends, the area of the air channel was less than throughout the remainder of the cooler.

About ten years ago the Author's firm conducted a series of experiments on air coolers in order to find out the relative merits of different pipe arrangements in an air stream. These experiments were carried out on coolers of a size met

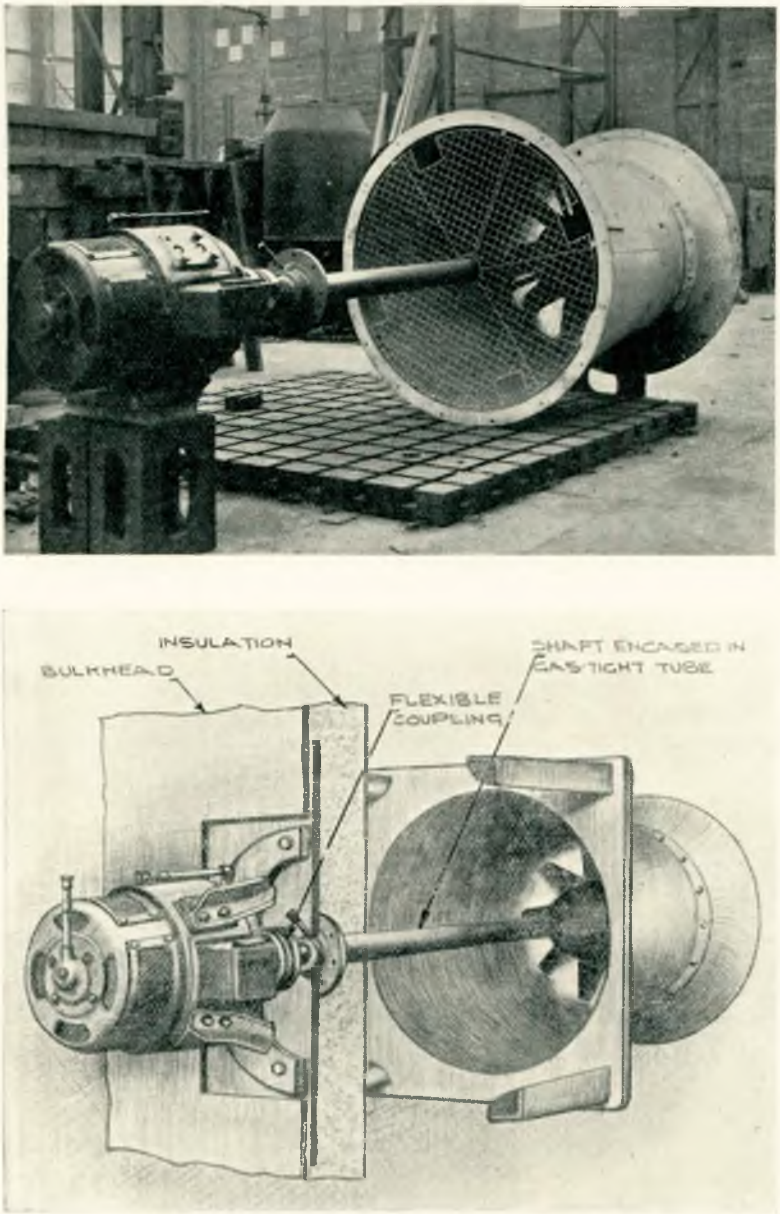


Fig. 3.—Photograph and make-up drawing of special type of fan, the motor being outside the refrigerated chamber.

with in actual installations. The points investigated were the friction of air flow and brine flow, the formation of frost and the heat transfer coefficient of the pipe surface under varying conditions of brine flow, air flow and temperature. The results of these experiments showed that the highest efficiency was obtained with the pipes lying at right angles to the flow of air and arranged so as to form triangular pitch. A battery of pipes built up in this manner was found to possess a heat transfer coefficient 50 per cent. to 70 per cent. greater than that of the same quantity of pipe arranged parallel to the air flow in a box of the same cross sectional dimensions, the speed of the air through the empty box, the speed of the brine and all other conditions being the same. This type of cooler is now generally referred to as the "cross grid triangular pitch" type and it appears in a number of different forms. When used under conditions at which frost is formed it is found with a properly designed cooler of this type that the pipes throughout the cooler become coated with frost of almost a uniform thickness, no one pipe having much more frost than another. This results in the cooler being able to carry a large amount of frost before becoming so choked as seriously to impede the air flow.

Recent examples of this design of cooler installed in spaces loaded with frozen produce have run for over five weeks before requiring defrosting. Fig. 6 shows a typical cooler with case and tray as installed in a 'tweendeck. In the case of fruit carriage at 30° to 33° the general experience with these coolers is that they require defrosting once in six to ten days. This type of cooler lends itself very well to a compact arrangement and in most cases coolers are now constructed as a unit complete with watertight tray and sheet steel casing and shipped on board the vessel in one lift. Coolers containing 3,000ft. of 1¼in. bore pipe are frequently made in one unit. This type of construction avoids the necessity of any but the simplest foundations.

Another form, Fig. 7, which these coolers may take is that of long grids with wooden baffles so arranged as to make the air pass two or three times over the grids at right angles to the pipes. This form of construction is used when it is found to be the most convenient for the arrangement of the cooler in conjunction with the air system. See Fig. 11.

The speed at which the air is passed through these coolers depends very much on the purpose for which they are intended. In the case of banana carriage, where no frost is formed, and where a high rate of air change is employed, the coolers are designed for an air speed among the pipes of 25 to 30ft. per second. For coolers which are likely to become frosted, about half this speed is employed and the pipes are placed further apart than in the high temperature cooler. In the cases of coolers which will never be required for use under conditions where frost forms, pipes with gills

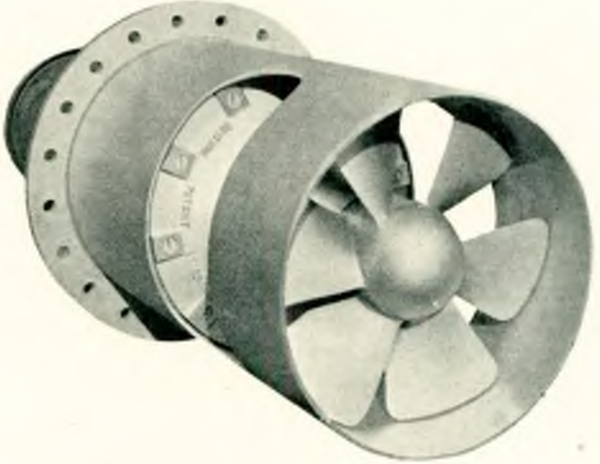


Fig. 4.—Another type of fan with external motor.

either spirally wound or separately put on may be used.

Coolers constructed from gilled piping with the gills fairly close together and of suitable thickness can be designed to occupy very much less space than coolers for the same duty made from plain pipe. It appears from careful consideration of the matter that gilled piping is not an economical proposition for coolers which have to carry frost. The gills must be so far apart that they do not increase the heat transfer of the pipe to a sufficient extent to compensate for the increased cost of the piping and the more complicated construction. The Author's experience is that even with non-frosting coolers the cost per unit of heat passed is virtually the same for both plain pipe and gilled pipe coolers, but the latter show a distinct saving in space occupied over the former. Two years ago three ships were fitted, by the Author's firm, with gilled pipe coolers for the carriage of bananas. These have proved to be quite successful and have yielded very interesting information as to the technical and financial merits of this design.

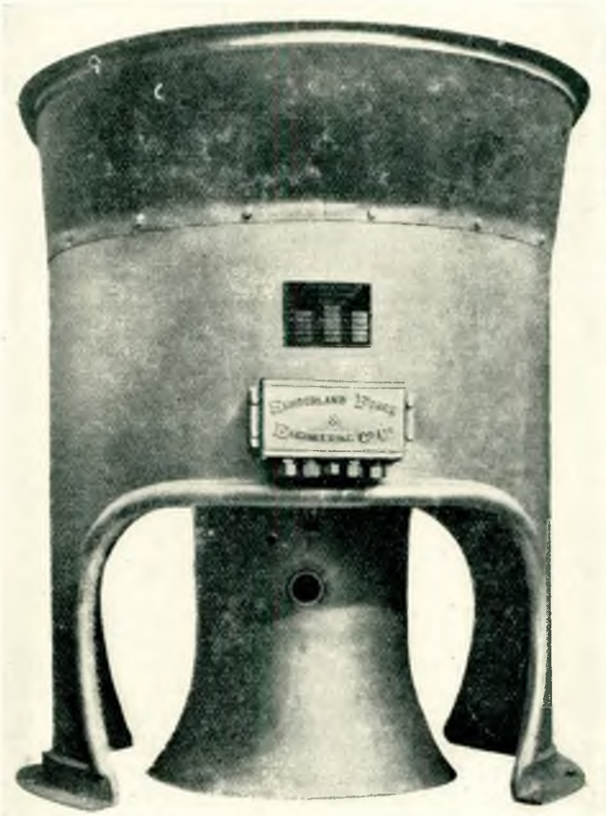


Fig. 5.—Fan for vertical air flow.

The last type of air cooler which need be mentioned as having made its appearance in the marine world of recent years is that in which the air comes into direct contact with the brine. There are several types of these coolers, those using brine sprays, those using direct expansion gas pipes over which brine is sprayed, and those in which cold brine is showered over a layer of porcelain ferrules or any other suitable surface, the air being driven up through this layer of wetted surfaces. This latter type seems at the moment to be the most suitable for use on shipboard, both the other types being used extensively on land. The German Mercantile Marine have for some years used this type of cooler for the cooling of both cargo spaces and provision rooms. The Author's firm came into contact with it during the execution of some foreign contracts and as the cooler seemed to have certain attractive features a licence for manufacture was obtained from the German firm who brought it out, the Germania Werft of Chemnitz, now combined with the great organisation of Borsig. This type of cooler is known in this country as the "Hall-Germania" cooler. It consists of a rectangular steel box containing a layer of porcelain ferrules, well known in the chemical world as Raschig rings, about 1ft. deep. Above this layer is a set of brine spray pipes made from non-corrodible metal and finally above these spray pipes another layer of rings about 6in. deep which prevent drops of brine being carried over in the air stream. See Fig. 8.

This type of cooler, in fact any "wet" type of cooler using brine, does not become choked with frost as do dry pipe coolers. The water normally deposited out of the air in the form of snow passes into solution with the brine, gradually reducing its density until such times as the brine becomes so weak that it freezes on the cooling coils in the evaporator unless calcium chloride is added in order to raise the density. This class of cooler tends to dry the air more than the dry pipe type of cooler, which usually discharges air at 93 per cent. to 98 per cent. saturation.

Calcium chloride solution has a natural dehydrating effect due to the fact that at any given temperature its vapour pressure is lower than that of pure water. The greater the density of the solution

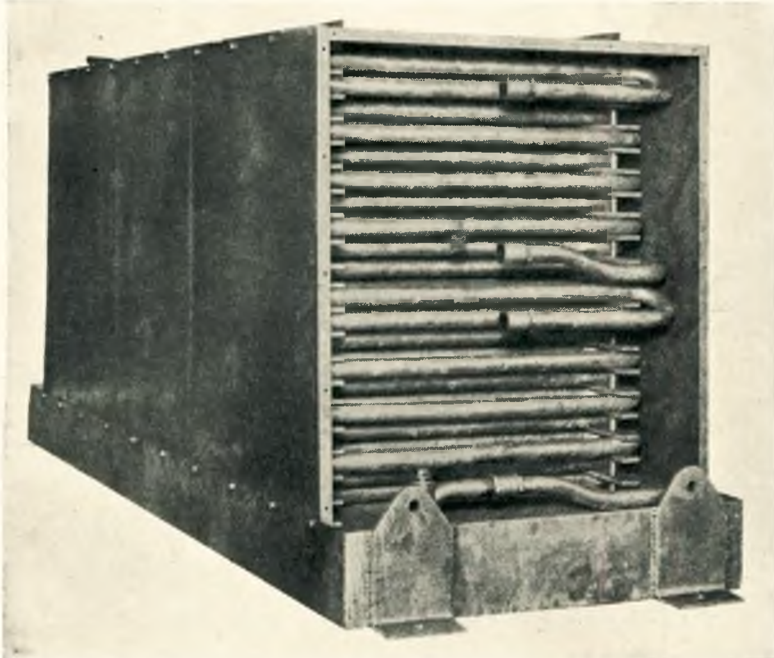


FIG. 6.—Typical cooler with case and tray as installed in a 'tweendeck.

the less its vapour pressure and the greater its dehydrating effect on the air. At the freezing point of the solution its vapour pressure is approximately equal to that of water at the same temperature. Thus, in a system fitted with any type of wet cooler, the strength of the brine must be maintained by the addition of calcium chloride, but at the same time if it is desired to avoid drying the contents of the chambers too much the brine density should not be made too great. The most efficient way of attending to the brine both for economy of calcium and reduction of drying is to add the calcium frequently and in small doses, keeping the minimal density of the brine no greater than necessary to prevent it freezing on the cooling coils with which it comes into contact.

The following table gives the freezing point of brine at various degrees of density, this density being measured at 60° F.

Density. Twaddell degrees.	Density. Specific gravity.	Freezing point. °F.
10	1·050	26½
20	1·100	19½
30	1·150	9
35	1·175	1
40	1·200	−6
45	1·225	−16½
50	1·250	−30

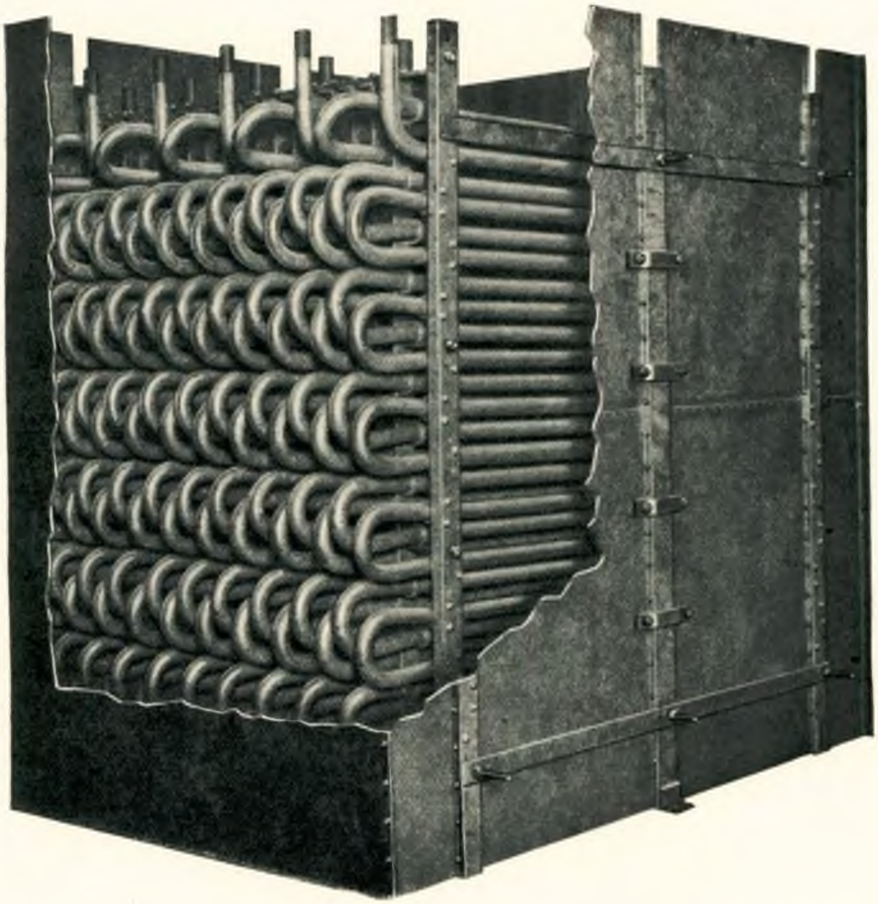


FIG. 7.—Small close pitch cross grid air cooler and casing.

The Hall-Germania cooler has been applied to several ships. Two large fruit carrying vessels for the trade from the West Coast of the U.S.A. were fitted with this cooler about six years ago, and since then it has been applied to several installations for ships' provision room cooling.

In the light of experience it does not seem that the wet cooler has any great claim for consideration in the case of the equipment of cargo spaces. Its consumption of calcium is heavy and its size is greater than that of any pipe cooler. Moreover the dry pipe cooler has now been so improved in design that frosting up has become a matter of no great detriment. For application to ships' provision rooms, however, the

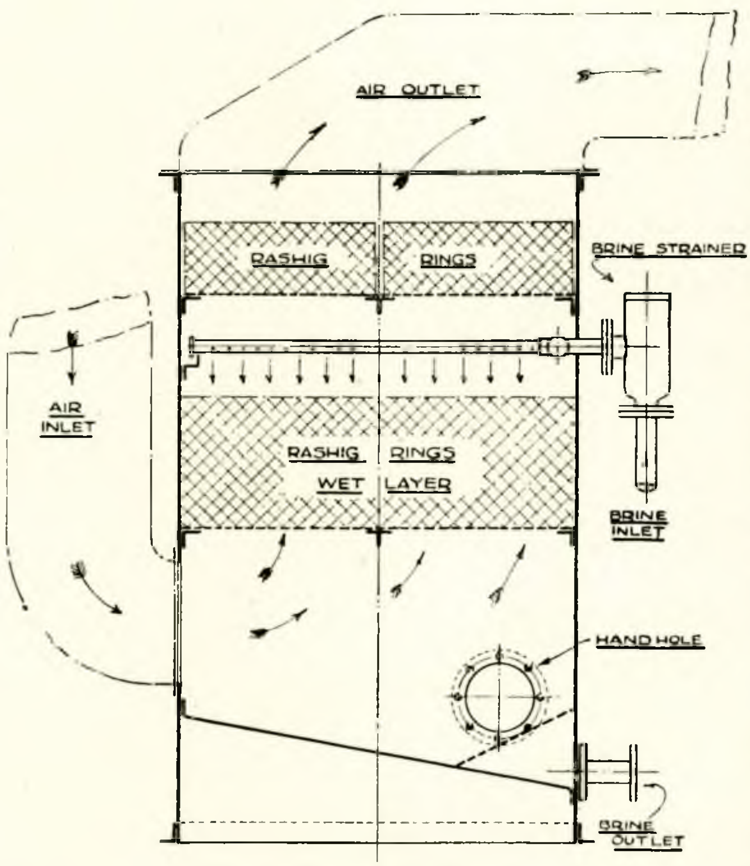


FIG. 8.—Diagram of air cooler.

Germania type of cooler is worthy of serious consideration. The fact that the air is washed by the brine keeps it thoroughly clean and it is found that a number of different rooms may be served by one fan and cooler without the odour of any one room being discernible in the others. Experience has proved that in rooms equipped with these coolers vegetables remain more crisp and that the general atmosphere of all rooms so cooled is cleaner and fresher than in rooms equipped with brine pipes.

Five large passenger vessels are now being fitted with this system of cooling their ships' stores and for some years several British and many German owned passenger liners have been operating with ships' store rooms cooled by air circulation through wet coolers of the Germania type.

Systems of Air Circulation.

In the paper given by Mr. Greenfield before this Institute in 1928 a comprehensive description was given of the various methods of air circulation in vogue at that time. In most cases the direction of air flow was horizontal, either from side to side or in a gyratory manner round a trunked hatch or artificial screens arranged so as to give suitable air travel through the body of the cargo. One system was shown which gives a partially vertical direction of air flow; in this system the air is discharged from trunks running the length of the roof port and starboard of the hatch and is collected from a floor trunk running port and starboard at the end of the space at which the cooler and fan equipment is located. This system was brought out in 1928 by the shipping company concerned in conjunction with the scientists responsible for the carriage of fruit from one of the Dominions and is very suitable for spaces intended for the carriage of boxed fruit only. In this case the air is returned by the space formed under the bottom layer of boxes by battens laid fore and aft.

In spaces of the average length, say 60ft., the distance of travel is so great that apparently much of the air tends to

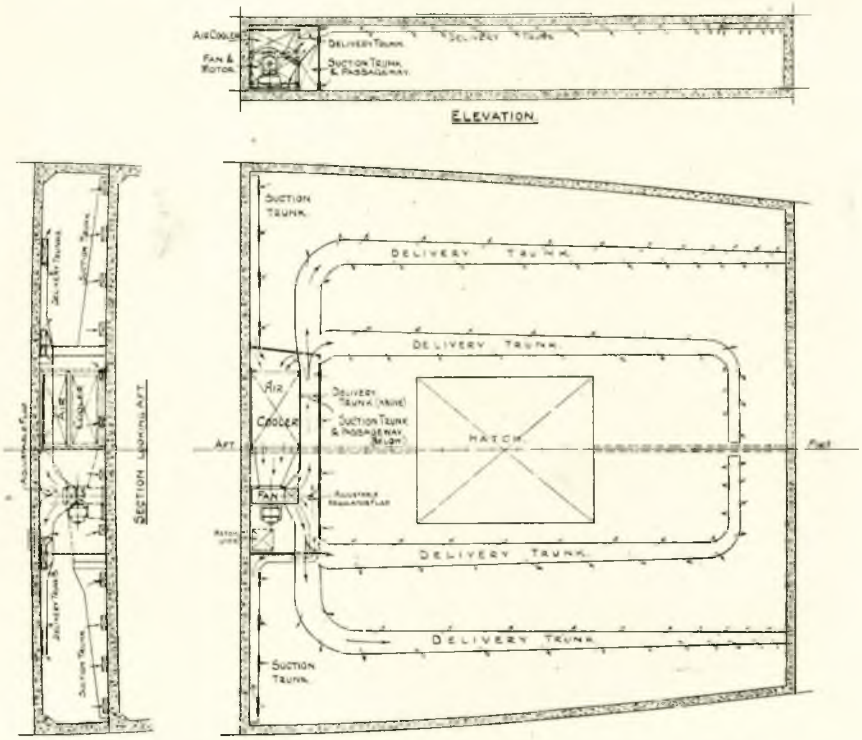


FIG. 9.—Typical diagram of air circulation (spraying system).

travel diagonally between the boxes and also to short circuit straight back along the roof, falling to the floor as it approaches the suction. However, with boxed fruit well dunnaged experience has shown that this system gives very even temperatures.

Lately a considerable amount of attention has been paid to the design of systems embodying reversible vertical air flow normally discharging from overhead and being drawn either from suction ducts running the full length of the bottom of the sides of the space or from the trunks laid inboard on the floor. In this case the travel of the return air in the athwartship dunnage space between the bottom boxes and the floor is only about half that of the fore and aft flow return in the system mentioned previously. It is fair to assume, therefore, that with shorter travel of suction the air flow obtained than with horizontal circulation through a stack with the normal ½in. battens between the boxes.

The experimental hold at the Ditton Laboratories is a fully insulated chamber with an internal dimension of 30ft. 6in.×34ft. 6in.×15ft. deep and can be equipped as desired with any variety of cooling system—whether air circulation or grids. The experimental work has been carried out with full knowledge of conditions as they exist on board ship and therefore may be taken as having a true relation to actual practice. The following table, given by permission of the Director of Food Investigation, shows the results of several seasons' work on the experimental hold at Ditton concerning air circulation and temperature distribution in a stack of boxed fruit filling the space as fully as would be the case in a ship's compartment.

YEAR OF TRIAL.	1932-1933.				1933-1934.				1930-1931.	
DIRECTION OF AIR CIRCULATION.	HORIZONTAL FLOW (EAST TO WEST).				VERTICAL.				VERTICAL.	
System of dunnage.	⅜in. horizontal laths parallel to air flow. South half of stack.		No dunnage. North half of stack.		No dunnage.	No dunnage.	No dunnage.	No dunnage.	12 towers 9in. by 9in. vertically through stack.	
Temperature outside insulation	40-60	40-60	40-60	40-60	80	80	80	80	40-60	40-60
Period of observation (days)	20	10	20	10	5	5	3	5	10	5
Rate of air changes/hour ...	34 (R8)	26 (R8)	34 (R8)	26 (R8)	30 (R8)	1 (R8)	16 (U1)	16 (U2)	34 (U2)	26 (U2)
No. of thermometers in stack	60	60	59	59	113	113	113	113	95	95
Mean fruit temperature ...	37·52	38·43	37·50	38·66	36·27	36·22	36·23	36·31	36·17	36·06
Maximum fruit temperature	40·62	41·88	40·16	41·84	38·04	37·98	38·48	38·24	37·60	37·76
Minimum fruit temperature	35·48	35·98	35·72	35·97	35·40	34·00	35·10	35·00	35·04	35·00
Maximum fruit temp. range ...	5·14	5·87	4·44	5·60	2·64	3·98	3·38	3·24	2·56	2·76
Mean deviation	0·85	1·17	0·95	1·17	0·38	0·47	0·50	0·52	0·46	0·54
Air inlet temperature	34·85	34·50	34·85	34·50	35·60	34·80	35·30	34·60	—	—
Air outlet temperature ...	35·87	35·58	35·87	35·58	37·20	37·70	38·80	37·10	No reliable figures.	
Mean air temperature	35·36	35·04	35·36	35·04	36·40	36·25	37·05	35·85		
Mean fruit minus mean air ...	2·16	3·39	2·14	3·62	−0·13	−0·03	−0·82	+0·46		

R8=Reversed every 8 hours. U1=Undirectional floor to roof.
U2=Undirectional roof to floor.

For vertical circulation air was discharged at top of each side and was sucked in by trunk at centre line on floor. Floor battens 3in. high.

In 1933-34 experiment boxes used were of the Tasmanian type 9½×15×20in. with minimum bulge and stowed at density of 7,540 boxes (139 tons) in 14,780 cu. ft.=106 cu. ft./ton.

Stack of fruit 18 boxes high.

In previous experiments in 1930-31-32 with battens between boxes, 6,100 boxes were contained in same space.

tends to be more nearly vertical. Many ships have been fitted in the last two years with air distribution based on this principle.

Our ideas about air circulation have been greatly stimulated by the very useful experimental work carried out at the Ditton Research Laboratory, run under the supervision of the Director of Food Investigation, which work is fully described yearly in the annual special report of the Food Investigation Board and at other times by papers written by Dr. A. J. M. Smith and others published in periodicals or presented before sundry committees. These researches show that in a stack of boxed fruit the vertical system of air circulation gives far more even temperatures than any form of horizontal circulation. Furthermore, it has been shown that with vertical circulation through a stack of fruit, stowed without any battens between the boxes, more even temperatures are

In the Ditton experimental hold with horizontal air flow the travel is only 30ft., about half that met with in the lower holds or full sized 'tweendecks of modern refrigerated vessels. The depth of the experimental hold, however, is very nearly that of a full sized hold and something like double that of a 'tweendeck. With athwartship horizontal flow it is found that there is a great tendency for most of the air to flow along the spaces above and below the cargo block.

Let us consider the example of a 'tweendeck 10ft. high in the clear and 60ft. long×60ft. wide. Boxed fruit stowed in this will have a space formed by the floor dunnage 3in. to 4in. clear underneath and may have a space 6in. to 9in. clear above between the topmost layer and the roof. The fore and aft sectional area of these clear passages at right angles to the flow in a length of 60ft. may reach a total area of 60 sq. ft., allowing all the air circulated at 30 changes per hour, viz. 18,000 cu. ft. per minute, to pass above and below the fruit at the moderate speed of 300ft. per minute.

Calculations made by Mr. J. K. Hardy, of the Ditton Research Laboratory for a space of these dimensions, stowed with tightly packed fruit, with dunnage strips ⅜in. deep laid athwartships between the boxes, show that the air volume passing directly through the stack is of the order of 240 cu. ft. per minute, the remainder, namely, 17,760 cu. ft. per minute, passing through the 6in. space above and the 3in. space below the stack. These figures are derived from the frictional resistances of the many air passages between the boxes and of the air passages above and below the boxes, and give the relative amounts of the volumes which tend to pass for the same resistance through the main body of the cargo and outside it. The loss of pressure resulting is approximately 0·03in. of water. The same calculations show that if the air passages above and below the stack could be blocked off entirely and all the air could be forced through the fruit boxes, the loss of pressure would be 2·4in. approximately.

Consider now what happens in vertical flow in this same deck. The area at right angles to the flow is $60 \times 60 = 3{,}600$ sq. ft., against 600 sq. ft. in horizontal flow and the cargo can be so stowed that there is very little space left round it against the ship's sides and bulkheads to allow the air to short circuit direct from ceiling to floor. Such bulges as there are in the boxes tend to provide vertical air passages of far greater area than those offered by horizontal battens between the boxes for horizontal flow and, moreover, the distance of travel from roof to floor is only about one-sixth that of the distance athwartships.

Calculations based on experimental results obtained at Ditton show that with no free passage of air round the cargo stack the loss in pressure through the stack with vertical flow is of the order of 0·02in. of water compared with 2·4in. for all the air passing through the stack with horizontal flow or 0·03in. with the usual free passages above and below the boxes. Moreover Mr. J. K. Hardy has calculated from data derived from stowage in the 30ft. square hold at Ditton that the free area available for vertical air flow through the body of a stack of fruit stowed as closely as possible in a 60ft. square space is of the order of 234 sq. ft. allowing a velocity of about 175ft. per minute for the air volume of 18,000 cu. ft. per minute, thus giving a very much lower velocity than occurs in the air passages above and below the cargo stowed in the 'tweendeck exemplified.

It is obvious from these considerations that with horizontal flow most of the air circulation in the heart of the fruit stack must be due to induced currents and natural convection. Nevertheless many ships equipped with horizontal flow of modern proportions are running to-day and giving the utmost satisfaction. A point that should be well noted, however, is that with vertical flow through boxes packed as tightly as possible, there is no appreciable loss in pressure, certainly not enough to restrict in any way the flow of the air. Direct measurements recently taken at the Ditton Laboratory confirm this statement.

If in the Ditton hold, where comparatively little difference exists between both distance and area of travel in either vertical or in horizontal flow, there is the superiority of conditions given by vertical flow shown in the table, how much more in the average lower hold and still more in the average shallow 'tweendeck is there a claim for vertical flow. It must be remembered that at Ditton the fruit temperatures were taken by carefully calibrated electrical thermometers with the thermometer heads packed inside the box with the fruit.

The fact that the mean air temperature and the mean fruit temperature are so much closer with vertical than with horizontal flow is in itself a point of great importance. In any space, cooled either by pipe grids or by forced circulation, only the air temperature can be controlled and generally only the air temperature is indicated by the thermometers normally provided. Surely it is a great point to have a system in which the ordinary thermometers, both electric and standard tube type, can be relied upon to reflect the temperature of the body of the cargo with reasonable accuracy. It may well be asked of course, what is the good of horizontal dunnage when the flow of air is vertical? Finally, while on this subject of vertical and horizontal air flow, it may be said that surely all this is only what common sense would lead one to expect without experiment.

Having considered the relative merits of vertical and horizontal flow, it would be of interest to describe one or two systems by which vertical flow can be accomplished.

'Tweendecks. Fig. 10.

A fan and two batteries are placed against the bulkhead at one end. The air is drawn from port and starboard through the batteries and is discharged upwards by the fan to a trunk running right across the ship over the top of the batteries. The side trunks are sub-divided into two sections by an airtight runner. The top half of the side trunk is the delivery and feeds air to a number of trunks let into the roof insulation between the beams, while a certain proportion of the air is discharged direct from the top of the side trunk. The bottom half of the side trunk is the suction drawing through openings on floor level.

According to the quantity of air to be passed these sunken roof trunks vary in size between 12in. wide×3in. deep to 18in. wide×4in. deep, leaving at least 6in. of cork between the top of the trunk and the deck overhead. They are placed generally in every third to every fifth beam spacing according to the number required. Those abutting the hatch discharge air through the hatch coaming by means of pipes of say 3in. bore led through the fore and after girder. Every effort should be made to give the hatch area its fair proportion of air.

By sinking the overhead discharge trunks in the roof insulation a perfectly smooth roof surface without any projections is obtained, and this is essential when the space has to be equipped with meat rails for hanging chilled beef. Moreover, in an ordinary 'tweendeck 7ft. 6in. to 10ft. high in the clear, external roof trunks 6in. to 9in. deep form very inconvenient obstructions and tend to spoil cargo stowage.

Vertical Air Systems in Lower Holds. Fig. 11.

The figure shows one method of equipping a deep lower hold with vertical air circulation employing the two-pass battery shown in Fig. 7. Two batteries and two fans are provided, each battery being divided midway along its grids by an airtight division of wood. The air is drawn in from outboard, passes down the outboard half of each cooler and up the inboard half to the fan.

The air is discharged by two trunks running the full length of the space as close to the hatch as pillars, girders, etc. will allow. Feeders from the air trunk are led into the hatch, piercing the girder and insulated hatch coaming at regular intervals, in a manner similar to that for hatches of 'tweendecks. The holes for these feeders must be as high as possible in the coaming so as to blow the air along the underside of the hatch plugs clear above any cargo. On reaching the bulkhead remote from the coolers the delivery trunks, by then much reduced in size, branch out port and starboard and also towards the centre line in comparatively small trunks which discharge air downwards over the face of the bulkhead, which is fitted with vertical battens so as to provide a

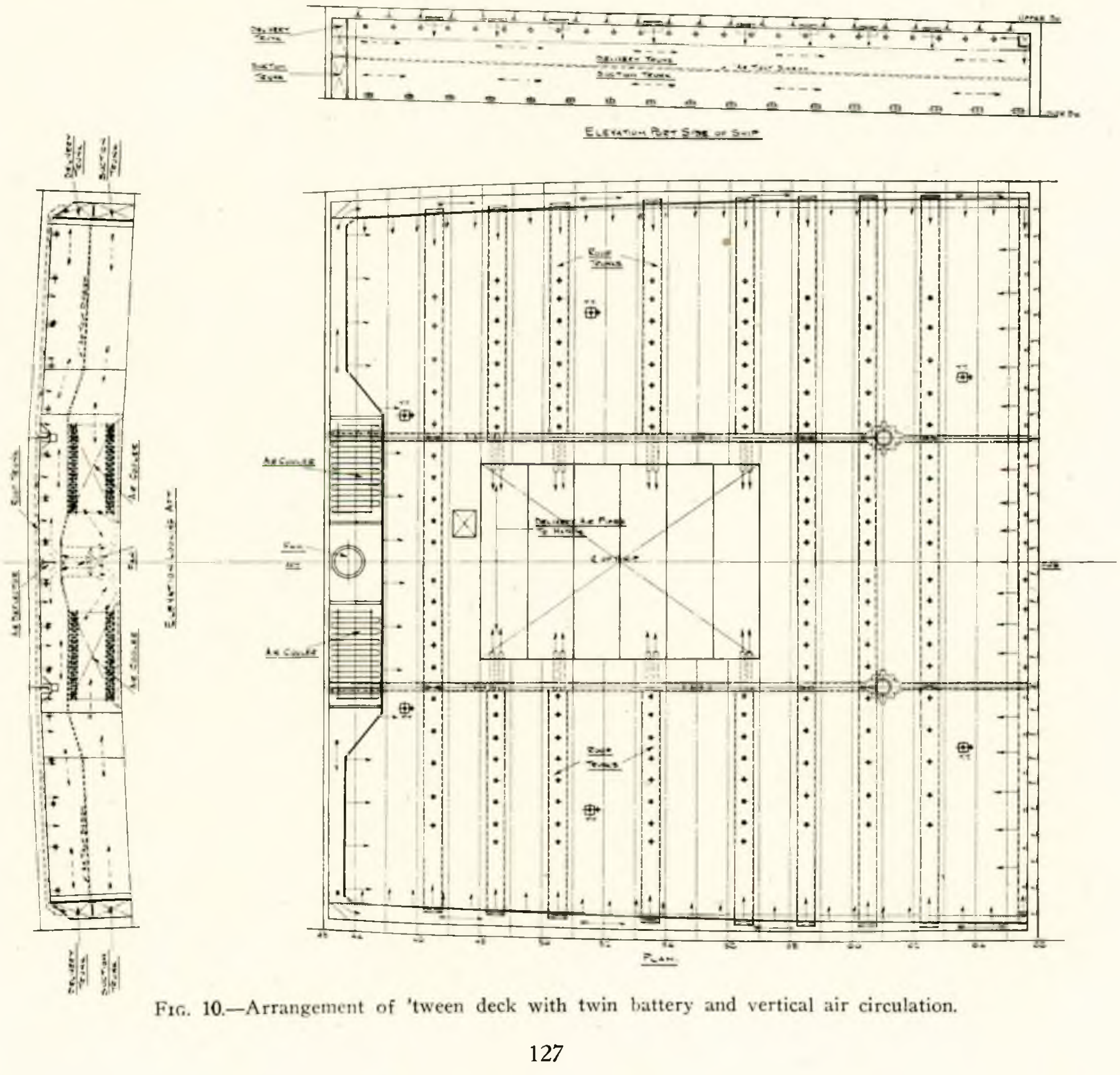


Fig. 10.—Arrangement of 'tween deck with twin battery and vertical air circulation.

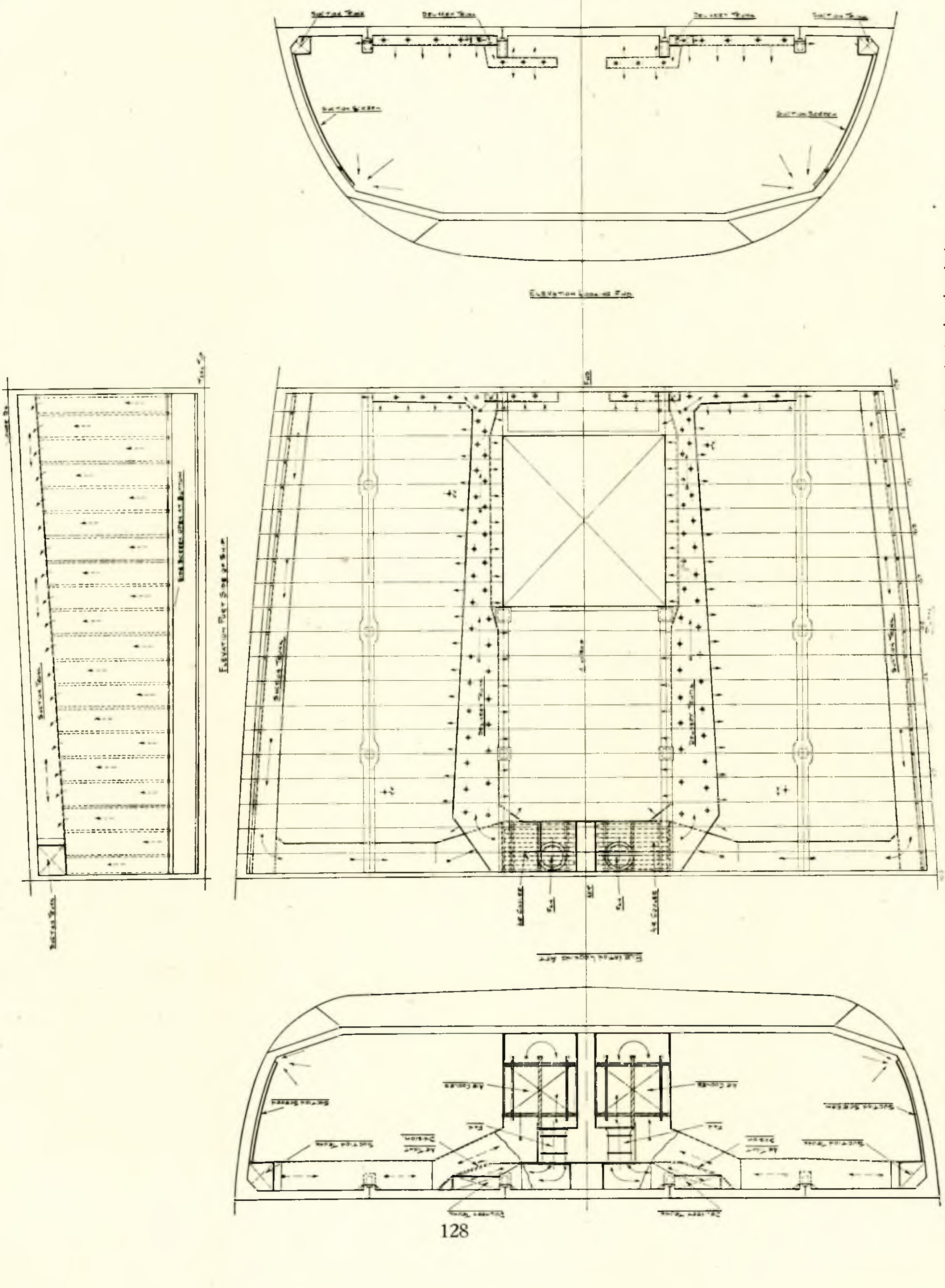


FIG. 11.—Arrangement of lower hold with twin battery and vertical air circulation.

screen of cold air to remove any heat entering through the insulation.

To feed the centre space forward and aft of the hatch, small trunks are led along the centre line on the roof as shown on the drawing. These have openings at the ends so as to blow into the hatch centrally at each end. The suction air is drawn from the bottom of the hold over the full length of the sides by a false side formed by boarding over vertical grounds laid over each frame, these grounds generally providing an air space 3in. to 4in. deep. The false side so formed falls right down to the turn of the bilge, which is overlaid with battens similar to those used on the floor proper whenever refrigerated cargo is carried. The air from the false sides is collected by fore and aft trunks at the top, these trunks leading into the batteries. All this can be understood from the diagram better than from verbal description.

In another variation of the same idea the air is drawn in by rectangular section trunks laid inboard on the floor to port and starboard of the hatch.

Both of the systems shown in Figs. 10 and 11 are suggestive of a scheme put forward by Dr. A. J. M. Smith, of the Cambridge Low Temperature Station, which he calls the "jacket" system and in which the air in its return from the cargo to the cooler passes over all four walls, thereby picking up the heat entering through these walls. The 'tweendeck system shown has only half each side wall exposed to the return air and the lower hold has only two out of the four sides directly covered with the return air. In both of these systems, however, the "jacketing" so achieved came about incidentally rather than intentionally, due to the convenience of air trunking construction and layout.

The recent developments in methods of application of refrigeration to insulated spaces on ships have taken place gradually over the last say five years. No special credit can be given to any one organisation or individual for the various improvements which have taken place in that period, for the process of development has been rather one of evolution, each ship in the last few years being some modification of its predecessors. In fact, we are tending to revert to methods which were employed in the earliest days, which methods are now capable of successful application owing to the improved design of the units from which they are built up.

The general interest in the problems and the many discussions by all the parties concerned, together with the experimental work of the scientific investigators not only of this country but of the U.S.A. and the Continent have brought about a much more intelligent and open outlook on these questions than existed before.

The ideal equipment for each of the spaces of a ship built to carry any type of refrigerated cargo is that which allows each compartment to be completely independent of any other and permits any type of cargo to be loaded at short notice without special preparation of the space to receive it.

It appears from the state of our knowledge at the present moment that of all methods, the vertical air system approaches most nearly to that ideal.

In connection with air circulation the question arises about the drying effect of air on such cargoes as frozen meat and chilled meat. There is no evidence at the moment that the drying effect of air circulating in a closed cycle is dependent on its rate of circulation.

In an insulated space equipped with a fan and a battery, also, perhaps, some roof grids, the same air passes round the system 20, 30 or 40 times in each hour. All moisture it acquires from the cargo must be deposited on the pipes of the battery or grids. Therefore the air can only take out of the cargo exactly the same amount of water as it loses on the cooler and grid pipes. As the air passes round the system it rises in temperature due to the addition of heat caused by friction in the fan and air trunks and of heat coming in through the insulation. For any given amount of heat to be removed we have the option of either a large volume in circulation with a small temperature rise or a small volume with a large temperature rise. It cannot be said yet which of these two has the greater drying effect.

Suppose we have a lower hold 60ft. square × 20ft. high internal dimensions giving 72,000 cu. ft. capacity. With 85° external temperature and 15° internal temperature the heat flowing into this space with normal insulation will be about 60,000 B.T.U./hr.

Suppose we have air circulating at 15 changes per hour = 18,000 cu. ft./min. In absorbing 60,000 B.T.U./hr. this air will rise 3° F., entering at say 13° F. and leaving at 16° F.

Now saturated air at 13° F. contains 0·898 grains of water vapour in each cubic foot and at 16° F. 1·032 grains per cubic foot. Ignoring change of volume due to change of temperature the amount of water the air is capable of acquiring on its way round is therefore 0·134 grains per cubic foot = 2·07lb. per hour for 18,000 cu. ft./min. Suppose now we double the quantity of air the temperature rise will be 1½° F. and the air will enter say at 14° F. and leave at 15½° F. Between these temperatures the weight of water vapour in a cubic foot of saturated air changes by ·067 grains equivalent to the deposition of 2·08lb./hr. Thus for double the volume of air in circulation we deposit the same amount of water vapour in the form of snow on the grids or battery pipes. If now we decrease or increase the amount of heat carried by the air the temperature range will alter accordingly for any given rate of circulation. Thus the deciding factor in the potential drying effect is not how much air is in circulation but how much heat has to be carried by the air, irrespective of the volume circulated. Furthermore, the actual design of the battery has a considerable effect on the dryness of the air discharged by it.

A battery with small or inefficient surface requiring a low brine temperature in relation to the air temperature will discharge air at a lower relative humidity than one of efficient design where the brine temperature is comparatively close to the air temperature. Thus with a badly designed battery the air will start on its travel through the cargo with a greater drying power than will be the case with a well designed battery.

The ideal system is either that in which the air removing the heat coming in through the insulation does not become mixed with the air passing through the cargo or else that in which the air removes the insulation heat after it has passed through the cargo. This latter idea is the basis of the "jacket" system mentioned earlier.

In the systems shown in Fig. 10 and 11 the air picks up heat from the roof, part of the two sides, and part of the bulkheads before entering the cargo. Also, the fan is placed after the cooler which in itself dries the air somewhat. In the several examples of these equipments which have been operating for the last two or three years there is no evidence of excessive drying either of frozen or chilled meat; in fact, by observation of the amount of frost collected on the battery and roof grid piping in comparison with the amount which is generally visible on the grids covering the overheading and sides of simple gridded spaces it appears that, if anything, less frost is formed.

A large hold of say 70,000 cu. ft. equipped with roofing and side grids contains about 11,500ft. of pipe on the roof and four walls. The same hold equipped with battery and fan for vertical circulation would have about 4,000ft. in the battery and 3,500ft. on the roof, very much less than the simple gridded space to give the effect of a complete air cooled and grid cooled hold suitable for all purposes.

As mentioned earlier, it appears that a hold battery will last five weeks without becoming choked with frost, so that it cannot acquire a very great deal of water in that period. However, our experience with this equipment is comparatively limited. Such as it is, however, it has given every indication that fears based on the drying effect of air circulation are entirely groundless.

Economic Aspect.

In the search for a system of cooling spaces which will answer all varieties of purposes we have, therefore, arrived at this vertical air cooling system in which every space has its own fan and battery located inside it. The battery house and air trunks take up more space than plain grids on the roof and walls.

It appears from calculations made from drawings of the two systems applied to identical spaces that in a normal full sized 'tweendeck fitted with grids the useful capacity is about 95 per cent. of the insulated capacity while with the latest design of air with roof grid system the useful capacity is 91½ per cent. of the insulated capacity, or an increase in loss of 3½ per cent. of the gross insulated capacity. In a large lower hold of say 70,000 - 90,000 cu. ft. these two figures are 96 per cent. and about 93 per cent., giving an increase in loss of about 3 per cent.

So far as the costs of installation are concerned it seems that the two systems cost practically the same for the refrigeration equipment, but that the insulation and trunk work in the air system cost rather more. Against the loss of capacity and the extra original cost of the total equipment must be set these advantages :—

I.—For general frozen produce the temperatures are much more even with the vertical air system than with the grid system.

II.—The air system is able to take fruit and cheese without any expensive alterations such as are necessary with plain gridded spaces to make them suitable for these commodities.

III.—The vertical air system will permit stowage of fruit cargoes at much closer density than any other system previously employed, owing to the permissible omission of any battening or dunnage between the cases and stowage close to the roof.

IV.—The vertical air system obviates the necessity of portable hatch grids, as the hatches are cooled by air alone under all conditions of carriage.

V.—Grids on the roof and sides are cut down to a very small quantity on the roof only, thus reducing the cost of upkeep and the possibilities of damage to cargo from brine leaks

All brine grids may be cut out by the adoption of flat air trunks located on the roof or sides forming a closed air cycle. As can be seen, the chief advantages of the air system lie in its suitability for fruit and cheese carriage and it is a matter of considerable importance to weigh up carefully in the light of the various factors for and against each system how many and which spaces should be equipped with the air system and how many with the grid system.

Chilled Meat.

In the last three years has arisen the new trade of carrying chilled meat from Australia and New Zealand. Hitherto the chilled beef trade has existed virtually only between this country and the Argentine. For many years the maximum permissible time for chilled beef to be on board ship has been about 21 days, after which the beef starts to deteriorate due to the growth of moulds and other fungi.

Several years ago attempts were made to carry chilled beef from the Antipodes by the use of formaldehyde, which proved a satisfactory method of preventing fungal growths but had to be abandoned owing to Government objections. Experiments carried out by the staff of the Low Temperature Station at Cambridge showed that CO_2 gas acts as a deterrent against the growth of moulds and the like. An experimental shipment of chilled beef was brought home from Australia in 1932 by the "Port Fairy" of the Port Line, and attempts were made to keep the concentration of CO_2 gas in the 'tweendeck chamber used at 10 per cent. throughout the voyage. An enormous loss of gas was experienced, but nevertheless the quality of the beef showed that the CO_2 had practically prevented the appearance of any moulds or other blemishes on the surface of the meat during about 60 days on board. Since then the trade has steadily grown and in all the new ships recently built for the Australian run many compartments of varying sizes have been provided for the carriage of chilled beef. Moreover in all the more modern vessels already built for this run special chambers have been added or existing chambers have been converted for this purpose. In the first chambers converted in existing vessels attempts were made to render gastight the existing wooden dividing walls and steel structure but in most cases the results were far from satisfactory.

In all new ships and in most ships where chambers have been added or converted for chilled beef carriage the whole of the steel structure containing the chilled chambers has been welded, so as to make the steel envelope gastight in itself. It is usual now to apply a test for gastightness to these steel containers before any insulation is applied. Great care has to be taken with all pipes or thermometer tubes which enter the space, and it is preferable to weld all pipes to the steel through which they enter. Since the adoption of welding and the provision of special doors or bolting plates for the entry to the chambers the loss of gas has been reduced to a reasonable amount.

It has been found necessary to provide air circulation in spaces for the carriage of chilled beef. This air circulation has the effect of sweeping out the damp corners which exist in the quarters of beef themselves, also it tends to effect better distribution of CO_2 gas and of temperature. Furthermore in the light of most recent investigation it appears that the colour of the meat is improved by the air circulation.

The exact rate of air circulation has been the subject of much discussion and investigation. In the earliest days the requirement was for air circulating at the rate of 5 - 7 changes per hour based on the air capacity of the chambers when empty, no notice being taken of the way in which the air flow travelled through the chamber. As any effect the air may have on the meat is probably due to its velocity only, the stipulation of rate of change without due regard to the resultant velocity is illogical. At the moment many investigations are going on concerning this point and it seems probable that in the near future further information will be forthcoming which may modify our present ideas. The necessity for air circulation in gastight chambers brought out the special fan shown in Fig. 4. This fan is fitted with a gastight gland on the driving shaft and is mounted as a complete unit bolting on to either a deck or bulkhead from vertical or horizontal mounting, the fan wheel being inside the gas space, whereas the motor is outside and readily accessible. The whole unit can be withdrawn for inspection by releasing the bolts on the ring flange.

Refrigerating Machinery (CO_2 Plants).

There has been no real change in the essential principles of refrigerating machinery in the past few years. The gas compression machine is still supreme and so far as marine plants are concerned the CO_2 machine has been almost universal in its application to ships for large plants. This machine has undergone certain changes in its design and lately we have seen the introduction of the high

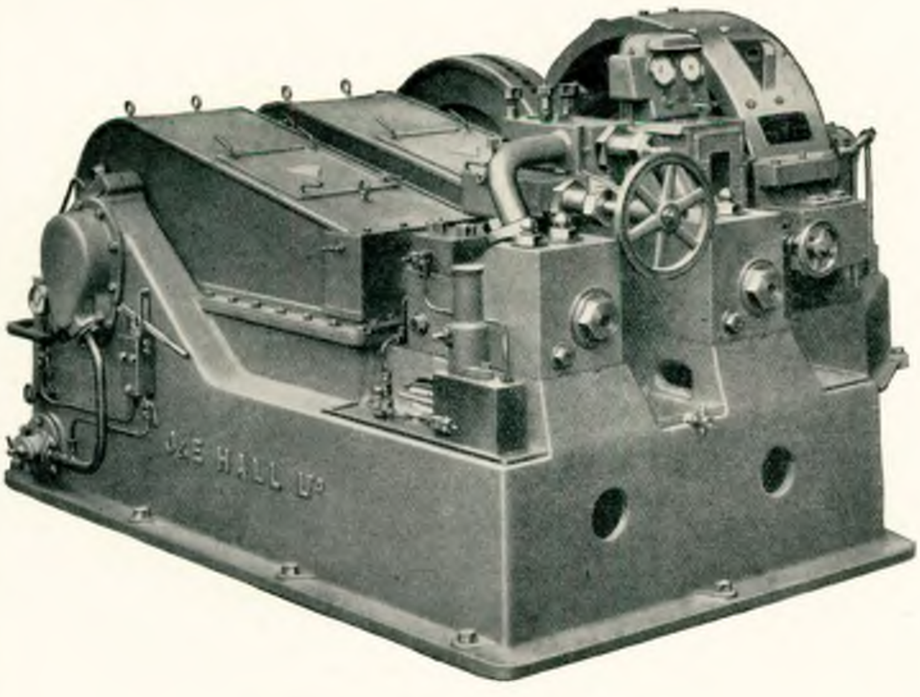


FIG. 12.—Electrically-driven CO_2 machine.

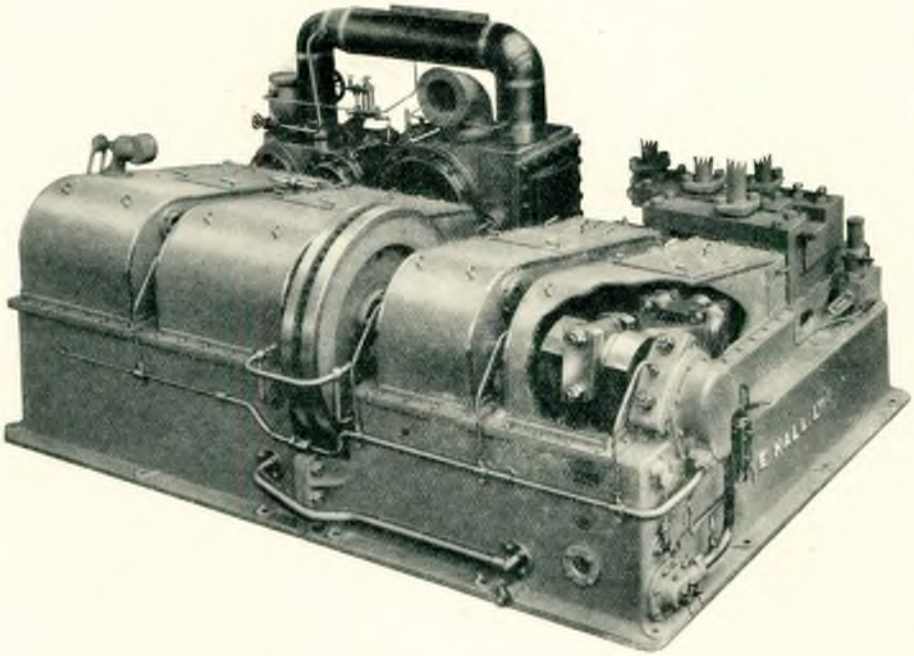


FIG. 13.—Steam-driven CO_2 machine.

speed horizontal compressor for large installations in place of the vertical machine, in which form the machine running at 300 - 500 r.p.m. with forced lubrication to all bearings made its appearance about ten years ago.

Fig. 12 shows a modern horizontal CO_2 compressor driven by a direct-coupled electric motor. This model has two single-acting compressors with 10in. stroke running at 300 r.p.m., and the particular machine illustrated has an output of 56 tons (13,440 B.T.U./hour/ton) based on evaporation at 5° F. and sea water at 70° F. This class of machine has been extensively fitted to ships for the Australian and New Zealand trade which have been built in the last few years.

The horizontal machine of this type is most suitable for fitting in 'tweendecks as it requires low head room and is comparatively free from vertical out of balance forces, which are undesirable in cases where the machine is mounted high up in a ship on an intermediate deck. Fig. 13 shows the same machine driven by a steam engine built for it. Fig. 14 shows a similar machine direct-coupled to a four cylinder horizontal Diesel engine of 250 b.h.p. at 250 r.p.m. In this case the compressor is of 12in. stroke and is equipped for running on the "intermediate liquid cooling" cycle. Sixteen sets of Diesel driven machines as shown have been built for one shipping company alone in the last two years.

The Diesel engine has proved itself to be a most reliable and flexible prime mover. The engine illustrated has four cylinders set in opposed pairs on each side of a two-throw crankshaft. The combined compressor and engine set shown has proved itself to be very free from vibration and entirely suitable for mounting on a deck high up in a ship.

Condensers and Evaporators.

The type of CO_2 machine shown in the illustrations is generally fitted with simple submerged condensers and evaporators consisting of circular coils contained in closed casings. By close attention to design the performance of these units has been considerably improved.

FIG. 14.—Diesel-driven CO_2 machine.

Fig. 15 shows the type of CO_2 condenser most commonly fitted at the present time, consisting of copper coils in a cast iron case. In the design of this unit, special attention has been paid to the velocity and distribution of the water flow with the idea of producing high heat transfer and at the same time preventing the deposition of sludge. This class of condenser is now capable of giving liquefied gas at the outlet at only 2° - 3° above the temperature of the inlet water. Very much the same kind of design has been followed in the case of evaporators and we find that with the modern coil type evaporator the brine leaves the evaporator only 3° to 6° above the temperature of the gas inside the coils compared with the 10° which was considered correct some few years ago.

The low liquid temperatures and high evaporator gauges achieved in the modern CO_2 machine as compared with machines of some years ago have done much to improve the efficiency of this machine, for the CO_2 compressor more so than those using any other gas is very susceptible to the temperature of the liquid leaving the condenser and also to that of evaporation.

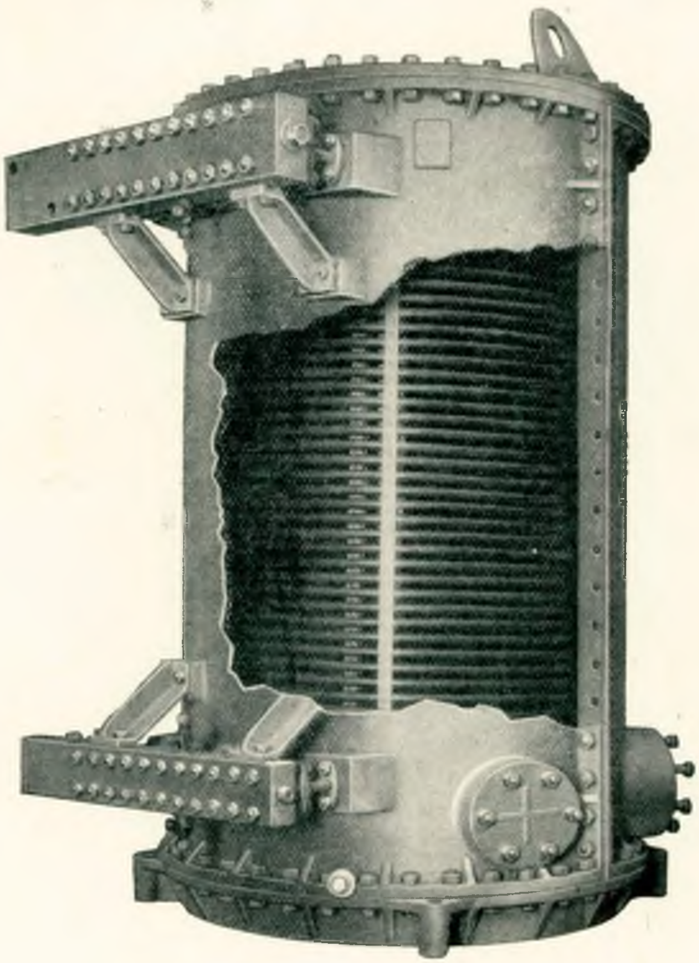


FIG. 15.—Standard circular type CO_2 condenser.

Brine Circulating Systems.

In days past by far the greater number of ships were equipped with what is known as the open brine system, in which the returns from the various circuits supplying the grids or coolers in the spaces fall into an open tank. The brine is pumped from this tank through the evaporators and thence to the delivery headers. In all the large ships constructed in the last few years the "closed" brine system has been fitted. In this system the returns from the circuits instead of falling into an open tank are connected to a set of headers which are virtually the same as those on the delivery side. The brine, therefore, is never exposed and all judgment of the brine control has to be effected by reading the return thermometers.

Fig. 16 shows a modern brine header for three temperatures of brine. The top three boxes are those for the return brine, the bottom three being for the delivery brine. In both sets of headers the leads are connected to multiway selection cocks, those for the top (return) header having volume control valves and thermometers fitted while those for the bottom are plain three-way selection cocks for the deliveries. The top (return) cocks have four ways, the fourth connecting to a steel main running under the cocks. This main provides an extra connection which may be put to a variety of purposes such as open sighting, reverse circulation, special local thawing, etc.

It is found that with the "closed" system internal corrosion is reduced to a minimum, in fact almost entirely stopped due to the absence of air which in the "open" brine system becomes entrained in the brine streams, which fall from the open returns and in the powerful jets which issue from evaporator relief and air vents under the full pump pressure. In the average return tank the brine is kept in far too great a state of disturbance to allow all of the air to escape.

Small Automatic Refrigerating Machines.

During the last five years great strides have been made in the use on shipboard of small automatic refrigerating machines of ½ to about 5 b.h.p. These machines generally are charged with methyl chloride, that being the most harmless of all the low pressure gases available at the present time. Fig. 17 shows a typical methyl chloride machine driven by belt from a high speed motor. The machine and motor are mounted on a cast iron sub-base containing the condenser.

Fig. 18 shows the application of this type of machine to a bar cupboard in a large passenger vessel. Shipowners have found that it is preferable to give each cupboard its own small automatic plant than to run brine leads from the main plant all over the ship. These long brine leads have proved to be very troublesome in upkeep and in many cases the loss of "cold" from the lead is almost as great as the demand made by the cupboard in its normal use. Furthermore, the removal of all such cupboards from the main plant reduces very much the frequent starting up of this plant which the sudden demand from these cupboards is liable to necessitate.

Generally these small methyl chloride machines are coupled to direct expansion grids or plates lining the inner walls of the cupboard. In other cases the small machines are provided with coil type evaporators cooling brine which in turn is circulated through one or more cupboards in the vicinity.

As well as for bar cupboards and small cold boxes in special places these methyl chloride machines have found on sundry large passenger vessels built recently special applications such as for ice cream making and storage, milk cooling and local air conditioning. This same machine has been fitted in large quantities to tramp steamers for keeping the temperatures in the ship's provision room which until quite recently usually consisted of a large ice box in this class of vessel. The greater flexibility in provisioning obtained by having the cold box maintained constantly at lower temperatures than can be obtained by ice has proved to be an economic as well as hygienic advantage and the extra cost for the mechanical refrigeration can be recovered in a very few voyages.

As well as the application to small cupboards and special requirements described, methyl chloride machines are being installed to deal with provision chambers in ships carrying up to 100 passengers requiring say three rooms totalling about 3,000 - 4,000 cu. ft. capacity. These plants again are automatic in operation and are proving to be a better proposition than the small CO_2 machines of 3 to 5 tons refrigeration capacity which used to be fitted for this class of installation. Several ships have been built recently in which a large CO_2 plant has been installed for the carriage of fruit in the cargo holds and a methyl chloride plant consisting of two automatic machines working in parallel has been provided for the provision stores.

While on the subject of this class of machine it is as well to mention the comparatively new refrigerant commonly known as Freon or F12, of which the correct name is dichlorodifluoro methane. This gas has been produced in the U.S.A. as the result of a search for a low pressure harmless gas. Freon is neither inflammable nor does it affect human beings to the same extent as methyl chloride, which acts as an anæsthetic if breathed in sufficient quantities, with unpleasant but not fatal results; moreover under certain circumstances it is inflammable.

With Freon the yield of refrigeration per unit of power consumed is about the same as that of compressors using ammonia or methyl chloride. The compressor must have a displacement about 50 per cent. greater than with ammonia for the same output.

In the U.S.A. Freon gas has found extensive application for large air conditioning plants, also

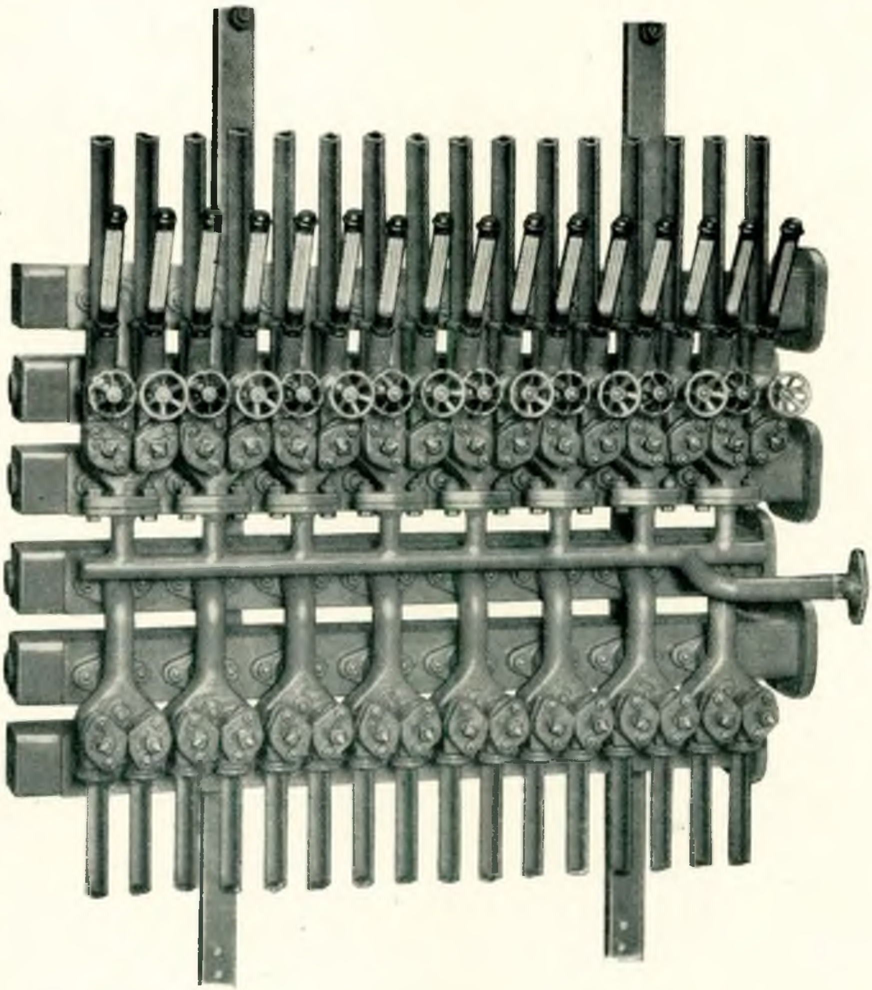


Fig. 16.—Control headers as used in three-temperature closed brine system, showing volume control valves, thermometers and temperature distribution cocks.

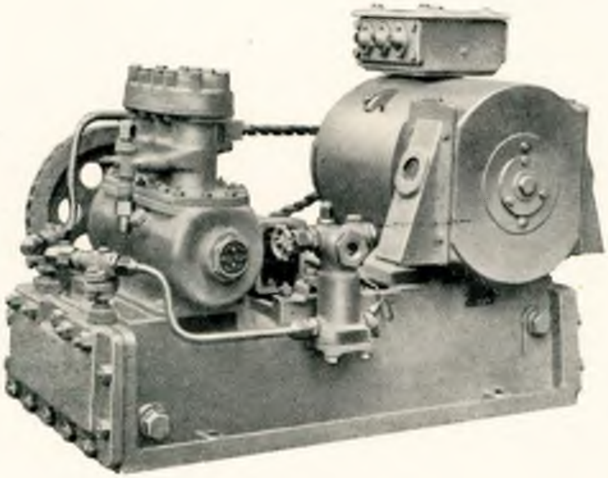


Fig. 17.—Typical methyl chloride machine.

lately sundry fruit carrying ships have been equipped with Freon machines, while both in the U.S.A. and this country it is being used for charging small automatic plants of the domestic and commercial types. Freon gas is very expensive and difficult to obtain in this country and it has yet to be proved to be a satisfactory gas for use in large machines working at low evaporation temperatures, so that as yet it cannot be considered to be a proposition for British shipowners. Moreover, both the initial and running costs of the CO_2 machine are so small in comparison with the cost and installed power of a ship built principally for the carriage of refrigerated cargo, that any new venture in the way of refrigerating machinery will have to be very well proved before it is justifiable to risk the success of the whole purpose of the ship for a reduction in two such already small components of the complete expenditure.

Fig. 18.—Pantry cupboard in the "Queen of Bermuda".

The Author's firm has recently received an order for a large Freon plant for air conditioning abroad consisting of two machines of about 50 b.h.p. each. This plant has been run in the Works and has yielded a lot of interesting information concerning the design of valves, evaporators and pipe lines.

It may be that in the course of time Freon or some other new gas of similar properties may become universally obtainable at a reasonable price and that machines using this gas will gradually displace the CO_2 machine, but before we reach that state there is a great deal of work to be done.

Refrigeration in Trawlers.

In the last few years the small refrigerating machine has made its appearance in trawlers, not as a substitute for, but as an adjunct to the normal cooling by ice. At various times in the past small CO_2 machines have been installed in trawlers but have never proved successful owing to their size, cost and power consumption. The small steam-driven machine using methyl chloride has proved to be very suitable.

Fig. 19 shows a machine of which the Author's firm has fitted about 40 to British trawlers. The triple cylinder compressor with its steam engine is mounted on a sub-base containing the condenser. The automatic regulator and the requisite control valves are mounted in some place convenient to the machine in the trawler's engine room. The cooling of the hold is effected by grids of galvanized steel pipe on the roof and sides of the hold, these grids containing the expanding methyl chloride.

A trawler's fish hold is usually divided into two compartments, the larger forward division being used for the carriage of ice outward bound and the smaller aft division for the outward bunker coal. The refrigerating plant has two circuits in the evaporator, that for the forward compartment being in use outwards to reduce the melting of the ice. On reaching the fishing ground the bunker division is cleared of coal and its refrigeration circuit turned on so as to cool it down ready for the reception of fish and ice.

The effect of the plant fitted in these trawlers is to produce more even temperatures all through the body of the mass of ice and fish, at 5° to 12° lower than the lowest normal temperatures obtained with ice only, and also to reduce by a considerable amount the ice melted, in itself a considerable economy.

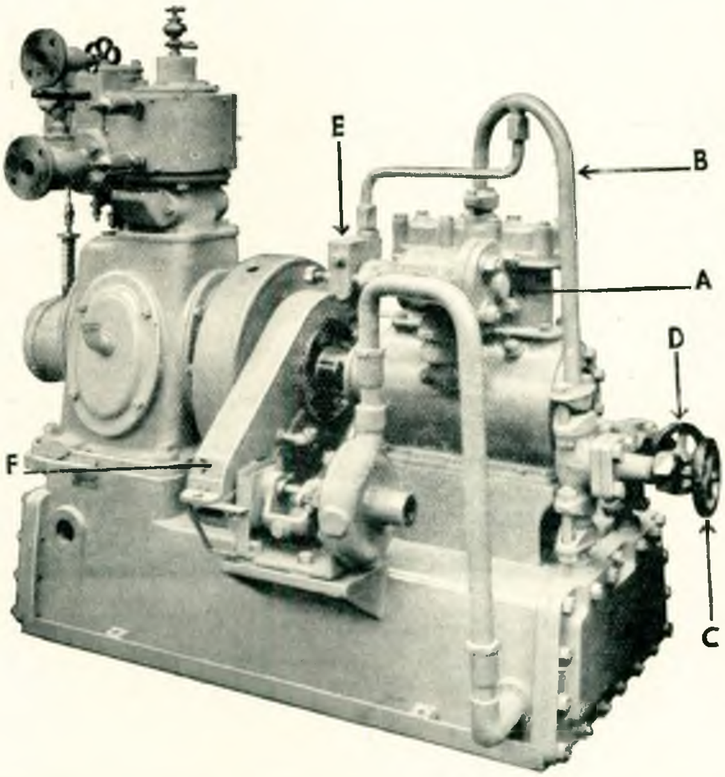


FIG. 19.—Steam-driven methyl chloride machine with water pump as fitted in trawlers.

bulb temperature and the velocity. As the air temperature approaches that of the human body, viz., 98½° its cooling effect by the removal of dry heat decreases. The body then relies more and more on the extraction of heat by the evaporation of moisture from the skin and respiratory tracts, the intensity of this effect being dependent on the ability of the air to absorb moisture.

The wet bulb temperature is indicative of the quantity of moisture in the air and moreover it records the temperature at which a wetted surface will evaporate water into the air. As the wet bulb temperature approaches that of the body so the ability of the body to evaporate water into the air decreases. Increase in the velocity of the air enhances the effect of either of these cooling actions, but by reason of possible discomfort this means of producing the desired result has severe limitations. Similarly, owing to undesirable contrast it is not good to attempt cooling by lowering the dry bulb temperature too much.

The most effective way of producing a sense of comfort in rooms situate in oppressive atmospheric conditions is to reduce both dry and wet bulb temperatures of the air in these rooms to such a degree that the body can rid itself of its heat by evaporation and by natural dry cooling without

No attempt is made to stop the melting of the ice. The fish is landed as "wet" fish but it is found that with the lower temperatures produced the quality obtained is distinctly better than that from the ordinary fish room using ice without refrigeration.

Air Conditioning.

During the last few years we have seen the advent of a new application of refrigeration to ships, namely, that of air conditioning. "Air conditioning" is a term coined in the United States to signify the cooling and dehumidifying of air and its introduction into a building or a set of rooms in a state in which it produces not only a lower temperature but also a lower relative humidity than that obtaining in the external atmosphere.

The cooling effect of air on the human body is dependent on three characteristics of the air, namely, the dry bulb temperature, the wet

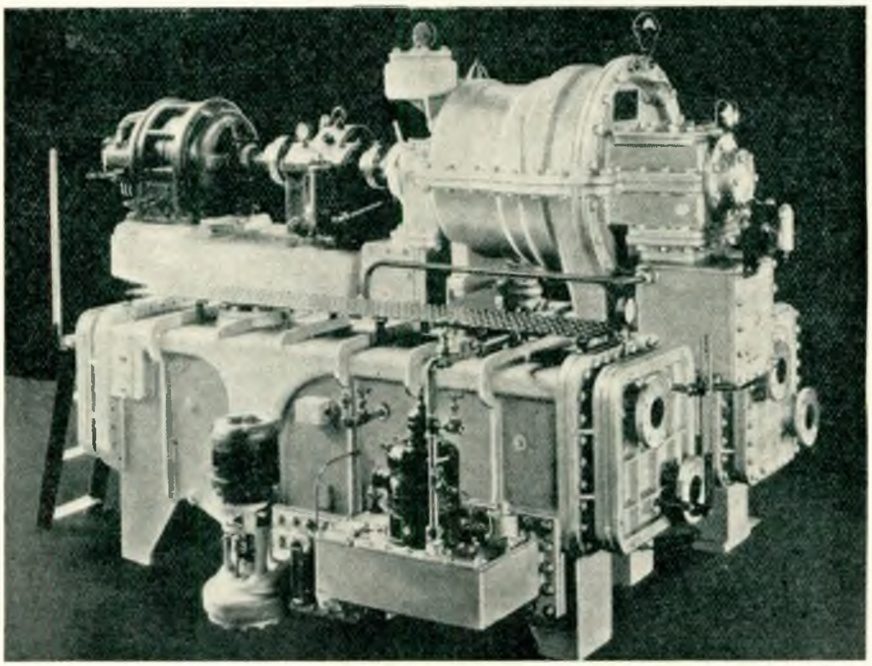


FIG. 20.—Carrier machine consisting of a five-stage centrifugal compressor mounted on two cast-iron casings which form the condenser and evaporator.

producing on it the sense of cold by too great contrast with previous dry bulb temperatures.

It must be remembered in taking readings of wet bulb thermometers that when located in stationary air, a wet bulb thermometer does not record a true reading. Unless the speed of the air passing over the wet bulb exceeds 6ft. per second the thermometer does not read truly, hence the various types of the instrument such as the whirling hygrometer which is operated like a policeman's rattle, and other versions with fans to produce the velocity of air requisite to remove the layer of wet air with which the wet bulb tends to surround itself.

From experience obtained in various ships and buildings equipped with air conditioning it appears that in tropical weather a very agreeable relief to the human body is achieved if the dry bulb temperature is reduced by 5° to 10° and the wet bulb temperature by 10° to 15° below those obtaining in the external atmosphere. In a ship especially it is undesirable to maintain such conditions in the cooled compartments as will produce on leaving these compartments a sense of undesirable contrast In most buildings and also in all the ships which have so far been equipped with air conditioning the air has been cooled by passing it through a series of sprays supplied with fresh water cooled to something like 45° to 55° F. This spray chamber produces air at about 5° to 10° F. above the inlet water temperature and also almost fully saturated, viz., with a wet bulb temperature almost the same as the dry bulb. By the admixture of air re-circulated from the rooms the temperature of this air can then be raised to about 10° to 15° F. less than the internal temperature of the rooms before introduction thereto, the rise in temperature having the effect of drying the air. The sprays thoroughly cleanse the air of all suspended matter. The surplus moisture extracted from the air in cooling it from its dew point temperature at entry to that at which it leaves the spray chamber will be added to the water in circulation through the sprays.

In certain circumstances it may be necessary to re-heat the air by steam or electricity before it enters the rooms. It is also possible to cool air by dry pipe coolers of similar construction to those used in the cooling of cargo spaces. In this case it is permissible to employ designs allowing of high velocity of air and close pitching of surfaces owing to the absence of frost formation on the cooler. This type of dry cooler has in certain circumstances a claim for use in air conditioning as it occupies less space than the spray type and can be connected into a normal refrigerating circuit using high temperature brine. So far all the installations that have been fitted in ships, except one small one for local air conditioning, have been, as far as the writer knows, of the spray type.

While on this subject, it may be of interest to study one or two important figures relating to the cooling of air. The following table gives the vapour content of saturated air, its total heat above 0° F., and the density of dry air at 30in. barometer for temperatures met with in ordinary climates :—

Temp. °F.	Water per cu. ft. (grains).	Total heat B.T.U. per pound.	Density pounds cu. ft.
110	26·11	87·7	·0698
100	19·76	68·8	·0710
90	14·79	54·1	·0724
80	10·93	42·6	·0737
70	7·98	33·4	·0751
60	5·75	26·2	·0766
50	4·07	20·2	·0781
40	2·85	15·2	·0796
30	1·94	10·9	·0811

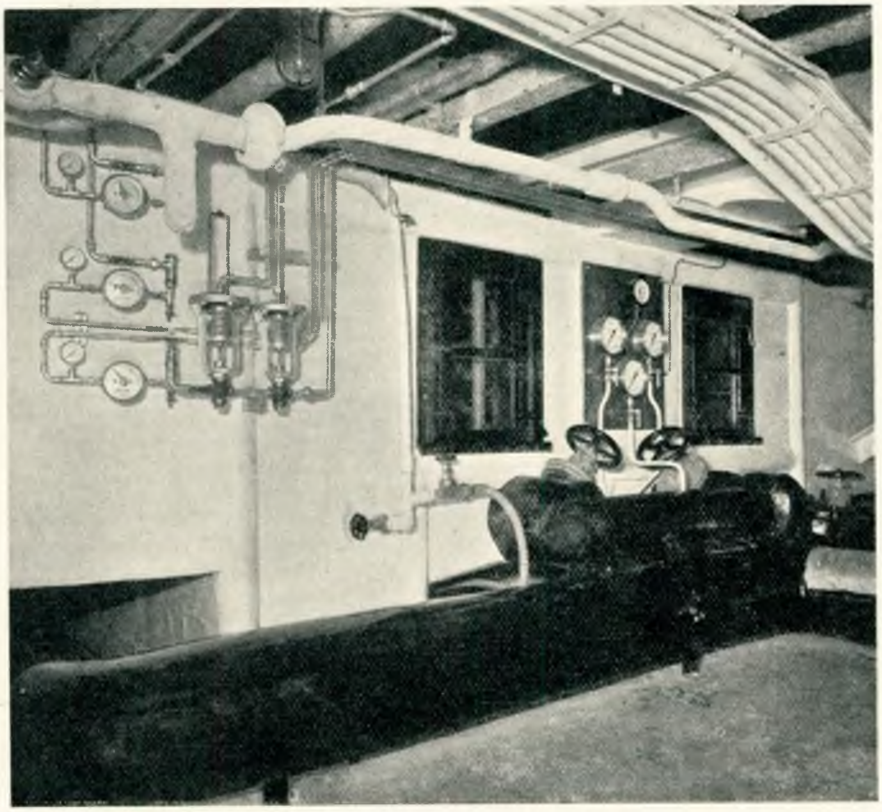


FIG. 21.—Dehumidifier of a Carrier plant.

In cooling air from one condition to another the air has to be cooled as dry air at the rate of ·24 B.T.U. per pound per degree and also any moisture deposited as water has to be condensed at the rate of about 1,030 B.T.U. per pound. It has been found, however, that the total heat of air under any given dry bulb and wet bulb conditions is equal to that of air saturated at the wet bulb temperature.

Thus, if we wish to cool 10,000 cu. ft. of air at 100° F. dry bulb and 80° wet bulb to 60°, at which the dry bulb and wet bulb temperatures will be the same, as the air, being below its original dew point, will be saturated, we must change the total heat of the air from that at 80° = 42·6 B.T.U./lb. to that at 60° = 26·2 B.T.U./lb. The heat to be removed from the air is $10{,}000 \times {\cdot}071 \times (42{\cdot}6 - 26{\cdot}2) =$ 11,600 B.T.U.

of these vessels is fitted with full air conditioning equipment consisting of spray chambers and automatic controls for the 1st class dining saloon. It now seems probable, owing to the success of the equipment on these two ships, that in future ships of this class for tropical service will have not only their dining saloons but also other public rooms treated in a similar manner.

The requirement of air conditioning which necessitates a large cooling effect at a high temperature of evaporation has brought into the marine field two interesting newcomers in the way of refrigerating machines. Firstly, we may make mention of the centrifugal compression machine. This machine first made its appearance in the United States some 14 years ago, being brought out by The Carrier Engineering Corporation, for use in their extensive work in air conditioning for buildings such as hotels and theatres. Very many of these machines have been supplied for use on land but the first Carrier machine to be put in a ship is that installed in the French liner "Normandie".

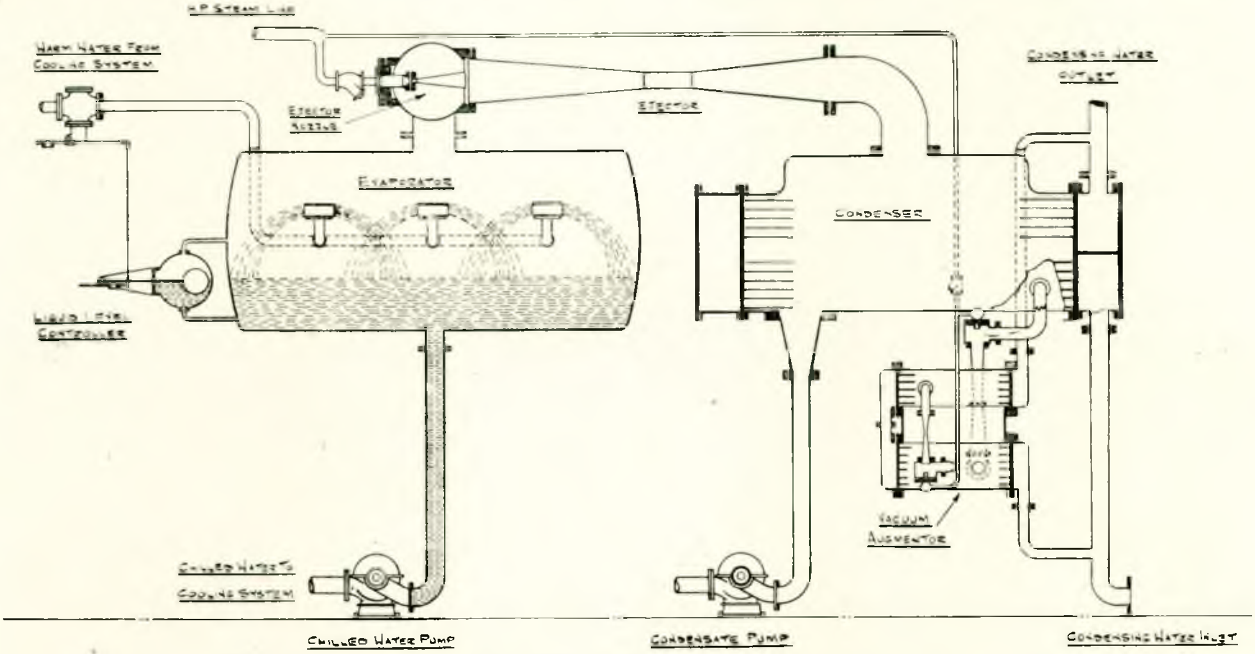


Fig. 22.—Diagram of water vapour ejector machine.

It appears that air conditioning will in future nearly always form a definite part of the equipment of large passenger vessels trading in hot climates or calling at ports where hot damp weather prevails for a large period of the year. For some years past several passenger ships owned in the United States and one owned in Italy have had air conditioning applied to dining saloons. The large French liner "Normandie" has a complete plant dealing with the dining saloon, and finally we have our own large liner, the "Queen Mary", with several rooms treated with air conditioning.

The first British ship to appear equipped with air cooling and conditioning was the Orient liner "Orion", and immediately afterwards came the P. & O. liner "Strathmore", both of which were placed in service in the latter half of 1935. Each

Fig. 20 shows a Carrier machine which consists of a five-stage centrifugal compressor mounted on two cast-iron casings which form the condenser and evaporator. These two latter units are very similar in construction to the ordinary marine steam condenser, consisting as they do of standard non-ferrous metal tubes expanded into tube plates forming the ends of the casings. The refrigerant condensed by water circulation through the condenser tubes passes through an automatic regulator valve into the evaporator, where it is circulated by means of a special pump over the tubes containing the water to be cooled. The refrigerant used in the Carrier machine is methylene chloride, which not only evaporates but also condenses at less than atmospheric pressure.

The compressor has to rotate at a very high speed and is geared up from the electric motor. It may also be directly driven from a steam turbine. A special air evacuating pump driven from the liquid circulating pump shaft is provided to remove any air which may enter the casings containing the refrigerant. The same type of machine is also made by Brown Boveri of Baden, Switzerland who, so far as the Author is aware, have not yet installed one on shipboard.

Fig. 21 shows the spray type dehumidifier of a Carrier plant installed in a large liner recently completed.

Another interesting unit which has appeared in ships recently for high temperature refrigeration is the water vapour ejector machine. This machine is really an adaptation of the vacuum augmentor and consists of a vessel where the water to be cooled is brought, in a suitably broken up state, under the influence of a very high vacuum created by a steam ejector discharging into a condenser. Fig. 22 shows this machine in diagrammatic form. This water vapour ejector unit can only be used where there is a large amount of steam available.

Both of these machines may be used for marine type air conditioning plants with success, but it is the considered opinion of the Author that in most cases where ships are fitted with a compression plant for their normal refrigeration, both cargo and provisions, the most economical proposition is to merge the air conditioning plant and the normal ship's plant into one equipment.

In the ordinary passenger and cargo vessel equipped with large cold store rooms and a certain amount of refrigerated cargo space, the plant installed generally consists of two or three compression machines, one of which is a complete spare under all conditions of loading. It is the Author's contention that it is legitimate to use the spare machine for air conditioning with, if necessary, another machine installed as well, the four machines being suitably interconnected. When the air conditioning and the low temperature refrigeration demands are put together it generally can be found possible to work up a plant consisting of a number of identical machines, say four, with two allocated to the low temperature cold storage load and two to the high temperature load for air conditioning. Under all but the very worst conditions, which then only occur for a few hours daily, one machine will be sufficient for the air conditioning demand.

With machines of such proven reliability and robust construction as modern CO_2 compressors, amply provided with spares, the likelihood of complete breakdown of one machine is extremely remote. If one machine were temporarily out of action during the peak air conditioning load the other, rising as it would in evaporation temperature, would give more than half the full load demand and in all probability thus provide sufficient cooling to prevent any but the mildest protests from the passengers.

In most of the ships so far fitted with air conditioning the cold water required for the air washers is cooled by a CO_2 plant. In the "Orion" and "Strathmore" four identical CO_2 machines cover the refrigeration and air cooling requirements.

In conclusion the Author must thank first of all the Directors of his own firm, J. & E. Hall, Ltd., for allowing him the use of photographs and data generally. Secondly, he would express his gratitude to the Director of Food Investigation and Mr. J. K. Hardy of the Ditton Research Laboratory for information and advice on the statements made concerning the work at Ditton. He is also indebted to Messrs. Davidson of Belfast and Winsor Axia Fans Ltd. and Messrs. Thermotank of Glasgow for information and photographs of fans.

Further he wishes to thank Mr. C. L. Sainty of The Carrier Engineering Co. for information concerning the Carrier machine and for checking over the statements with regard to air conditioning.

Finally he would add that his colleague Commander J. H. Mather has given him considerable help throughout the writing of this paper both as regards suggestions and wording.

Discussion.

Mr. Edward A. Thomson (Member), opening the discussion, said that it was very interesting, particularly to those who commenced their experience with the cold air machine, to read the description of the advances made since then which had been given in Mr. Farmer's admirable paper.

Consider the cold air machine, with the air expansion cylinder cover nuts lined with white metal so that when ice destroyed the clearance the threads stripped before the cover broke, and then turn to the modern marine machine with its light plate compressor valves and running at 300 r.p.m. What a contrast! The Author had been rather modest in his description of the developments for which his firm had been responsible. The scientific design of modern plants and the space which had been saved were really remarkable achievements.

With regard to the air cooling equipment at Ditton, the speaker considered that the Department of Scientific and Industrial Research were to be congratulated on the work which had been carried out. He would like to know if the boxes referred to were stowed exactly one above the other, so that the most would be made of the space due to the bulge on the cases used.

There was an experimental shipment of apples from New Zealand last year, which was successful. The vertical air system without dunnage was used, and another experiment was in progress now. The New Zealand pack, and the American pack in use in vessels loaded on the Pacific Coast, both with bulged sides, were very suitable for grid ships, and had been used successfully without special dunnage or systems such as the tower system for many years.

The speaker had recently inspected a cargo of fruit that had been loaded at five Australasian ports, two in Tasmania and three in Australia, and he had been amazed at the diversity of packs used. Better stowage and air circulation would be obtained if some measure of standardisation could be obtained.

In Fig. 10 Mr. Farmer showed a modern form of vertical air circulation, and he got to the core of the problem when he stated that "sufficient volume of air taking the shortest path through the cargo gives the best results". The speaker endorsed this view. The system referred to was first fitted to the "Imperial Star" laid down in 1933 and completed in 1934, and also about the same time to the "Port Wyndham". Since then over two and a half million cubic feet of ships' space had been fitted with this vertical system.

The speaker was glad to have an opportunity to show the accompanying illustrations (Figs. 23 and 24) of an earlier vertical system. The air was circulated over ammonia d.e. batteries in the shelter deck, and passed along the tween decks where the circulation was from side to side. In the lower holds, however, the air was introduced at the bottom and passed up through the cargo and was taken off to the main suction duct through athwartship branch ducts (which could be seen in the illustration) recessed in the insulation between the beams; alternatively, the circulation could be reversed and the cooled air admitted at the top of the hold and then taken off at the bottom. This system was installed in a vessel in 1894, only fifteen years or so after the first successful frozen cargo arrived in this country from the southern hemisphere. It was designed by the Linde Company, now the Lightfoot Refrigeration Company. Five such vessels came under the speaker's supervision.

He mentioned this early system partly as a matter of interest and partly because it formed the basis of the design of air circulation shown in Fig. 10. There appeared to be an impression in Australia and New Zealand, as well as in this country, that all the new air circulating systems fitted in recent vessels for this trade were based on the designs of the Department of Scientific and Industrial Research. He wished to state that in respect of the system he had referred to, this was certainly not the case. The Department, of course, deserved very great credit for the excellent work it had done in connection with air circulation and other matters.

The Author described the closed brine system which was now so much used. This was chiefly due to the pioneer work of Mr. A. R. T. Woods, who recognised its advantages for marine installations many years ago and had always fitted it. The speaker's Company adopted it in 1920 and had used it ever since. The Author's firm had since taken it up and developed it to its present pitch. It illustrated a case of evolution of design, which was how most things developed.

Mr. C. E. Coombe (Royal Mail Lines, Ltd.) said that most of the Author's statements were proven facts, but the speaker considered that the brine-piped space had fallen into disrepute through no fault of its own. The following remarks would, he hoped, indicate his meaning.

The difficulty experienced in the past in obtaining satisfactory out-turn of mixed cargoes such as fruit, cheese and eggs in vessels equipped for frozen and chilled meat, was the haphazard treatment to which they were subjected. This was partly attributable to the brine distributing system being inadequate and partly to the personnel. Engineers would not use overhead grids unless the cargo demanded a carrying temperature below freezing point. Some ships were fitted with a cold brine injection to each chamber delivery header, but the operation was very difficult, if not impossible, owing to the inconstant brine pressures. Electrical machines had altered that. Those engineers who did use overheads did not get the results required because the system of stowage was wrong, the boxes having narrow horizontal air spaces provided between the tiers, instead of the proper vertical air spaces, and even these were often spoiled in an effort to get a few more boxes in the space. An ordinary tween deck, brine piped for chilled meat carrying and using overheads with good brine temperature control, could and did turn out fruit cargoes (bananas excepted) equal to forced air-cooled spaces, the temperatures in the cargo stack, with proper stowage, being within 1° deviation. But this could only apply for carrying temperatures up to 38°; higher than this, air was essential. Holds or chambers with a depth of 9ft. or over were hardly the thing to use without some form of forced air circulation for any cargo, except frozen produce.

No doubt the forced air cooling delivered from overhead and induced by proper cargo stowage to pass through the whole stack and return by the floor and sides of the chamber would be ideal, but the question of maintaining temperatures during loading and discharging was very important. If the cargo workers were provided with suitable clothing, say coats with hoods, would they object to the conditions? Those working in land cold stores, even in Australia, did not object. If this were possible, a brine spray wash for the battery pipes would keep down or get rid of surplus snow formed during the open period of the chamber without interfering with the temperature at the battery, the fan being stopped only during this washing. The inclusion of brine grids in the chamber should be avoided, if possible.

It was not clear why the wet battery took up more room than the piped battery. It was understood, if the comparison was with the usual undersized crowded nest of pipes usually fitted which quickly lost efficiency with very little snow formation obstructing the passage of air.

It was known that wet batteries caused a considerable amount of drying of the cargo. This would not occur if the density of the brine to each cooler was arranged for its own independent temperature, could this be done with a system of small evaporators to each compressor, say three or four, instead of only one.

In the event of Freon (F.12) becoming a commercial proposition, could they have direct expansion to air coolers with all the advantages it would offer, i.e. eliminating brine pumps, etc.?

In regard to refrigerating plants, the Author advocated horizontal machines because they were accommodated so well in tween decks, but what of the condensers and evaporators which, to meet the new requirements of Lloyd's, had to be periodically opened up and coils withdrawn for testing? The design illustrated would be a difficult and costly business. Also, the de-mudding doors were inadequate.

The Diesel engine was no doubt a satisfactory prime mover and had its advantages, but added considerably to the work and worry of the refrigerating engineer. It was more difficult to do justice to the valuable cargo with the more complicated equipment. Demands by shippers, adjustment of temperatures, humidity control and ventilation took up all his time and thought, the cargo outturn, of course, being first consideration. Electrically-driven compressors relieved the refrigerating engineers of any worry outside of refrigeration, without adding to the duties of other engineers, as the latter had electrical generators to attend to for brine pumps and other auxiliaries in any case.

Regardless of how well a Diesel engine ran or how reliable it might be, little things happened and the machine must have constant attention to prevent big things happening, and these should not be saddled on the refrigerating engineer.

The speaker regretted that Mr. Farmer had nothing to say about ozonising.

Mr. D. Gemmell (Member) said that refrigeration played a most important part in the Mercantile Marine and the transport of perishable produce had developed into a highly specialised industry which most nations depended upon for a large percentage of their food supplies. The quantity of chilled goods transported overseas now greatly exceeded the frozen products, which meant that they had to thank refrigeration for the constant supplies of fresh foods which they now enjoyed. Of the highly perishable products this applied particularly to fruit, which was a product exported and imported by nearly all countries.

The transport of the higher temperature products had necessitated much scientific and practical research, and refrigerating installations had assumed a more complicated aspect in the achievement of greater accuracy and control of temperatures. They knew that the refrigerating machines of to-day could operate with the utmost reliability in maintaining the temperatures required, the machines being subjected to strict periodical surveys with this in view, but although the modern installations had attained a high degree of efficiency there was still much to be learned about the distribution of cold air throughout refrigerated spaces. He was glad that Mr. Farmer had drawn special attention to this throughout his paper and the speaker agreed on the whole with his deductions.

The ideal flow of cold air was one which was distributed uniformly throughout the whole cargo and there should be a definite relationship between the speed of air flow and the heat flow. It was impossible to attain this ideal, but it appeared to the speaker that the vertical flow of air through the cargo would approach the ideal much nearer than would the horizontal flow, provided the spaces between the boxes were more or less uniform and no clear gaps were left between the sides of the chamber and the cargo. This, however, necessitated the omission of the usual 2in.×2in. cargo battens on the ship's side, which woul short circuit a proportion of the air down the sid.s.

Unfortunately, most vessels were r confined to one class of goods, and should lamb carcases and particularly milk lambs be stowed against the sides without fixed battens it seemed to him that there might be a danger, especially in a deep stow, of damage to the lower tiers if these should be somewhat soft when loaded. During loading the cargo would be dependent upon convection currents from the overhead brine piping and it was recognised that battens were necessary in grid-cooled chambers. The Author drew attention on page 130 to the relative unevenness of temperature in grid systems, and he also pointed out that in the combined air and grid system only a very small quantity of grids were fitted to the roof, which would emphasize the necessity for battens being fitted.

The improvement in condensers and evaporators in speeding up the velocity of the water and brine was an important step in obtaining efficiency, particularly in preventing the deposition of sludge in condensers through the circulation of muddy water. In some cases condensers opened up after service had been found almost completely blocked with the exception of a passage between the water inlet and outlet.

Mention had been made of the refrigerant called Freon which had recently come into extensive use in America. It was mainly due to its non-toxic properties that it had received any preference over other refrigerants. It had been ascertained that exposure to Freon gas for thirty minutes was not dangerous up to an 80 per cent. concentration, whereas a ·25 per cent. concentration of ammonia was dangerous over the same period. As it had a low working pressure and had no injurious effect upon produce it should be a very suitable refrigerant for direct expansion cooling. Could the Author say if this gas had been used for direct expansion systems and if they had proved successful?

Reference had also been made to the water vapour ejector machine. This type of machine had recently been installed in several vessels trading to the United States for the carriage of bananas and was reported to be giving good service. The insulated capacity of these vessels was about 150,000 cubic ft. and the machines were rated at 200 tons refrigeration at an evaporating temperature of 45° F. It had been reported that with an atmospheric temperature of 68° F. the holds were reduced to 39° F. in twelve hours.

Mr. W. Hamilton Martin (Member) said that the paper reviewed what had been the practice in marine refrigeration and air conditioning up to quite recently.

With regard to jet refrigeration, since all ships were self-contained and all power required was primarily supplied by steam boilers or Diesel engines and waste-heat boilers, it would be interesting to have comparative steam consumptions for a steam jet refrigerating plant and a CO_2 plant for an air-conditioning duty. For certain air-conditioning duties the steam jet vacuum refrigeration system was proving advantageous. Control, moreover, was much simpler. After all, a jet could give 30 per cent. thermal efficiency making direct use of steam, as against other methods requiring power conversion steps and special gases at high pressures, resulting in extra weight, space, repairs and attendance.

They were bound to see some very interesting developments before long in the application of jet-vacuum refrigeration, not only for air conditioning but for certain applications in which it would increase the overall efficiency of industrial plants of widely varying nature, as well as for marine plants, and its value would be especially proved in tropical operation. For chilling and in the trawling industry the jet system would also find good application.

Was the Author aware that refrigeration on the vacuum system was not now entirely dependent upon the use of the steam jet? It was well known that in the United States great headway was being made by applying the high-speed rotary vapour compressor to this system, and that this method was now also being exploited in this country under certain patents of Continental origin.

In view of the fact that no special gases (which might be comparatively dangerous) or high pressures were necessary with vacuum cooling plants, it would appear that the margin of safety in ships was considerably increased by its use. The use of high-speed rotary vapour compressors in vacuum-cooling plant for large marine installations would allow of efficient working at the various climatic conditions experienced *en route,* while repairs, attendance, and power costs would no doubt be appreciably reduced.

Vacuum refrigeration plant had not yet been developed for holding temperatures as low as those required in cases on board ship where it was necessary for the spaces to be maintained well below freezing point. For ships, however, in which hold temperatures of 34° F. were required, vacuum refrigeration plant could be used.

In view of the fact that the usual ships' refrigeration equipment must be of, say, 100 tons (ice-melting) or more, the steam jet in such cases would not be advocated. A high-speed rotary vapour compressor would be put forward for such duties.

For temperatures of 34° F. in the hold the temperature of the brine leaving the evaporator would have to be approximately 27° F., corresponding to a vapour pressure of 3·7mm. of Hg. The temperature in the condenser in tropical waters might be as high as 103° F., equivalent to a vapour pressure of 53·3mm. of Hg., while in home waters the condenser temperature of the refrigerating plant might be as low as 70° F., equivalent to a vapour pressure of 19 mm. of Hg.

To deal with such a variation in condenser absolute pressure, a suitable arrangement would be to install two rotary compressors in series with a byepass to the condenser, so that in home waters only one compressor need be in service. The first compressor would compress vapour from 3·7mm. abs. to 19mm. abs. maximum. The second one would then compress from 19mm. to 53·3mm. absolute. Such an arrangement would result in considerable economy of power in home waters. A rotary vapour compressor was now being built in this country for service in a large factory. The following design figures would give some idea of the power consumption of these plants:—

Refrigerating duty	1,000,000 B.Th.U.'s per hr.
Leaving water temperature ...	38° F.
Absolute pressure in evaporator	5·9mm. Hg.
Maximum condenser water temperature	75° F.
Absolute pressure in condenser	48mm. Hg.
Number of stages	6
Maximum h.p.	104
Speed	6,200 r.p.m
Ratio of compression	8·14 : 1

These figures might enable some comparison to be made with CO_2 compressors.

Another study had been made of a vapour

compressor for a duty of 350 tons with a leaving temperature of brine of 25° F. for land service with condenser water at 70° F. The calculated power was 390 h.p. and the speed 4,200 r.p.m.

Attention might be drawn to continuous absorption refrigeration for the following uses, i.e. small automatic refrigerating plant mentioned by the Author for use in ships' pantries, bars, cold boxes, milk cooling, ice cream-making and conserving, small provision chambers, and possibly also local air conditioning; this field would seem to offer an excellent opening for a new type continuous absorption refrigerator operating on the Geppert principle. It possessed a valuable and unique feature in that no excessive absorption heat was transmitted to the absorber, as had been usual in absorption systems, in which a large part of the cold of evaporation had to be inefficiently expended, resulting in a low operating efficiency. Because of this feature the new system could operate efficiently without requiring any cooling water even in the Tropics. The advantages were obvious.

For those smaller marine services natural draught sufficed; for larger duties fan circulation became necessary. The system had now been produced with fan cooling in units of 1,000, 2,000 and 4,000 B.Th.U.'s per hour. They could of course be quite well arranged for water cooling on board ships in the larger applications, and would give a very good efficiency. Gland troubles referred to by the Author would be non-existent. Operation being non-mechanical, there was no noise, vibration, wear, lubrication, or gas escapes; hence no mechanical servicing would be required, it being a closed cycle simple tube system. Another point worth noting was that the quantity of ammonia and solution medium (water) required was exceedingly small. For example, a 1,000 B.Th.U. per hour set only needed about a pound of ammonia, which was an advantage in marine service. On board ship electrical current or steam was used as the means of heating, while for land work oil, gas, electricity, steam or exhaust gas would operate this new refrigerating system.

The Author's comments on the use of water-vapour compressors in vacuum refrigeration, and his opinion and comparative figures on steam jet vacuum refrigeration plant versus CO_2 plant for their respective marine services, would be greatly appreciated.

Mr. James K. W. MacVicar (Messrs. Thermotank, Ltd.) said that one very interesting point mentioned by the Author referred to the flow of air across a hold tightly packed with cases of fruit. According to calculations made by Mr. J. K. Hardy, of the Ditton Research Laboratory, it was shown that with 18,000 cubic ft. per minute total volume, 240 cubic ft. per minute would pass through the spaces above and below the cargo. The pressure drop in this case was given as 0·03in. of water. Furthermore, it was stated that should the passages above and below the stack be completely shut off, and all the air passed through the cargo, the pressure drop would be in the region of 2·4in. It would be interesting to learn if these figures were the result of calculation only, or if experiments had been carried out to verify them and, if so, what method was adopted in measuring the volume of air passing through the cargo, this being such a small proportion of the total volume.

The statement that a pressure of 2·4in. would be sufficient to pass 18,000 cubic ft. of air per minute through the cargo suggested that laminar or parallel flow existed, and that the resistance in this case followed a straight line law, and not the square law, associated with turbulent flow, as was usual in ordinary fan work.

Again it would appear that a much larger circulation must exist between the cargo and the air streams flowing above and below, otherwise enormous temperatures would exist in the interior of the cargo. In an arrangement like this, the ordinary convection currents due to the heat generated by the cargo would involve a volume of air many times higher than the 240 cubic ft. per minute referred to.

Mr. C. J. Hampshire (Member) asked if it was only for fruit storage that the air circulating fans referred to were made reversible, or if for meat as well. In his opinion air should always be delivered through the ceiling ducts. He was unable to see the necessity for these circulating fans being reversible.

On the proposal of **Mr. J. Carnaghan** (Vice-President) a very cordial vote of thanks was accorded to the Author.

The Author's Reply to the Discussion.

The Author was very interested to hear Mr. Thomson's remarks concerning the systems installed in vessels built in 1894.

He would like to take this opportunity of stating that the systems described in the paper where overhead discharge trunks were housed in the insulation between the beams were the result of a discussion he had with Mr. Thomson in which he told the Author about these ships which came into his possession fitted in this manner. It was entirely on account of Mr. Thomson's collaboration that this system was given its chance to reappear in its modern form first in the "Imperial Star" and later in all the seven sister ships built by the Blue Star Line. At the same time the Port Line fitted in the "Port Wyndham" two lower holds cooled by the vertical air system with external trunks as shown in Fig. 11 as well as four large 'tween decks fitted as shown in Fig. 10. Very shortly after this the same systems were fitted in the new Orient liner "Orion" and the P. & O. liner "Strathmore". Since that time these two systems had appeared in all the large ships recently constructed for the Australian trade, gradual improvement taking place in design as each ship came out.

The Author would like to take this opportunity of expressing his gratitude to all the superintending engineers and to the various operating engineers who had offered so much helpful criticism and suggestions in the design and operation of plants working on the new ideas now prevalent.

As Mr. Thomson remarked, the modern refrigerated ship was the result of evolution in design, but the Author would like to add that it was only due to very friendly open co-operation and entire frankness between the parties concerned that the recent developments in ships' refrigerating equipment had reached the state they had in the comparatively short time of two years.

Mr. Coombe raised one or two points of considerable interest. Firstly, concerning the question of carriage of fruit in spaces primarily designed for chilled meat it must be acknowledged that in small compartments, as were those in the average chilled meat ship, the grid system gave a very good account of itself in the carriage of fruit. There was even in such small compartments the difficulty of obtaining quick and even cooling throughout the body of the cargo.

When cooling effect was applied to stacked fruit from overhead grids there was every reason to believe that the thermometer tubes acted as downcasts for the convection currents in the same way as did the "towers" or open vertical ducts in the "tower" system mentioned by Mr. Thomson. Under such conditions there was every likelihood that the ship's thermometers recorded lower temperatures than those actually obtaining in the fruit especially during the cooling down period. This state of affairs had been proved by thermographs located in fruit boxes and by electrical thermometers placed actually inside the fruit cases where it had been shown that there was considerable difference between the ship's thermometers and the true temperature of the fruit. Moreover, it was generally found when logs were examined that the average grid cooled space showed a cooling rate indicated by the tube thermometers which was far greater than the cooling ability of the grids could possibly give if this rate applied to the whole body of the cargo.

With regard to Mr. Coombe's remarks concerning the relative merits of wet and dry brine coolers, the Author would like to say that the modern dry pipe battery was not an undersized crowded nest of inefficient pipes. Experience in recent years had shown that the modern dry pipe battery was very workable and efficient compared with the older type on which probably Mr. Coombe's remarks were based.

The Hall-Germania type of cooler was awkward to fit in shallow decks because the flow through it must be vertical. Also by reason of the slow rate of air flow the box section of these wet coolers must be much larger than that of the ordinary dry cooler.

The great advantage of the wet cooler over the dry pipe cooler was the lack of troubles due to frosting, but as remarked in the paper the dry pipe cooler had now been so much improved that troubles due to frosting had practically disappeared. In fact since the presentation of the paper the Author had visited several new ships which had brought home mixed cargoes of meat, fruit and cheese from Australia and New Zealand. In every case the engineers had reported that the batteries for meat, fruit or cheese had only been defrosted once on the voyage, that being immediately after the space had been closed after its last loading.

The system suggested by Mr. Coombe in which each wet battery had virtually its own refrigerating plant would be very costly and complicated to work.

A separate evaporator for each brine with a common expansion temperature was not a workable proposition, as the minimal density of the brine had to be such that the brine would not freeze on the expansion coils. Thus all the evaporators must have the same density brine and therefore might as well be one.

Freon gas certainly could be used for direct expansion cooling. Several banana ships had recently been equipped in the U.S.A. with plants working on this principle. The probability of employing direct expansion in ships like those for the Australian or Argentine trades was very unlikely. The control of the various temperatures and the distribution of gas in say 200 separate circuits would involve very great difficulties. The direct expansion principle might be successfully employed in plants containing a few batteries operating at practically the same temperature but further elaboration was not likely to come about.

The Author did not mention ozonising as it was considered that it came outside the scope of the paper.

In reply to Mr. Gemmell, the Author would state, as in the reply to Mr. Coombe, that Freon gas had been used successfully on direct expansion systems.

Mr. Gemmell further mentioned one point which had frequently come up in discussions dealing with the new systems described in the paper, this being the apparent inability of these systems to deal with cargo loaded in a soft condition, particularly milk lambs. The Author was of the opinion that whatever system was employed, lamb carcases when loaded soft would be easily distorted by superposed weight. The cooling effect of side grids and convection currents was so feeble that many hours must elapse before a soft carcase would be hardened by such cooling. The troubles experienced with soft carcases in the last few years had been experienced in ships equipped with grids on roof and sides. If soft carcases were loaded into a space equipped in the manner shown in Figs. 10 or 11 the engineer had at his disposal a means of cooling the bottom layers by a stream of cold air at 0° F. or lower across the floor from one suction trunk to the other. The requisite doors to effect this form of air flow were incorporated in the air duct equipment. The cooling effect of such a draught of cold air was many times greater than that obtainable from convection currents falling from side grids, and in a short pause in loading it was possible by this means to harden up soft carcases, whereas with grids the period required was likely to be many times greater.

In reply to Mr. Martin, the Author was fully aware of the development of the water vapour machine employing centrifugal compressors which was taking place in the United States. This machine was conceived many years ago by Rateau and also by Parsons and failed owing to the difficulty of constructing a centrifugal impeller wheel which would stand up against the erosive effect of water vapour and drops of water at the exceedingly high peripheral speed required.

It was also difficult to understand how a temperature of 34° F. could be obtained in an insulated space by means of any machine using water as its working fluid. To maintain a temperature of 34° F. even by means of rapid air circulation it was necessary to introduce the air at a temperature of about 32° F., which was at the freezing point of water. Mr. Martin mentioned brine at 27° F. having a vapour pressure of 3·7mm. Hg. This pressure was that of pure water at that temperature. Brine had a lower vapour pressure than water at the same temperature, this depression of pressure below that of water increasing with the density. Thus at 27° F. brine having a specific gravity of 1·2 at 60° had a vapour pressure of 3·0mm. Hg. and that of 1·25 specific gravity a vapour pressure of 2·6mm. Hg. Unless coolers employing direct contact of brine and air were used it would not be safe to reckon on brine at less than 20° F. to effect a cooling to 34° F. This brine must have a density of 1·1 at least and any engineer would run this at 1·2, viz. 40° Twaddell. Mr. Martin's pressure ratios, therefore, were on the low side for such a compressor.

Concerning the figures given by Mr. Martin for the 1,000,000 B.Th.U.'s per hour plant cooling water at 38° F. with condensing water at 75° F. the power consumption of a CO_2 plant for this duty would be 98 b.h.p. against 104 mentioned by Mr. Martin—in other words, for all practical purposes the two power consumptions were the same.

As regards steam consumption of the latest ejector machines, the Author was in possession of one figure given by a high authority in the use of these machines, which showed that a plant capable of giving 2,000,000 B.Th.U.'s per hour cooling water to 46° F. with water for the condenser at 80° F. required 4,400lb. per hour of steam at 160lb. per square inch. A CO_2 plant for the same working conditions would require 195 b.h.p. on the compressor. Given a good compound condensing steam engine consuming 21lb. of steam per b.h.p./hour the steam consumption worked out at 4,200lb. per hour.

To both plants must be added the power taken to drive the condensing water pumps which for the water vapour machine was considerably greater than that for the CO_2 machine, as also was the power required for the cold water circulating pumps by reason of the high vacuum from which they had to extract the water.

In reply to Mr. MacVicar, the Author would state that the figures given for the flow of air above, below and through the fruit stack were the results of calculations based on data obtained from the experimental hold at Ditton. The assumption as Mr. MacVicar suggested was that the flow of air was laminar.

The Author had never himself taken velocity measurements in a ship with 'thwartship flow when loaded with cargo but had done so on two occasions in spaces equipped with gyratory flow round an insulated hatch trunk. In these cases air speeds up to 800ft. per minute were recorded in an air space of 10in. between the top fruit boxes and the ceiling, which accounted for approximately 60 per cent. of the total air in circulation. As well as the space between the boxes and the ceiling in which the measurements were taken, there were inaccessible spaces below and on each side of the cargo. There was no doubt that the internal movement of air amongst the boxes must be greater than that which the calculations indicated, but this movement was mostly due to induced and convection currents.

In reply to Mr. Hampshire, the Author would state that in nearly all cases where propeller fans were fitted they were made reversible. The reversibility was not of much use for the carriage of meat when the flow was vertical, but was of considerable effect when the flow was horizontal. For the carriage of fruit it was always of help to have reversible flow in any system.

In several ships which had arrived home with fruit since the time the paper was delivered, it had been found that hot pockets which tended to appear in the fruit during the early stages of carriage could be levelled up by reversing the circulation.

First Official Visit of The Institute to Swansea.

A Meeting, arranged by a Committee of Members in the Swansea district under the auspices of The Institute Council, was held at the Mackworth Hotel, Swansea on Friday, March 6th, 1936 at 6 p.m., when a paper was read by Engineer Rear-Admiral W. M. Whayman, C.B., C.B.E., Vice-President, entitled "The Coal Fired Marine Boiler". The chair was occupied by Mr. T. R. Thomas, B.Sc., Chairman of Council. There was a large attendance of South Wales Members, and in addition to the Chairman and Admiral Whayman, the Council was represented by Messrs. S. N. Kent (Past-Chairman), Major E. W. B. Kidby, O.B.E., R.E. (ret.), Vice-President, G. Thompson, M.Eng., A. F. C. Timpson, M.B.E. and the Secretary.

The paper and discussion are subjoined.

Dinner at the Mackworth Hotel.

After the meeting a Dinner was held in the Hotel at 8 p.m., at which the Chairman of Council, Mr. T. R. Thomas, presided, supported by his Worship the Mayor of Swansea, Councillor A. R. Ball, J.P., the Deputy Mayor, Councillor William Dewitt, Alderman W. J. Davies, J.P., Sir Arthur Whitten-Brown, the pioneer Atlantic airman, Mr. Herbert W. Morgan, G.W.R. Docks Manager, Swansea, Mr. F. C. Mullens, Chairman of the Bristol Channel Ship Repairers' Association, Mr. W. L. Kelleher, J.P., President of the Swansea Chamber of Commerce, Mr. D. E. Cameron, Chairman of the South Wales Branch of The Institution of Mechanical Engineers, Captain R. B. Fisher, and other prominent representatives of the civic life of Swansea.

The toast of "The King" was proposed by the Chairman and enthusiastically honoured.

Mr. D. E. Cameron, proposing the toast of "The Institute of Marine Engineers", paid a tribute to our distinguished President, Mr. Maurice E. Denny, and the Chairman, Mr. T. R. Thomas. He also complimented Swansea upon having at the head of their Municipal Technical College Principal George Thompson, whose qualifications he described as unique.

Replying, the Chairman said that he was very glad to be presiding on the occasion of the first meeting of The Institute outside London. He thought it was most appropriate that the Council should come to South Wales, which was the place where marine engineering was "taught to walk", the first steamship to make a return crossing of the Atlantic having left the Bristol Channel just under 100 years ago. He hoped that their visit would stimulate interest locally among marine engineers and result in their enrolling as members of The Institute. It was only by improving the status of The Institute that marine engineers would improve their own status and prestige.

The toast of "The County Borough of Swansea" was proposed by Engineer Rear-Admiral W. M. Whayman. He complimented the borough on the erection of the up-to-date power station at Tir John, and expressed the hope that the visit of The Institute would explain to them to some extent what the marine engineer was trying to do for South Wales. (Applause).

The Mayor, Councillor A. R. Ball, responding, said that at Tir John they were turning anthracite

Some of the Members who attended the Meeting and Dinner at Swansea.

duff, hitherto a waste product, into something of commercial value by pulverisation, and visualised the day when this class of fuel would be sent abroad and thus assist the port's export trade.

"The Royal Merchant Navy" was proposed by Major E. W. B. Kidby, O.B.E., R.E., Vice-President, who paid a tribute to the magnificent services of the Merchant Navy to the Empire.

Principal George Thompson, who proposed the toast of "Our Guests", said that he had suggested the visit of The Institute Council to Swansea, and had recommended that they should make regular visits to the Provinces. Their stay in Swansea should make the townspeople appreciate The Institute, and The Institute appreciate Swansea. Mr. F. C. Mullens responded.

Musical entertainment was provided by Miss Cora Lockman, contralto; Mr. Bert Chapple and Party; and the Rhythm Three Orchestra.

The toastmaster was Mr. P. I. Chambers.

Visit to the National Oil Refineries, Llandarcy.

On the following morning, Saturday, March 7th, the visitors made a tour of inspection of the National Oil Refineries at Llandarcy, by courtesy of the Directors. The party was received by Mr. Thornton, the Chief Chemist, in the absence of Mr. W. C. Mitchell, General Manager. Mr. Thornton's instructive preliminary talk and the subsequent tour of the Refineries were highly appreciated by the party, whose only regret was that the short time available did not permit of a more thorough inspection of such an interesting plant and organisation.

Civic Reception and Luncheon at The Guildhall.

From the Refineries the visitors proceeded to the Guildhall, where they were received at 12.30 p.m. by the Mayor, Councillor A. R. Ball, J.P., and entertained at luncheon, after an inspection of the magnificent building. Outstanding among its artistic decorations the famous Brangwyn panels which surround the Great Hall were particularly admired.

At the conclusion of the luncheon a cordial interchange of sentiments took place in speeches by the Mayor, who proposed the toast of "The Institute of Marine Engineers" and Mr. T. R. Thomas, Chairman of Council, who, in responding, expressed the visitors' admiration of the progressive civic spirit represented by that splendid edifice the new Guildhall, and their warm appreciation of his Worship's hospitality.

The London party left Swansea by the 2 p.m. train for Paddington, with happy memories of a thoroughly successful visit, for which special credit is due to Major Kidby, Principal Thompson, Mr. M. W. Henderson, the indefatigable Honorary Secretary, and their fellow members of the local Committee.

The Coal-fired Marine Boiler.

READ

By Engineer Rear-Admiral W. M. WHAYMAN, C.B., C.B.E., (Vice-President).

On Friday, March 6th, 1936, at 6 p.m. at the Mackworth Hotel, Swansea.

Chairman: Mr. T. R. Thomas, B.Sc. (Chairman of Council).

Synopsis.

THE progress made in the past ten years in the direction of the more scientific utilisation of coal for marine propulsion purposes is reviewed. The mechanical stoker applied to the water-tube boiler receives detailed treatment, and it is suggested that if steam propulsion is to continue, the water-tube boiler should be adopted. Improvements in the design of stoker grate parts and the methods and control of the air supply are recorded, while improved methods of firing—both hand and mechanical—of cylindrical as well as water-tube boilers are discussed. It is shown that the mechanical stoker in association with the cylindrical boiler at sea is not yet a success on account of initial cost and upkeep expenses, but the Author points out that there are improvements such as special firebars which are giving satisfactory results. He concludes that if coal is to compete successfully with oil, close co-operation between the coalowner, shipbuilder and shipowner is essential.

When asked to prepare a paper for this meeting it seemed to the Author to be fully appropriate that as a Member of The Institute of Marine Engineers he should choose a marine subject and that owing to the location of this meeting those attending would be interested to hear some comments on the use of coal afloat. Hence the title of this paper.

When the Author commenced his service in the marine world by joining H.M. Navy just fifty years ago this year for service as an engineer officer, coal was the only fuel used afloat, and possibly there are many, especially in South Wales, who would welcome a return to similar conditions; doubtless all Britain would welcome such monopoly for coal if it could be achieved in fair competition with other sources of power supply and without hindrance to general improvement in economic conditions.

When all has been said and done it will still always be the case of the survival of the fittest and the source of power chosen will be that which gives the result most reliably and effectively, at least running cost and at fair and competitive first cost.

The Author has spent the past nine years in close association with the use of the marine steam boiler in the Merchant Navy, principally the water-tube boiler using both solid and liquid fuels and various methods of burning the same.

Some eight years ago the Author was associated with a small but influential Committee which included such eminent individuals as the late Sir Charles Parsons, Sir John Biles, the present Lord Weir and representatives of the coal industry, for the purpose of promoting the use of coal afloat in the form of powdered fuel. A machinery design proposal for a modern tramp steamer with turbine propelling machinery and water-tube boilers burning pulverised coal and working at 550lb. pressure with superheated steam was submitted for the consideration of two influential shipowning companies, but never reached the building stage. This was in 1928.

The pioneer in the use of coal in pulverised form afloat will probably go down to history as the United States collier "Mercer" which made her first voyage across the Atlantic to this country in 1927. The ship was thrown open to inspection at Rotterdam and the system shown and explained by Mr. Carl Jefferson, of the United States Shipping Board, who had superintended the experimental work and installation and continued to assist in the progress of pulverised fuel afloat for many years.

The system was tried in many English and foreign vessels and although it is still in use in a few vessels it has not yet been able to establish itself in competition with other methods of burning solid fuel, either by hand or mechanical stokers.

Both methods, i.e. either by pulverising the coal by plant on board ready for use as required, or pulverising the coal on shore and shipping the fuel into bunkers as powdered coal, have been tried, but it is considered to be true to say to-day that the initial cost, weight and space required for an installation to use pulverised fuel afloat makes it economically impossible—and the Author can see no prospect of this method of fuel firing being introduced afloat in the near future.

Undoubtedly the use of pulverised coal is extending in large power stations on shore, where the limitations on weight and space placed on marine installations do not apply and where suitable coal is available at a competitive price, but the mechanical stoker is more extensively used.

Until within the last few years coal afloat has been hand-fired to the boilers, generally of the Scotch or cylindrical type, into the completely water-cooled circular furnaces with fire grates of almost standard type and with perhaps little incentive to improve combustion results with the South Wales bunker coals which had established their pre-eminence in the market in pre-War days. With the large-size coal available, easily burnt, with little ash and high calorific value and average draught, and the absence of competitive fuels, the comparatively low-priced Welsh coal had the market to itself.

The introduction of the internal combustion engine altered the outlook to the extent that a very serious rival to coal as a source of power supply had arrived, and the situation to-day as regards the use of coal is precarious unless shipowners can be offered improved steam propelling plant using coal as fuel such as will be attractive to them in respect of first cost, weight and space and will provide durability and reliability for the life of the ship and economic advantage in fuel and running costs.

There is also another very important aspect of the situation and that is the alternative now offered to the shipowner to use oil as fuel for raising steam in the vessel's boilers, and although it is not intended in this paper to discuss the change that has come about in the choice of fuel to be used, it is important to realise that the present tendency is for the price of boiler fuel oil to fall and the price of coal for bunkers to rise, certainly in this country and generally throughout the world. It is not desired to provoke discussion on this aspect of the fuel question, but it is desired to emphasize the importance of this fact on the choice of propelling machinery for ships and the continuance of the use of coal for power supply afloat.

Since retiring from H.M. Navy and entering commercial life the Author has been endeavouring to exploit the advantages of the water-tube boiler in comparison with the cylindrical or Scotch type and as the years roll on there seems to be accumulating experience that if steam propulsion is to continue the water-tube boiler should be adopted.

With steam propelling machinery there is the choice in the use of either solid or liquid fuel at will and as may be most suitable for the vessel's particular service and the shipowner's pocket, but this advantage in choice of fuel and the ability to use either kind as availability and price of fuel demand, although most efficacious in controlling the price of fuels, is not alone sufficient to induce the shipowner to choose steam propelling machinery. The steam plant must be such that for a given type of vessel and trade it will show economic advantage in the shipowner's balance sheet of first cost, depreciation, maintenance and running costs for repairs, fuel and staff.

It was therefore considered that it would be interesting in this paper to review some of the changes and progress that have been made in the last ten years in the direction of the more scientific utilisation of coal for marine propulsion purposes.

It is proposed to undertake this review under two main headings, viz. :—

(*a*) The water-tube boiler and the mechanical stoker, and

(*b*) Cylindrical and water-tube boilers and improved methods of firing, both hand and mechanical.

(A) The Water-tube Boiler and Mechanical Stoker.

As long ago as 1919 the use of the retort type of mechanical stoker was tried in association with the Babcock & Wilcox water-tube boiler by the Royal Packet Navigation Co. of Holland, and subsequently adopted and used in some 40 vessels

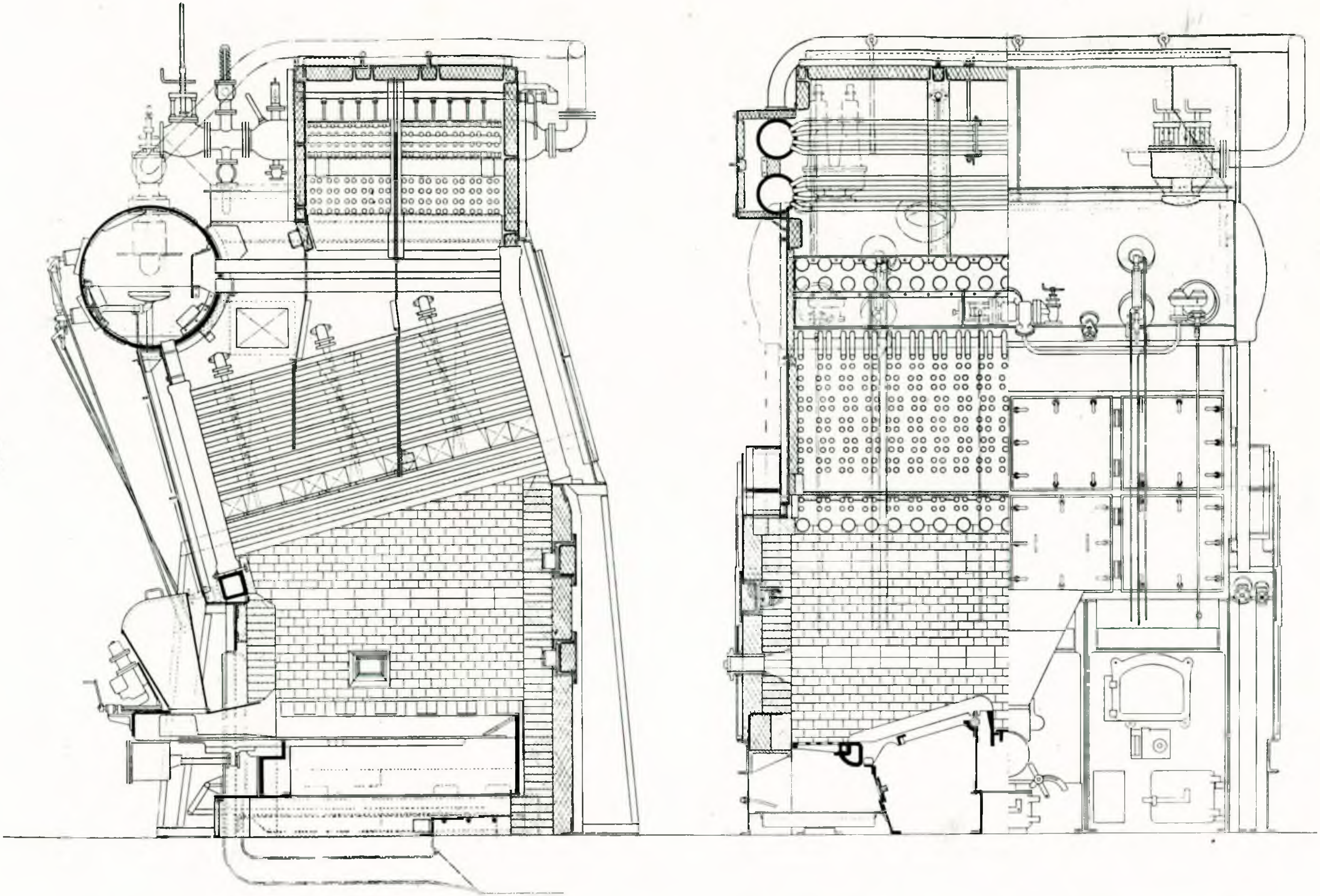


Fig. 1.—Typical boiler with mechanical stoker as used in vessels of the Royal Packet Navigation Co. of Holland for their Dutch East Indies service.

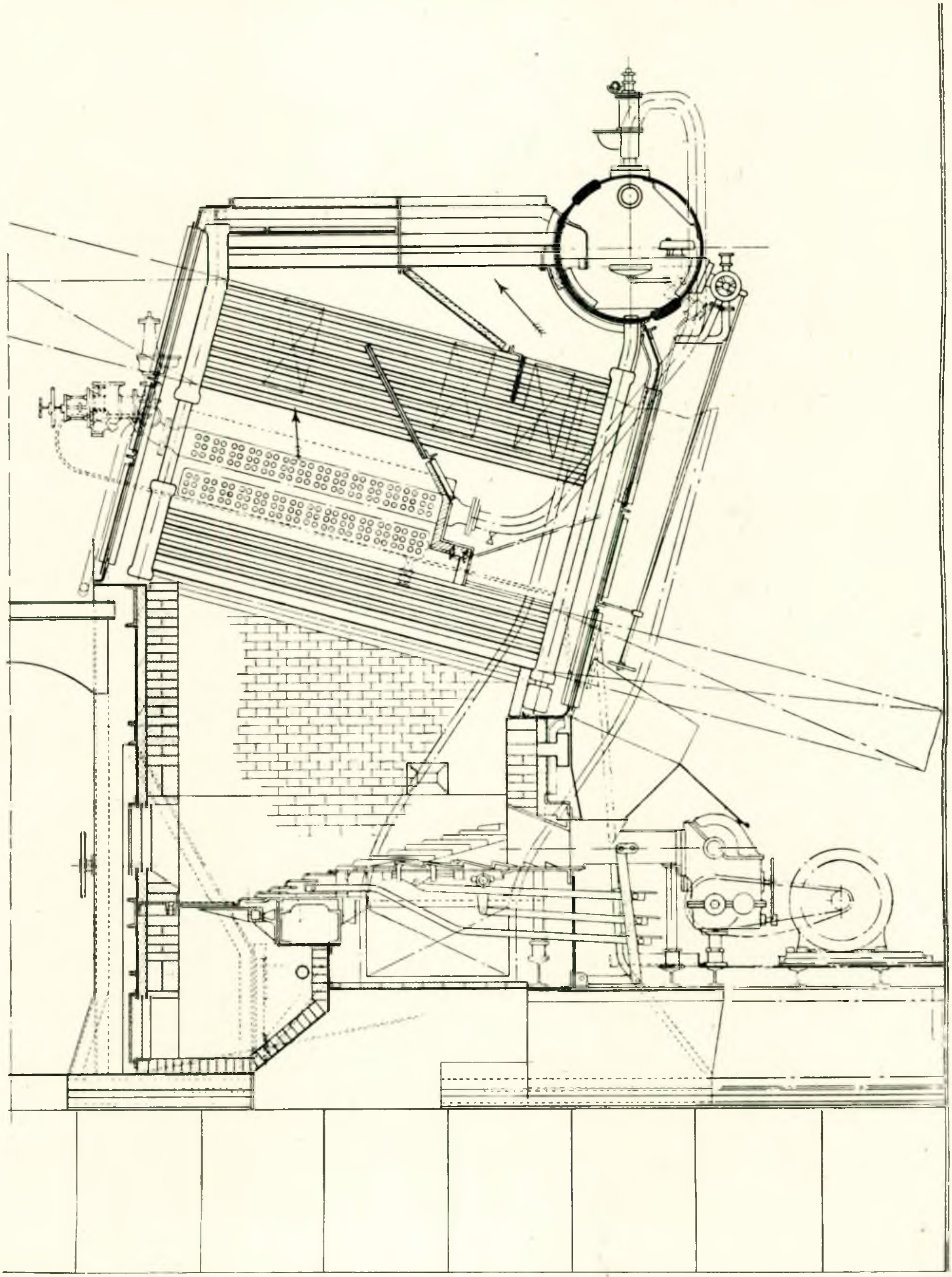


Fig. 2.—Boiler with Erith-Roe stoker in the "Beaverbrae".

in that Company's fleet trading in the Dutch East Indies, where the Company own coal mines producing a class of coal which can be used more effectively with a mechanical grate than with hand firing.

The use of the mechanical stoker afloat is not new therefore, but it is practically only within the last ten years that it has been adopted to any extent in this country.

Fig. 1 shows a typical two boiler installation (s.s. "Van Swoll") as an illustration of the early use of the retort-type stoker. The heating surface of the two boilers is 4,986 sq. ft., the superheating surface 1,496 sq. ft., the working pressure 206lb. per sq. inch, and the final steam temperature 570° F.

The first important use of the water-tube boiler and the mechanical stoker in this country was in the Beaver class cargo ships of the Canadian Steamship Co. built for a fast cargo service between this country, Europe and the Canadian ports. There were five ships in the class and they came into service in 1927 and 1928 so that they have now been in actual service for about seven years. Steam turbines are used as propelling machinery and the service results are known to be very satisfactory. Three ships of the class are fitted with Yarrow boilers and Erith-Roe stokers, and the other two ships have Babcock & Wilcox boilers, one ship being fitted with the Erith-Roe stoker and the other with the Taylor stoker. The two last mentioned ships, the "Beaverbrae" and "Beaver-

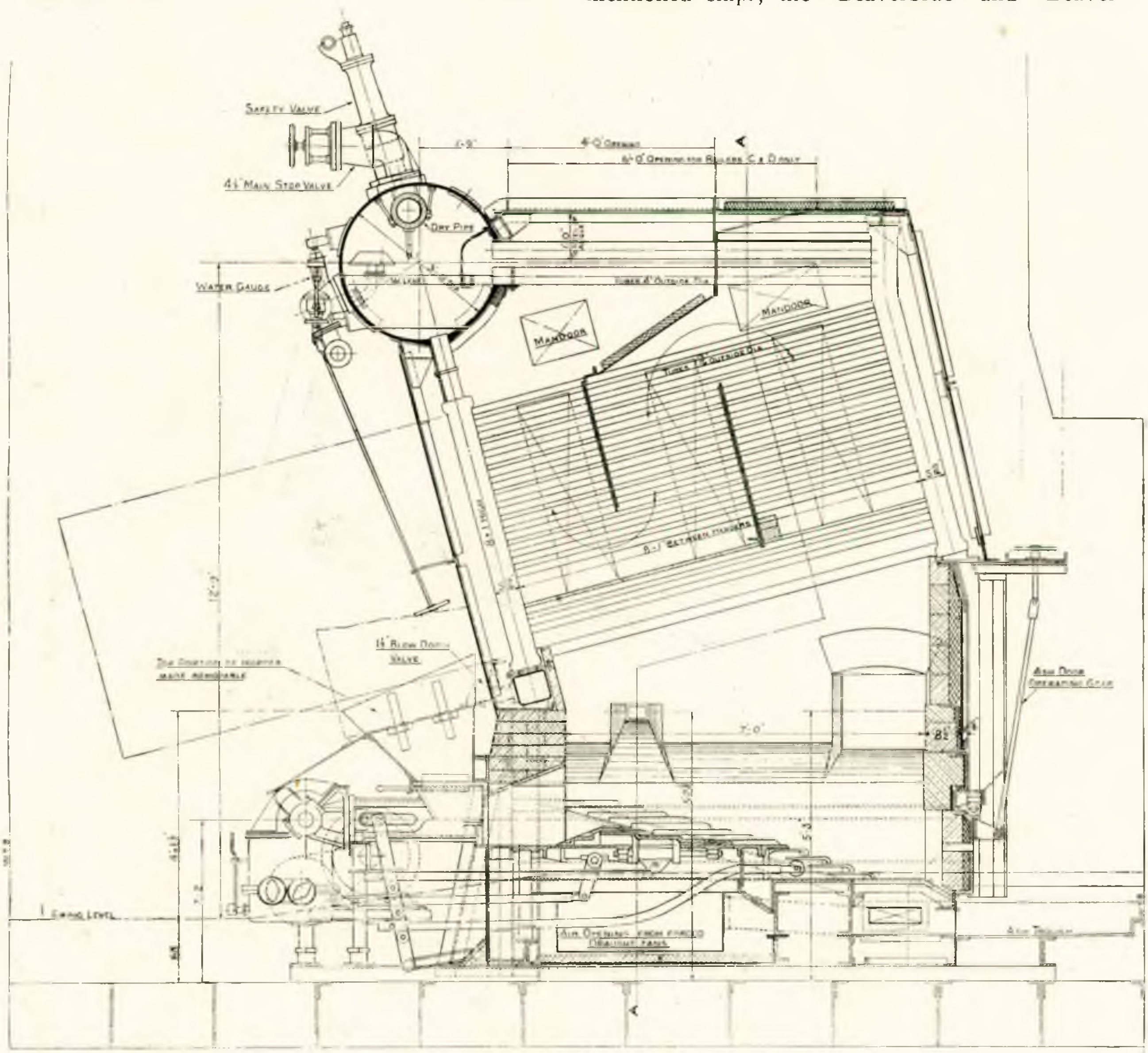


Fig. 3.—Cross sectional view of boiler with mechanical stoker in "Duke of Lancaster".

hill", were originally hand-fired, but when the success of the mechanical stokers in the other ships equipped with the Yarrow boilers was established conversion to mechanical stokers was adopted in these two cases also.

Fig. 2 shows the installation in the "Beaverbrae".

Recent outstanding interest however in the use of the mechanical stokers afloat has been directed to the cross-Channel steamers of the L.M.S. Railway Co. for their Heysham-Belfast service, three ships of the "Duke of Lancaster" class. These vessels, which were put into service in 1928, have twin-screw turbine-driven machinery with Babcock & Wilcox water-tube boilers and were originally using hand-fired coal as fuel. Each vessel has six boilers with a total boiler heating surface of 19,770 sq. ft. and 600 sq. ft. grate area.

In the latter half of 1931, after all three vessels had done considerable service using steam coal under hand-fired conditions, and following a full enquiry into all the attendant factors by the responsible official, it was considered that there were substantial reasons for anticipating the realisation of satisfactory economies by a conversion to a mechanical firing device capable of burning low-grade fuels; hence it was decided to experiment in the first instance with the conversion of the two forward boilers of the "Duke of Lancaster" to the Erith-Roe retort-type stoker. It will be appreciated that a vessel already built was not the most suitable choice for a trial of a new type of improved firing as the stokers had to be adapted to the limited space available, and alterations in air supply to the stoker grates presented special difficulties.

It took some time to get through what may be called the teething troubles of the new installation, and to determine the best method of using the two mechanically-fired boilers in association with two, three or four of the other hand-fired boilers as the steam requirements demanded. Time and experi-

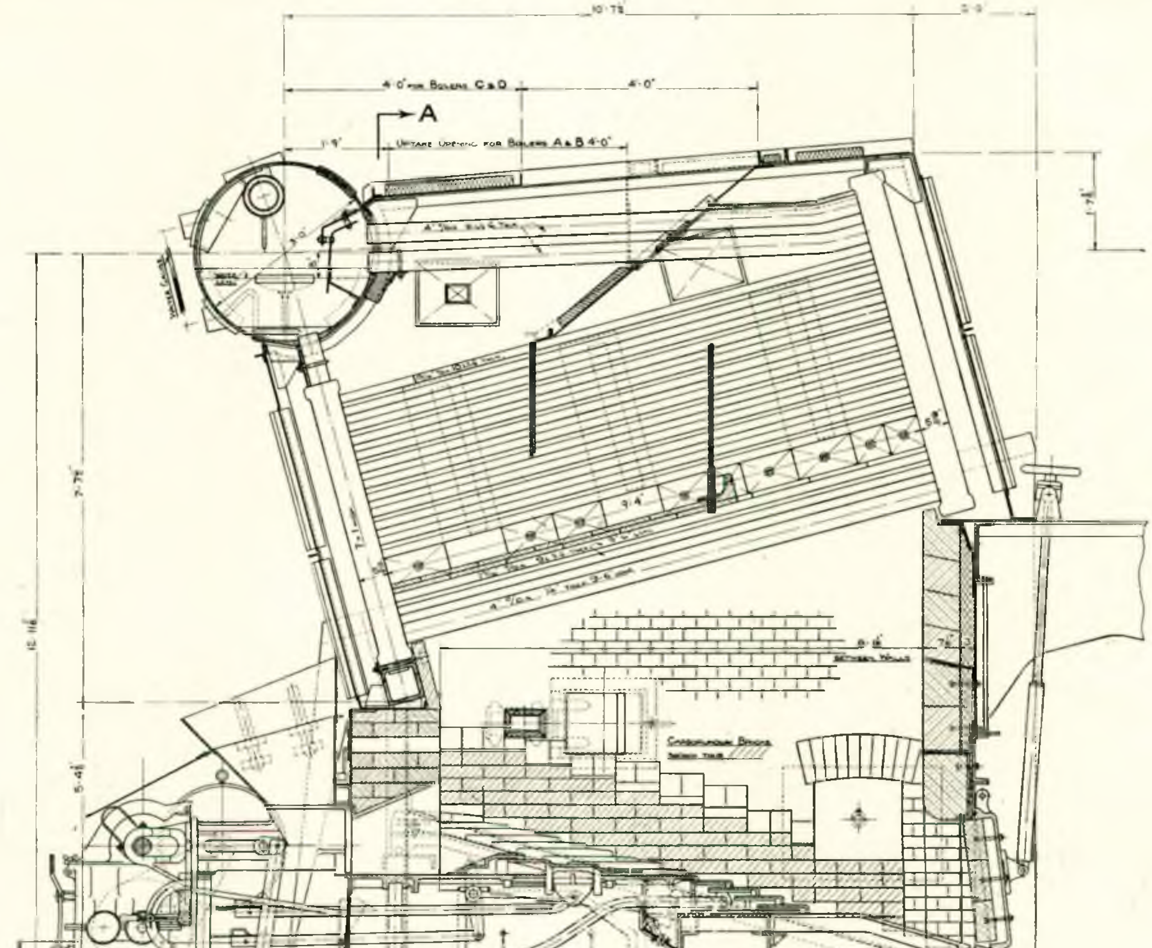


FIG. 4.—Cross section of boiler and stoker in "Princess Maud".

ence, however, demonstrated that the two mechanically-fired boilers had fulfilled expectations from an economical standpoint, for trials extending over a considerable period showed that low-grade fuels covering a wide range could be efficiently utilised.

The more efficient operation of the two forward boilers, consequent on the conversion, permitted the steam output of these boilers to be increased beyond the originally designed normal output, thus allowing the hand-fired boilers in use to give more efficient results at a reduced rating and even in their case to use an inferior quality coal without detriment to the service of the vessel. It will, therefore, be recognised that two principal advantages are secured by the use of a mechanically-fired grate over that of the hand-fired design, i.e., increased evaporative rating and ability to burn fuel of a lower grade and less costly variety; the increase in evaporative capacity per unit is approximately 30 per cent., the calorific value of the fuels used being of the order of 13,500 B.T.U.'s.

Another advantage obtained with the mechanical stoker is the absence of smoke emission usually associated with hand firing, except at low boiler ratings. There was, however, some emission of grit at the higher ratings of the boilers it was desired to use in the "Duke of Lancaster", but this has been successfully eliminated by the fitting of grit arresters in the boiler uptakes. Fig. 3 shows one of the two forward boilers of the T.S.S. "Duke of Lancaster" and gives details of the mechanical stoker.

The Erith-Roe design, which with its slicing bars is peculiarly suited to controlling the combustion on the short grate which obtains in marine practice, will successfully burn all types of bunker coal varying from South Wales slacks to coals of high volatile content. Naturally, being of the retorting type, i.e., distillation of volatiles forming part of its chain of functioning, it is not suitable for anthracites or for near-anthracites, that is, coal of say less than 15 per cent. total volatile.

Early in 1933 the L.M.S. Railway Co. placed an order for a new steamer, the "Princess Maud", for the Stranraer-Larne route, and as a result of the experience gained with the mechanical stokers in the "Duke of Lancaster" that Company was encouraged to equip the new vessel's boilers with the same type of mechanical stoker, i.e., the Erith-Roe. The boiler section of the machinery installation closely follows the installation fitted aboard the "Princess Margaret" built some two years previously, with the exception that the new ship is fitted with mechanical stokers instead of hand firing. The four boilers are arranged in pairs, back to back, in a single boiler room, with a total tube heating surface of 15,400 sq. ft.

Fig. 4 shows the arrangement of the boilers in the ship with the mechanical stokers.

The boilers were designed to give 95,000 lb. of steam per hour, converting feed water at 180° F. into saturated steam at 225lb. pressure, under normal service conditions, with coal of 11,500 B.T.U's. per lb. calorific value. Each boiler has an eight-retort stoker arranged with rear-ashing doors. The total grate area is 448 sq. ft. and the total combustion chamber volume 2,400 cubic ft. The closed-stokehold system of air supply for ventilation and for air for combustion is used, and in this vessel the coal is man-handled from the athwartship bunkers into the coal hoppers. Steam control is regulated with the same ease and certainty as with an oil-fired boiler and with the same degree of flexibility in a clean and dust-free stokehold. The coal used is an Ayrshire slack and service conditions have been regularly maintained with three boilers out of four in use.

The "Princess Maud" commenced service early in 1934 and about the middle of that year the L.M.S. Railway Co. decided to order another vessel for the Heysham-Belfast service to run in conjunction with the three vessels of the "Duke" class.

With the continued experience in the "Duke of Lancaster" and the "Princess Maud" this new vessel was designed to give sensibly equivalent performance on service to the three early ships of the "Duke" class, with four water-tube boilers instead of six, the new ship being of practically the same tonnage and speed. Each of the four boilers, however, was fitted with a seven-retort Erith-Roe stoker operated under the closed-stokehold system of air supply as in the earlier vessels.

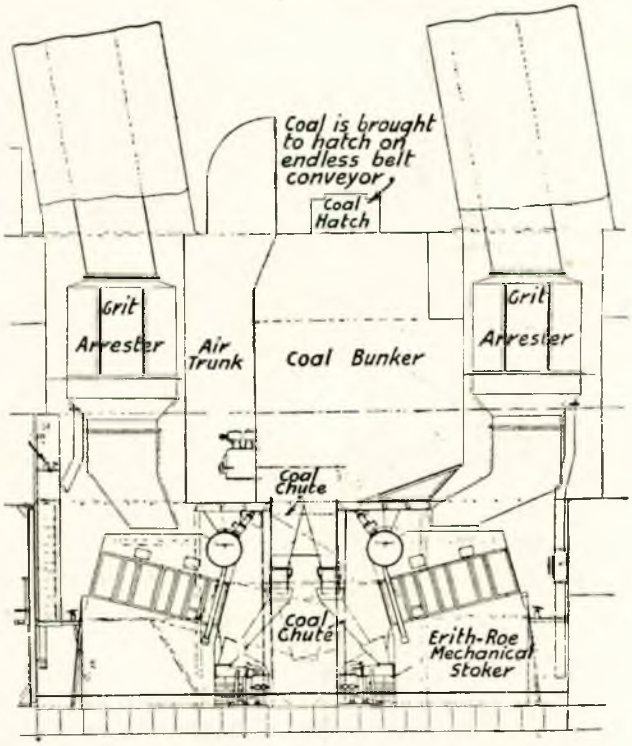


Fig. 5.—Fore and aft section showing arrangement of boilers, stokers and self-feeding hoppers and bunkers in the "Duke of York".

The boilers were designed to produce under service conditions 120,000lb. of steam per hour at 225lb. pressure per sq. in. from feed water at 215° F. using a slack coal of 12,500 B.T.U.'s value. As is usual in vessels of this class with very limited boiler room space and head room, no superheaters are fitted, saturated steam being used.

A further distinct advance was made in this ship by arranging the position of the bunkers in the ship so that the coal is self-trimming into the stoker hoppers. In this vessel, therefore, using coal as fuel we have the whole boiler room operation performed mechanically as in an oil-fired ship, and it is not an exaggeration to say with the same degree of flexibility and cleanliness as in an oil-fired ship. Incidentally it may be mentioned, as a matter of interest, that mechanical coaling plant is used at Heysham for bunkering the "Duke" class

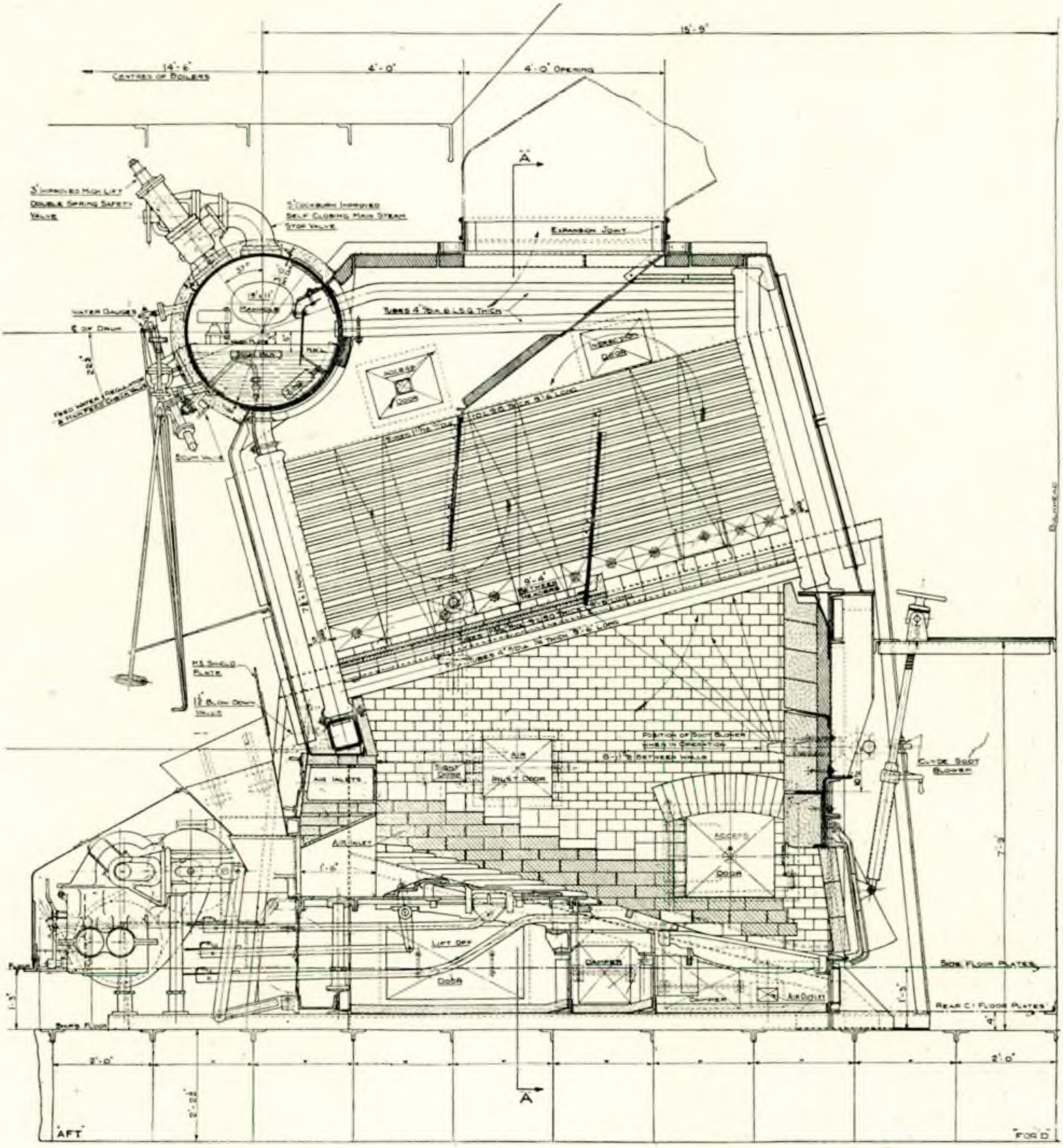


Fig. 5a.

steamers. Fig. 5 shows the arrangement of boilers and mechanical stokers and the coal supply from the bunkers to the stoker hoppers.

The mechanical stoker equipment of the boilers in the "Duke of York", though essentially the same in principle as in the earlier ships, has an improved method of air supply to the stoker grate and fuel bed. In the early installations the air supply to the retort portion of the grate was fed to the front and rear ends of the retort through one supply and damper control between the air boxes under each portion of the grate. It has been found beneficial to arrange for entirely separate and individual control to these two portions of the retort section of the grate. This improvement and difference in design of air control can be seen by reference to Figs. 3 and 5A showing the section through mechanical grate in the "Duke of Lancaster" and "Duke of York" respectively.

At the same time as this alteration was made, the design of grate parts at the rear end of the retort portion and the dump bars at the rear end of the grate has been improved in order to ensure improvement in air supply and durability of the grate parts.

At the end of last year, 1935, Erith-Roe mechanical stokers were fitted to the two forward boilers in each of the remaining ships of this class of steamer, viz. the "Duke of Rothesay" and the "Duke of Argyll", and both these ships are now again in service, working under the same conditions as described in the case of the "Duke of Lancaster".

Sufficient experience has already been obtained to show that the fitting of mechanical stokers is an economical proposition and that continued progress on these lines will enlarge the prospects of

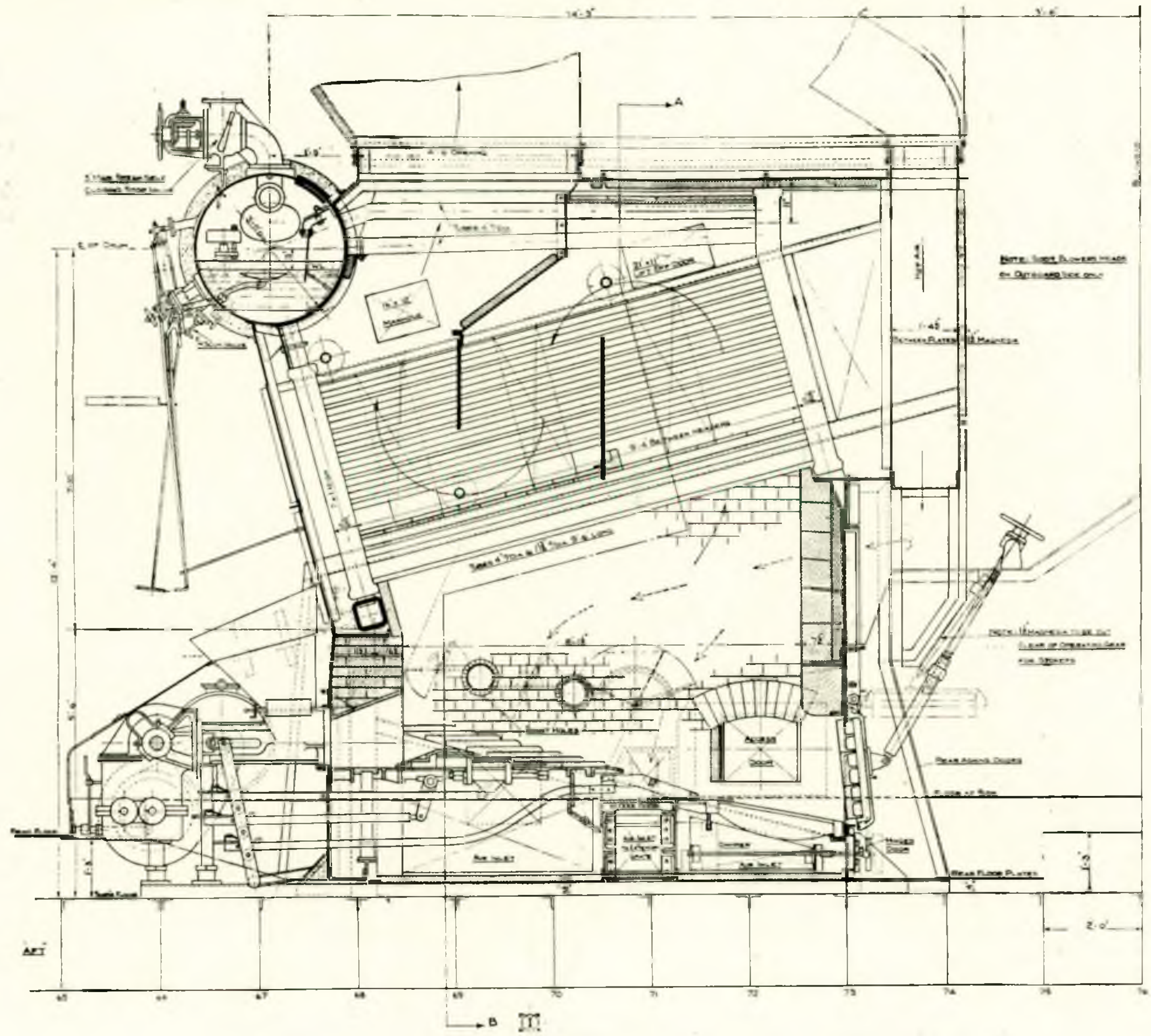


FIG. 6.—Side section of one boiler and stoker in "Great Western".

steam propelling machinery, for with geared turbine installations, boilers and auxiliaries and combustion conditions of continually improving design, and with coal of suitable description at a fair price, steam propulsion should be more than able to hold its own in a number of steamship services, as against the use of oil as the source of power.

There is corroborative evidence of this in the adoption of the use of coal for steam propulsion in the s.s. "Great Western", built by Messrs. Cammell Laird & Co., Ltd., for the G.W. Railway Co.'s Fishguard-Waterford service, the Channel train ferry steamers for the Southern Railway and the s.s. "Shuntien" for passenger and cargo service on the China Station.

The "Great Western" was ordered by the G.W. Railway Co. in 1933 and ran sea trials in January, 1934, and since then has been in service continually, with the exception of the annual periods for Board of Trade survey. When first contemplated it is believed it was intended to use oil as fuel for this vessel, but the G.W. Railway Co. decided that the vessel should be a coal burner rather than an oil burner, with a view to giving impetus to coal as fuel. In May, 1935, the G.W. Railway Co. invited to Fishguard a representative party of gentlemen interested in ships and coal to witness a demonstration of the vessel and the facilities for bunkering the ship which have been developed by the Railway Company.

The boiler plant of the vessel consists of two Babcock & Wilcox water-tube boilers designed to supply 26,000lb. of saturated steam at 200lb. per sq. in. from feed water at 220° F. when using a South Wales coal of about 14,500 B.T.U.'s calorific value. In this vessel air pre-heaters are fitted to improve the overall efficiency. The two boilers have a total tube heating surface of 5,280 sq. ft. and a total air heating surface of 2,240 sq. ft.

An overall boiler efficiency of 80 per cent. is obtained on service, and with this installation, as in those previously described, it was demonstrated that a variety of small coals can be used with the mechanical stoker, but the volatile content should not fall below 15 per cent. and the coal must have a slight caking tendency.

A washed, graded coal of peas and beans size is used, with an ash content of 5 to 6 per cent., volatile 16 to 18 per cent., and a gross calorific value as fired of 14,300/14,500 B.T.U.'s. The fusion point of the ash is over 1,400° C. and it is important that this figure should be high in order to avoid damage to the stoker grate parts which occurs with a low fusion point ash.

Fig. 6 is a side section of one of the Babcock & Wilcox marine type water-tube boilers and the

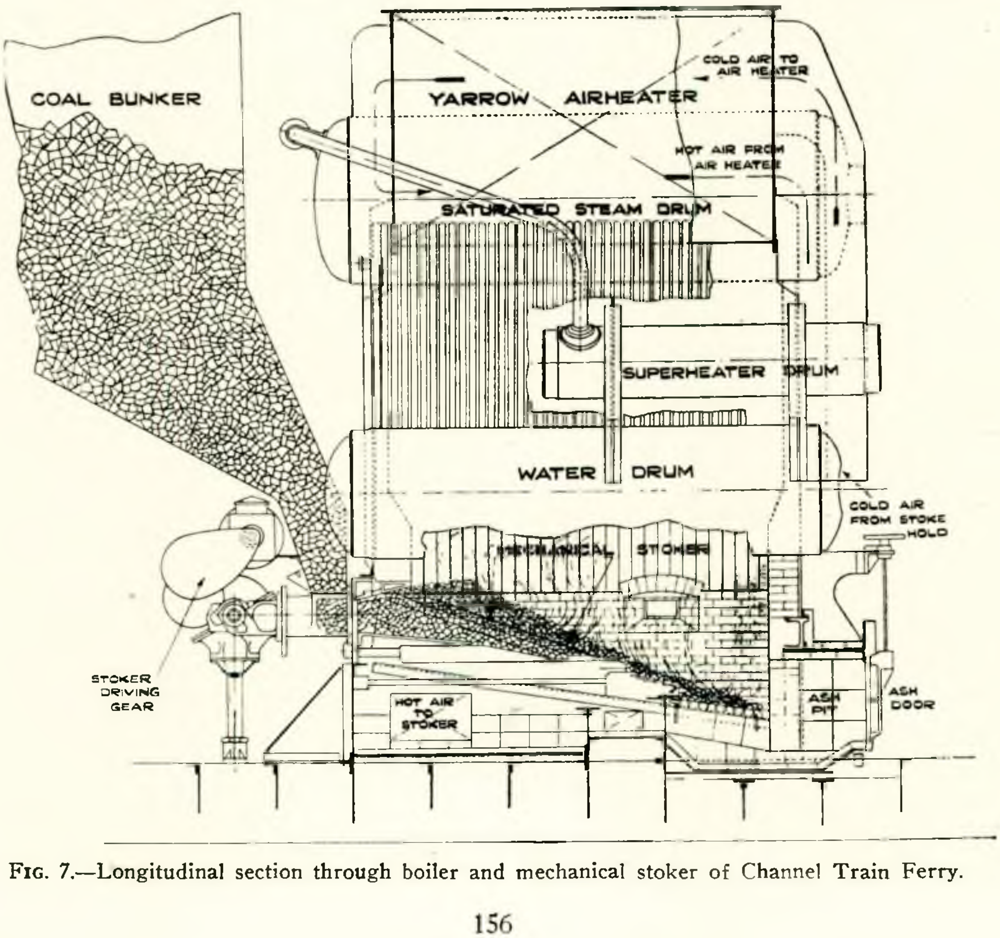


Fig. 7.—Longitudinal section through boiler and mechanical stoker of Channel Train Ferry.

Erith-Roe type retort stoker. The air pre-heater is not shown, but the supply of combustion air from the heater and the discharge of gases to the heater are well indicated.

This vessel has now been more than two years in service, and the Author is informed that the propelling installation generally gives really satisfactory results to the Railway Company.

The three Channel train ferry steamers, which are equipped with mechanically-fired water-tube boilers, have all been built and delivered to the Southern Railway Co. at Dover, and are now awaiting the necessary harbour facilities to be completed. It is understood that it is hoped to commence running a through service of trains with these vessels between London and the Continent this year.

The vessels and their machinery were fully described by Sir Westcott Abell in his paper read at the last Spring meeting of the Institution of Naval Architects, from which paper the following few comments have been gleaned.

Many different types of propulsion were investigated, the choice being governed principally by consideration of (1) the weight of machinery, (2) the first cost, and (3) the cost of operation. Steam turbines and water-tube boilers, using coal as fuel with automatic stokers and with mechanical gear in preference to electric drive were finally chosen. In the interests of coal economy, it was decided further to fit the water-tube boilers with air heaters and to use the closed-stokehold system. Only a moderate degree of superheat was provided, principally because it was desired to make the propulsion system as simple as possible. Steam is generated by four Yarrow boilers with small superheaters designed to give 100° F. superheat. The mechanical stokers were by the Taylor Stoker Co. and the bunkers arranged to be self-trimming. The installation of machinery and the general arrangements of the machinery and the auxiliaries was carried out by Messrs. Swan, Hunter & Wigham Richardson, Ltd. The trial results were very satisfactory, the overall boiler efficiency being estimated to be about 87 per cent. on the gross heat value of the fuel. The trials of the first vessel,

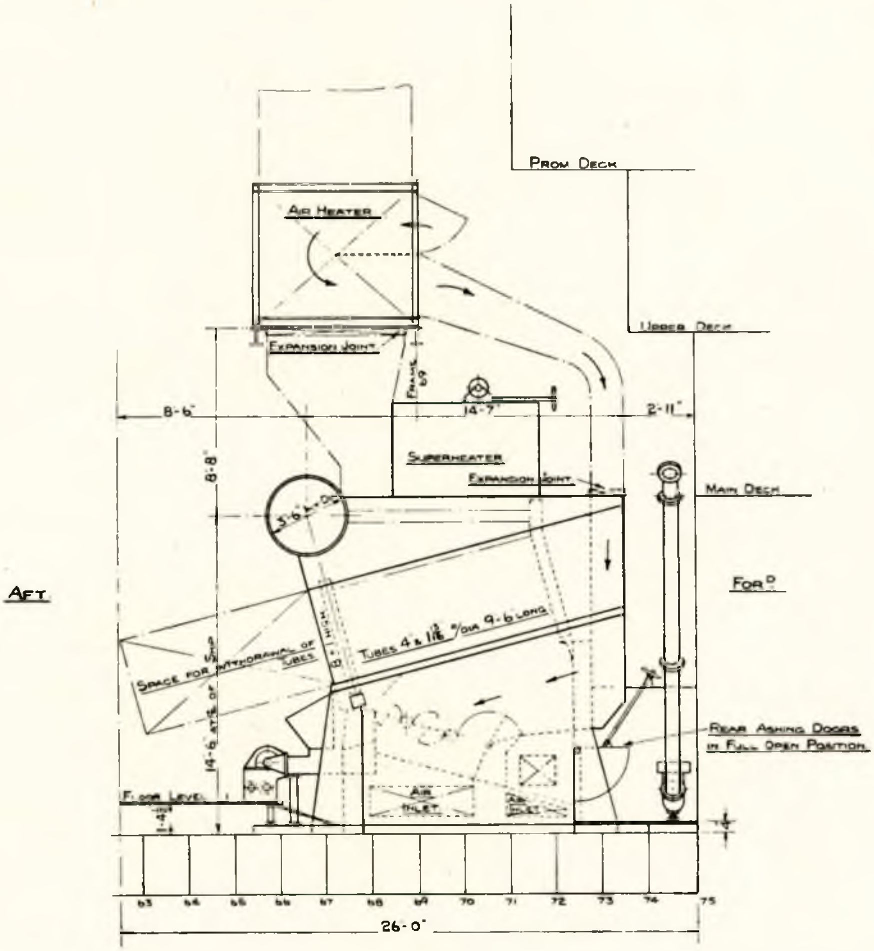


Fig. 8.—Cross section showing boiler, superheater, air heater and mechanical stoker in "Shuntien".

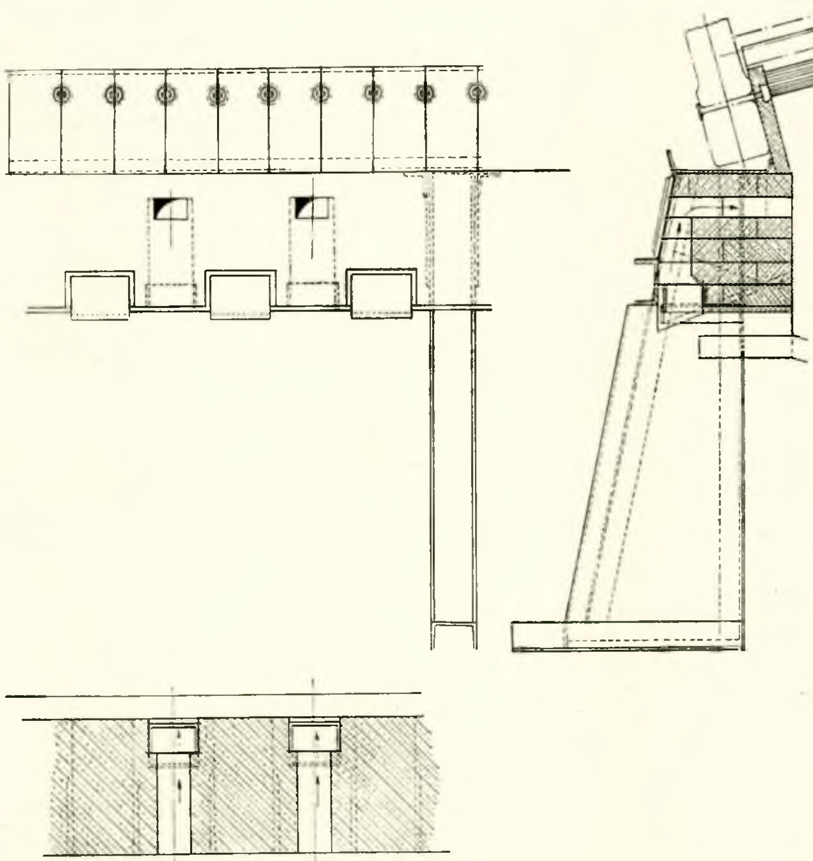


FIG. 9.—Sectional views showing arrangement of over-fire air supply as fitted with the stokers in "Duke of Lancaster".

the "Twickenham Ferry", were carried out in June, 1934, with Kentish coal, Betteshanger smokeless washed smalls, of about 14,000 B.T.U.'s (gross) per lb. The Taylor stoker and the Erith-Roe stoker are both of the retort-type differing only in detail construction. Fig. 7 shows a general section through the boiler and the mechanical stoker.

The machinery and boilers for the s.s. "Shuntien" were supplied by Messrs. Scotts' Shipbuilding & Engineering Co., of Greenock, and shipped out to Hong Kong where the vessel was built, for installation in that port. The vessel has two boilers with a total boiler heating surface of 7.254 sq. ft., superheating surface of 2,300 sq. ft., and an air heater surface of 3,850 sq. ft.; each boiler is fitted with a six-retort Erith-Roe stoker. The boilers were to provide under service conditions 40,000lb. of steam per hour from feed water at 215° F. at an outlet pressure of 210lb. per sq. inch and temperature of 600° F. when using a Chinese slack coal of about 12,000 B.T.U.'s gross value.

Difficulty was experienced during the trials with the particular class of coal it was desired to use in general service, but a change of coal (another Chinese variety) enabled the trials to be carried through and the vessel put into service. Recently some alterations have been made to the air supply to the fuel bed for combustion purposes and it is understood that the vessel is now in service using the particular class of Chinese coal desired by the owners. Fig. 8 shows the arrangement of boilers with the mechanical stokers in the vessel.

From this list it will be conceded that a com-

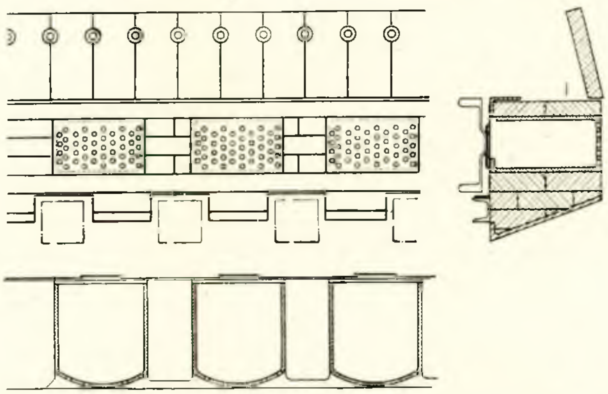


FIG. 10.—Sectional views showing arrangement of over-fire air as altered for stokers in "Princess Maud" and as fitted in "Duke of York".

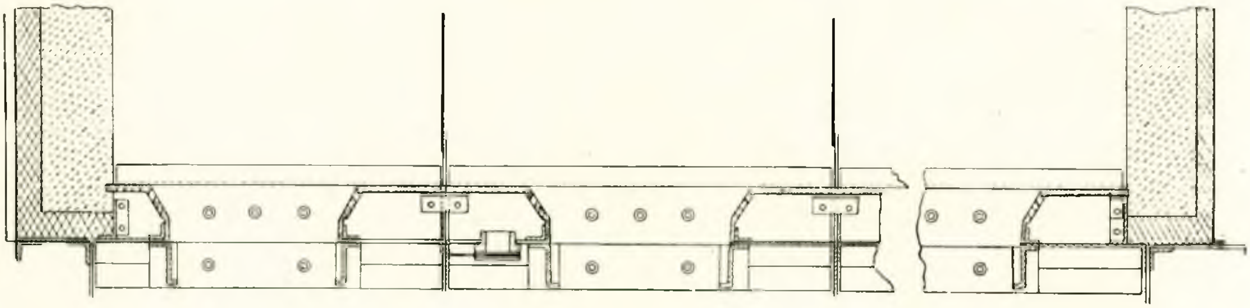


FIG. 11.—Furnace side cheek plates between furnace doors as fitted in vessels of "Slieve" class.

mencement has been made with the introduction of the mechanical stoker afloat in vessels of this country, and it is hoped that progress in this direction will be continued.

Since the installation of the stokers to the two forward boilers in the "Duke of Lancaster" experience has been obtained with a large variety of coals. This has resulted in several improvements in the design of the stoker grate parts and the methods and control of the air supply to the fuel bed, which alterations have improved the durability of the stoker grate and the efficiency of combustion.

It is not considered possible to describe within the scope of this paper all the small improvements in stoker parts, but it will doubtless be of interest to describe an alteration made to the method of supply of "top air" or the supply of air above the fuel bed, because similar alterations have proved beneficial also with hand-fired grates.

As originally arranged, top air was admitted through small plain openings just above the entering fuel, the amount of opening being controlled by the ordinary sliding louvres. The admission of this over-fire air was kept in practically the same position relative to the fuel bed, but under an improved device air is admitted to the furnace through a series of baffle plates, which are perforated with a large number of holes, drilled at varying angles to each other for the purpose of obtaining maximum air turbulence during its admission. A similar arrangement was first tried out in a hand-fired grate of a Babcock & Wilcox water-tube boiler and resulted in better combustion conditions and greater durability of the cheek plates at the sides of the furnace doors and between the furnace openings.

Fig. 9 shows the early arrangement of supply of top air to the Erith-Roe grate, and Fig. 10 the arrangement adopted in the "Duke of York". Fig. 11 shows the type of cheek plates with the multiple air inlet holes and slides for control of the amount of air, as fitted to a hand-fired furnace of a water-tube boiler. The device is patented.

(B) Cylindrical and water-tube boilers and improved methods of firing, both hand and mechanical.

The Author has not had extended experience with the Scotch or cylindrical boiler, as early in his service in H.M. Navy the water-tube boiler was adopted for all fighting vessels, and the remarks to follow concern only a few of the many different types of firebar and furnace fittings that have been tried at one time or another.

There still appears to be reluctance on the part of owners of vessels, the power of which falls below say 2,500 h.p., to adopt water-tube boilers. It is somewhat difficult to appreciate this attitude, since the up-to-date water-tube boiler has proved its dependability and efficiency under all kinds of working conditions, and its advantages over those of the Scotch boiler are very pronounced in several directions. So long as this prejudice exists, however, there is undoubtedly a call for a simple and inexpensive mechanical stoker for the completely water-cooled circular furnace of the cylindrical boiler.

Such a mechanical stoker must be simple in form, inexpensive, thoroughly reliable and able to burn efficiently a large variety of coals, or it cannot compete successfully against hand firing and the plain cast-iron or wrought-iron firebar.

The development of the Erith-Roe design for Scotch boilers is shown on Fig. 12. At the time of writing, this stoker is undergoing extensive shore trials, with a view to thoroughly trying out a variety of coals before the machine is fitted aboard a ship. It will be appreciated that in the confined space of the flue, it is much more difficult to design a robust mechanical stoker which will stand up to steady full power conditions on a variety of bunker coals without trouble.

Another interesting development in this category is the installation of the Bennis system of marine stoking which has been fitted in two ships, the "Manchester Hero" and "Manchester Port" of Messrs. Manchester Liners, Ltd.

The "Manchester Hero" has three single-ended three-flue Scotch marine boilers and the "Manchester Port" three similar four-flue boilers, i.e., nine Bennis stokers and twelve Bennis stokers respectively. The Author has not personal knowledge of this type of stoker, but it must be recorded that the mechanical stoker has been chosen for a second vessel after experience in the first.

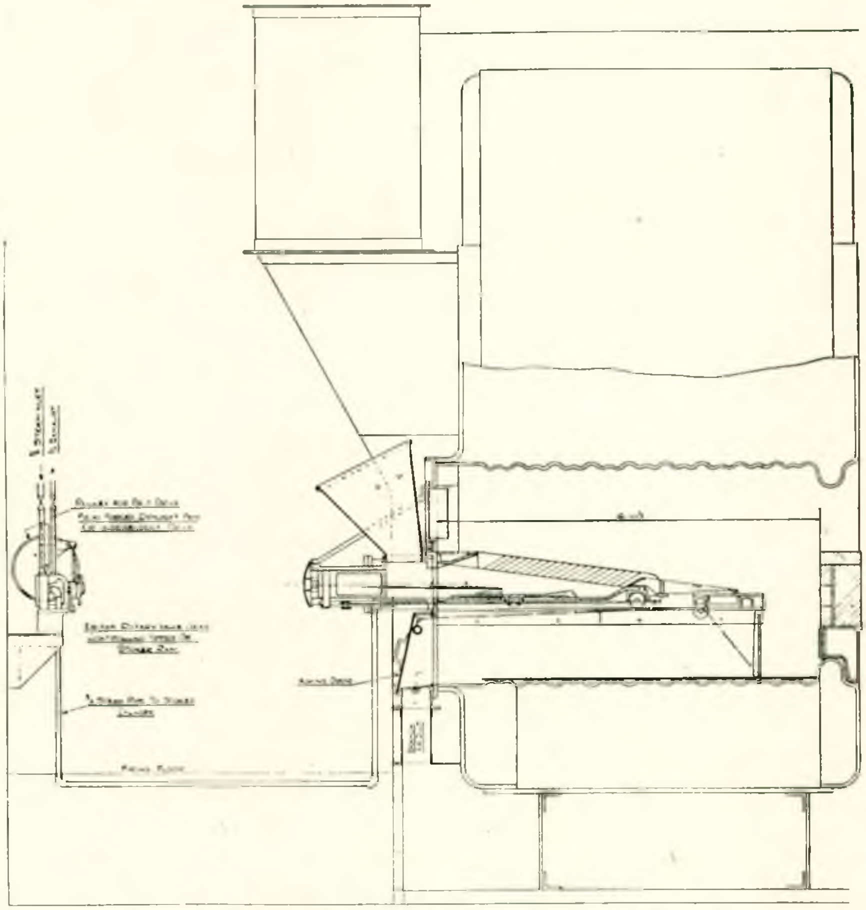


Fig. 12.—Erith-Roe stoker for Scotch boiler furnace.

The coal to each furnace is supplied from a hopper above the furnace door and fed to the grate by a distributing shovel from a reciprocating adjustable feed plate. The mechanism is designed to distribute the coal evenly over the grate and to be capable of regulating the feed. A special type of grate bar is used for regulating the air supply and the gradual movement of the fuel bed to the rear of the furnace. The stokers are understood to be capable of dealing with a wide variety of bituminous and semi-bituminous coals.

The reported results in "Manchester Hero" are a reduction in fuel costs (over 20 per cent.), some saving in the number of boilers in use, and less wear and tear on the boilers; in fact similar benefits are experienced as with the water-tube boiler and mechanical stoker, though perhaps not to the same extent.

There has not, however, been much progress in this direction up to the present, and one can only conclude that a mechanical stoker for the cylindrical boiler at sea has not yet arrived on account of initial cost and upkeep expenses being too great to show economic profit in its use.

There are, however, a fair number of special firebars, special both in material and in form, which give results superior to those obtained from the use of ordinary firebars.

In particular, the Author has had recent experience of one form of grate applicable to cylindrical and water-tube boilers which is special both in regard to the shape and disposition of the firebars and the method of air supply to the fuel bed, and in this connection reference is made to the "Turbine" furnace grate which is shown in Fig. 13.

This type of furnace bar was substituted for the ordinary bar in the third vessel of the "Slieve Bloom" class which was built for the L.M.S. Railway Co. for their cargo and live-stock service between Holyhead and Ireland. It will be seen from the drawing that the whole grate is made up in sections, each six inches wide, and having its own set of small firebars placed athwartships, or across the furnace instead of the more usual method of placing the firebar from back to front. Each section is independent and has its own air supply. The air is supplied to the circular trough under the bars by fan or by steam jet. In any case whether air supply is by natural draught or fan supply, a small steam jet is used to provide a small amount of steam to ensure humidity of the air, to assist combustion and to improve the durability of the firebars.

The fuel consumption results in service of the "Slieve League", the third vessel of this class, have been distinctly favourable in comparison with the two earlier vessels, and show increased boiler efficiency when using a lower grade of coal. The same type of grate is being adopted for the fourth ship of the class which is now being built by Messrs. Wm. Denny & Bros., Ltd., at Dumbarton.

In all the vessels of this class, the improved method of supplying air above the fuel bed, as mentioned earlier in this paper and shown in Fig. 11, has been adopted. This special attention to the supply of over-fire air has improved combustion efficiency and reduced upkeep expenses for furnace fronts, a gain in two directions. Reduction in smoke emission also follows from the use of these air distributing plates.

There are of course many other methods and appliances for the improvement of combustion in hand-fired furnaces, for the prevention of smoke and for reduction in upkeep costs, but probably sufficient has been written to show that with full efficiency and reduced upkeep expenses for furnace attention, thought and care in the design of boiler, furnace and all the necessary auxiliaries, particularly the supply of air for combustion, the marine engineer should not find it beyond his power to design coal-burning steam plant which gives the cheapest rate per lb. of steam.

This paper should be regarded as a brief resumé of the progressive efforts which are being made by marine engineers to make the use of coal economically successful in competition with its rival—fuel oil.

Generally it has to be acknowledged that the real hope of this competition resulting in favour of coal depends largely on the continued development of processes whereby the utmost value of coal can be obtained in consumption.

It is easily within the capabilities of designers to provide for dual or alternative use of coal and oil as fuel with the water-tube boiler and mechanical stoker, and if coal supplies of suitable type and at a fair and competitive price are available, such steam installations will be employed.

At the risk of repetition, however, it is desired to emphasize that if coal is to compete successfully with oil as a source of power for marine propulsion, close co-operation is essential between those most intimately concerned, viz., the coal-owner, shipbuilder and the shipowner, and their efforts should be directed towards the use and supply of suitable fuel at competitive prices.

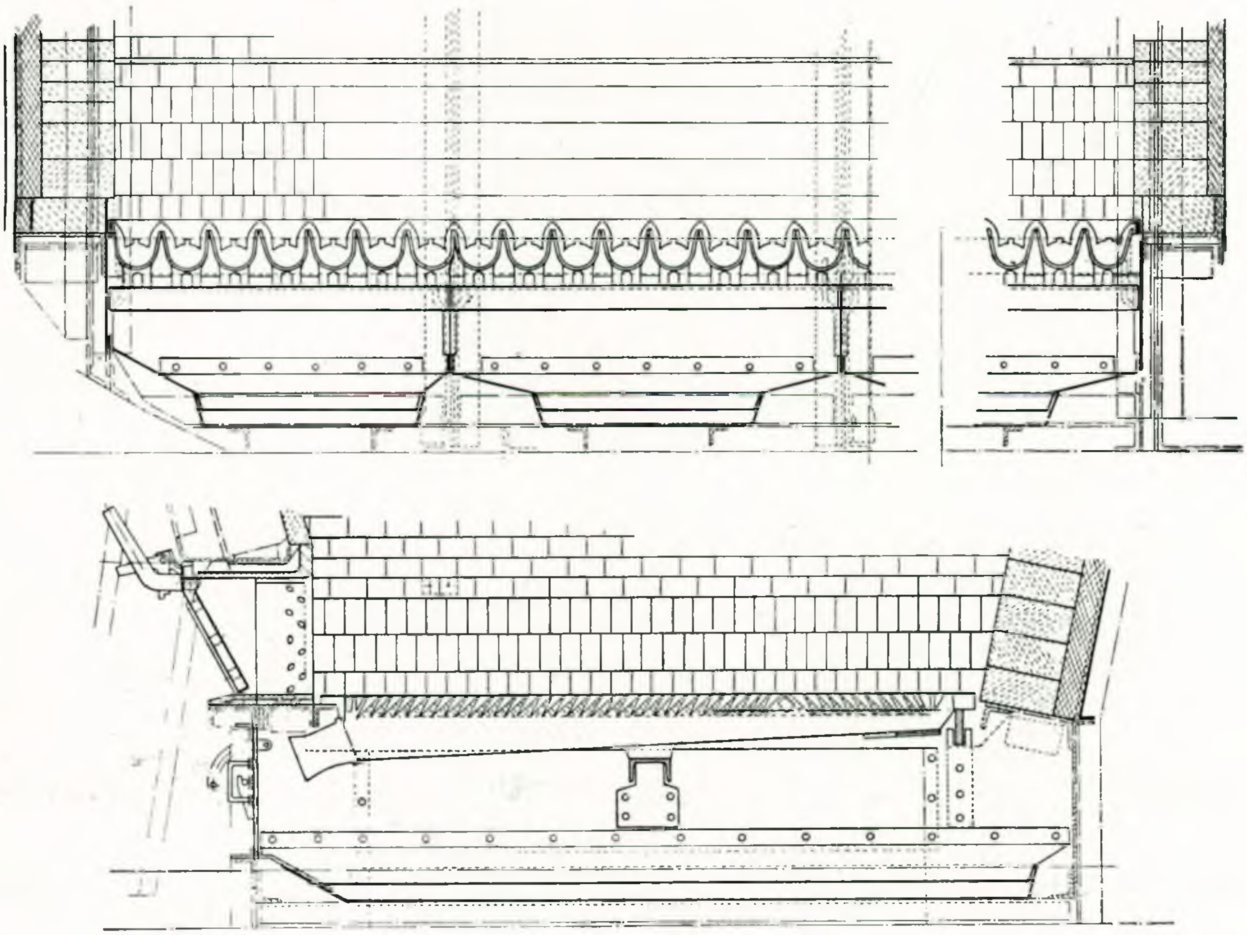


Fig. 13.—Sectional views of "Turbine" furnace grate.

Discussion.

Engineer Rear-Admiral W. R. Parnall (Member) said that he found very little to argue with the Author in this paper. He thought the Author had convinced him that it would be a most desirable thing if all hand firing could be replaced by mechanical stoking. He had given good reasons for such a change, including increased efficiency and the disappearance of that appalling half-hour at the end of a watch when one was trying to get steam and could not do it. The Author had convinced him that mechanical stoking in combination with a water-tube boiler was a practical proposition, but he had led him to understand that when it came to the Scotch boiler the problem was not quite so settled. Some of that audience—most of them probably—looked very "sideways" at a water-tube boiler. It was about thirty years since he, the speaker, had had anything to do with the Scotch boiler, and he had been very glad to say "goodbye" to it!

He himself required no convincing of the practicability of the water-tube boiler for merchant marine work, but he would like to hear how the Author would reply to objections raised to it; for example, people would tell him that the feed had to be watched like a cat watching a mouse. What had the Author to say to that argument? Then there was the question of the brickwork; an engineer to whom he had spoken a few days ago had objected to that, remarking that it might very well be a cause of anxiety and expense. As regards the necessity of clean water for water-tube boilers, he thought everyone agreed upon that, but he did not think there was any great difficulty in keeping the water reasonably clean. It was not always necessary to use distilled water, but at the same time it was not difficult, if the plant was available, to distil water. Nowadays they did not get many leaky joints, especially if they used turbines, so that the quantity of make-up feed was not very great. If they used clean feed water, the cost of providing it would be offset by saving what they would otherwise spend on cleaning out the boilers after using dirty feed water. It was very gratifying to him to know that the Author was satisfied that mechanical stoking in combination with water-tube boilers was a sound proposition, particularly because he, the speaker, was interested in the turbine; due to its simplicity the turbine could use steam of any practicable pressure and temperature, and a water-tube boiler was especially suitable for hot, high-pressure steam.

Mr. A. Ridings (Messrs. Bennis Combustion Ltd.—Associate Member) presumed that everyone present would agree that taken only from a national standpoint, the use of coal for the propulsion of ships was of paramount importance, it being our only natural resource of power available in any large extent. At the same time, steam engineers must make its use an economic proposition, for ships could not be run on sentiment, and therefore the shipowner and his engineers must consider the cheapest possible motive power.

He entirely agreed with the Author that mechanical stoking of boilers was a system requiring the closest attention of members of The Institute. He would go even further in stating that it was probably the only avenue open for considerable economies to be made in steam propulsion, as they had already arrived at high steam temperatures and pressures, but were limited at the lower end of the heat exchange cycle.

He did not think, however, that the Author had given a true assessment of the value of the Scotch marine boiler, especially when it was mechanically stoked. The boiler itself gave almost trouble-free service. It had large water capacity and therefore a steam reserve sadly lacking in the water-tube boiler. Mechanical stoker firing had definitely eliminated such troubles with the Scotch boiler as leaking tube ends in the combustion chamber tube plate, or leaking rivets.

A prominent member of the Institution of Mechanical Engineers had previously indicated the impossibility of fitting mechanical stokers to Scotch marine boilers. The Author indicated that the equipment was too costly both as regards the initial installation and repairs. There was, however, a certain truth in the epigram that "oft repeated fallacies many times lead to great discoveries", and he submitted that both these gentlemen were wrong, in that his Company's system of marine stoking was an accomplished fact and was a proved success in ocean going steamers with Scotch boilers.

As regards the cost of installation, suffice it to say that so far as 90 per cent. of steamers were concerned, the purchase price could be paid off by the savings to be effected in three, four or five years. This period necessarily varied under different circumstances such as details of the ship's machinery and disposition of the boilers, but he believed that engineers and owners would agree that this was an excellent return.

He had mentioned already the marked reduction in boiler upkeep costs. As regards the stoker equipment, it might interest members to know that not a single fire bar had been replaced in either of the installations in the s.s.'s "Manchester Hero" and "Manchester Port", although the system had been in use in the former since December, 1934. In fact, the overall upkeep costs including lubricants had been much less than under the previous natural draught hand-firing conditions. Upkeep in the s.s. "Manchester Hero" had been less than $1\frac{1}{2}$ per cent. of the cost of the installation.

He noticed that the Author had mentioned the increased evaporative capacity of the stoker-fired boilers in the s.s. "Duke of Lancaster" as being

30 per cent. In the s.s. "Manchester Hero", with the ship fully loaded and making full speed, the increase had been as much as 50 per cent., that is, by the use of two instead of three boilers. The efficiency of the installation in the s.s. "Manchester Port" steaming at sea with Scotch boilers had ranged from 82 per cent. to 84 per cent., this being for boiler, superheater and air heater, though even higher figures could easily be obtained by an increased heating surface of air pre-heater. These efficiencies were based on the gross calorific value of fuel as fired.

The fuels used had varied as follows:—

Name.	% Vol.	% F.C.	% Ash.	% Moisture.	Calorific Value as fired.
Yorkshire Washed Slack, 5/8... ...	27·26	54·79	6·75	11·2	12,059
New River W.Va. U.S.A. Slack ...	13·52	79·4	4·38	2·7	14,245
Notts. Washed Fines	28·07	45·45	11·28	15·2	9,879
Lancashire Dry Slack	29·6	46·94	19·26	4·2	10,548
Canadian, Sydney, Cape Breton ...	30·04	57·38	5·58	7·0	12,332
Lanarkshire Washed Pearls	32·22	50·02	6·76	11·0	11,312
Notts. Washed Slack	30·62	52·37	4·01	13·0	11,293

Crushers were fitted allowing coal of various sizes and degrees of hardness to be bunkered, e.g. from soft Eastern Asiatic fuels to the hard Nottingham and Indian coals.

His Company's system had been the outcome of years of experience on land installations and it was equally applicable to either Scotch or water-tube boilers. The system was at work on both types of boiler, giving excellent results.

The Author's reference to results in the s.s. "Duke of Lancaster" was interesting to him as he had made a double trip in that vessel some time ago. It was noticed that whereas with the retort type stoker there was a localised zone of fuel bed at a high incandescent temperature, in the system to which he had referred the whole of the grate area was in this state, which, in his opinion, added greatly to the evaporative capacity and efficiency of the boiler due to higher radiant heat transmission.

In the short time available for inspecting the plant in the s.s. "Duke of Lancaster" it had appeared to him questionable whether it would be an economical proposition to fit the four boilers in the aft stokehold, apart from difficulties which might be experienced in the withdrawal of clinker. He would like to ask the Author what were the overall thermal efficiencies of the stoker-fired water-tube boilers in the cross channel steamers, including lighting up, banking and port use over a three-months' period compared with the efficiency when steaming at sea only, and whether the range of the semi-unsuitable fuels was not rather wide due to coking and clinkering difficulties.

Finally, he would urge the members of The Institute to consider fully the merits of mechanical stoker firing on board ship, as without doubt large savings could be thereby effected, increased cargo space provided in new vessels and possibly more powerful engines or turbines, with no increase in the number or size of boilers, and a much wider market available for purchasing fuel.

Mr. S. N. Kent (Past-Chairman of Council) spoke as an advocate of the Scotch boiler. One could get inside these boilers and see whether they were clean and free from corrosion, but that was not possible with all water-tube boilers. As regards mechanical stoking it was essential that it should be possible to burn every kind of coal. In some cases if the mechanical stoker was "set" for coal of a particular grade or value everything went well so long as that grade was maintained, but if it was changed there was trouble. He would be interested to know the limit of size of furnace with which the mechanical stoker could be employed. He recognised that whereas mechanical stokers meant increased capital cost and periodical upkeep expenses, they required fewer men in the stokehold and in port, which were rather important items from an overhauling point of view. It was agreed that boiler feed water should be clean, but it was not uncommon for a ship to lie on the mud for a while, and if it became necessary to use water from the river, as much as one-third would be found to be mud. In such conditions as these it would be possible to take a certain amount of risk with a Scotch boiler, but not with a water-tube boiler. In conclusion he referred generally to the increase in the varieties of automatic apparatus for use in boiler operation, and questioned whether a right sense of proportion was being kept in regard to their adoption.

Mr. W. H. Gamble, B.Sc. (The Coal Utilisation Council—Visitor) desired to offer a few remarks both in his capacity as a combustion engineer and as a representative of the coal industries. Taking the latter case first, and referring to fuel supplies, the Author had stressed the importance of a suitable fuel being available at a suitable price. If the coal industry knew what fuel ought to be supplied it could be done. The Author had recommended a radical change in the bunkering industry, but who was going to pay the cost of the grading? The mechanical stoker makers were taking advantage of the low cost of small fuels, but how long would the supply of these fuels at present prices continue? Could the mechanical stokers show an advantage if the price of the fuel altered? Neither the Author nor Mr. Ridings had told them anything about the cost of the mechanical stokers, which were comparatively expensive. Was it worth while putting in expensive stokers in order to save in the cost of fuel? On page 153 the Author referred to a fuel of a low grade and less costly variety; did he consider fuel of 13,000 B.T.U. to be of a low grade? He (the speaker) considered it a high grade. The Author had mentioned 1,400° C. as the ash fusion point. He thought that was rather a high figure. What happened when low ash fusion coals were used, as many of the fuels in this country were of this class? Coals of a low volatile content were non-coking. Neither the Author nor Mr. Ridings had told them what happened when mechanical stokers were supplied with coking coals. They had referred to retort type stokers, but had made no mention of chain grate stokers. He suggested that the chain grate stoker would handle a lower grade coal than could be used in a retort type stoker, in which case there must be some reason for preferring the retort type to the chain grate stoker.

With reference to the Turbine furnace and similar furnaces he had often wondered how steam was supplied to the jets, and how much water had to be pumped into the boiler to make up for the steam that passed through the firebars. Was that a serious item or only a small matter?

Mr. J. E. Sellex (Lloyd's Register of Shipping —Member) asked whether the Author could give comparative consumptions in h.p. of water-tube and Scotch boilers under both mechanical stoking and ordinary firing conditions. The slides had not shown how to get rid of the ash in the back end of the boiler (in the case of the Scotch boiler).

Mr. A. C. Hardy, B.Sc. (Associate Member) said that he had been induced to speak by the Author having mentioned the s.s. "Mercer" of the U.S. Shipping Board during his reference to pulverised fuel firing. He (the speaker) happened to have been present on the trials of that ship, and he thought he would not be out of place if he recalled the need for asbestos umbrellas when one was on the top deck! Although his present interests were with the heavy oil engine he recognised that this paper was of the utmost importance and significance, as it indicated a trend in marine engineering. He made it a habit to follow trends in this great industry, and as a result he thought that there was no doubt that the ship of the future would be much more mechanised and that they would have many more of the push buttons to which Mr. Kent had referred. The adoption of the water-tube boiler was a step in that direction, and a step which was bringing external combustion nearer to internal combustion. He considered that the Scotch boiler could continue to render useful service if it were mechanised on the same lines as the water-tube boiler. Many shipowners now liked to reduce the number of men in their fleets as far as their substitution by machinery was possible and reliable. He (the speaker) had recently witnessed the trials of the s.s. "Hopestar", which was one of the most up-to-date tramp steamers yet constructed and might prove to be the salvation of the coal industry. As most of their South Wales members would agree, for the tramp class of vessel there was one fuel which would always be economical to burn—coal—although the trend of development was to burn less and less coal for every shaft horse power developed. The "Hopestar" showed what was possible in this direction with a combination of turbines and Scotch boilers. Could the Author give any idea of what was possible with a "Hopestar" fitted with water-tube boilers?

He referred to the success of several foreign nations in producing cheaper and more efficient cargo vessels by the adoption of higher steam pressures. He thought that the Author in his paper had given them a pointer in the direction in which the shipping and coal industries might go, to their mutual advantage.

Mr. C. Williams (Member) enquired what would be the weight of a mechanical stoking equipment for an ordinary tramp. The aim of a shipowner was to carry a full cargo the whole time and to keep the ship as light as possible. Would the extra weight of the stoker materially affect the cargo carrying capacity?

The Author's Reply to the Discussion.

The Author, before replying to the questions raised by the various speakers, said that the object and endeavour of his paper had been to provide an outline of what had been going on in just a few directions with regard to coal fired marine boilers. He did not pretend to say what was the best practice to be adopted by the country generally, but only to describe a movement that was going on in this particular field of marine propulsion. Shortly after he had written the paper and had mentioned the Bennis stokers in the Manchester liners he had been interested to read a letter in "The Engineer" of February 21st from Messrs. Hodgkinson in which they drew attention to the fact that they had fitted mechanical stokers in marine boilers in 1884. In the past few years there had been rather more success with mechanical stokers in the marine field, both with water-tube and cylindrical boilers. It seemed plain to him that the experiments with mechanical stokers would not have been continued had they not proved a financial success. The whole question was one of money, and if they were to progress each ship must show an improvement in the consumption of fuel and in the upkeep of the propelling plant. The main object of his paper was to show as briefly as possible that an attempt was being made in one or two directions to help in attaining that ideal.

Regarding Admiral Parnall's reference to feed water, as a former naval officer and with recent experience in the Mercantile Marine he had been drawn to the conclusion that it would pay every marine engineer to use the best water he could obtain, whether for water-tube or cylindrical boilers. That fact was becoming increasingly recognised. He would like to add that there should not be that fear of the results of discrepancies in the feed water that there seemed to be in connection with the water-tube boiler. He challenged the statement by Mr. Kent that it was not possible to see the internal condition of a water-tube boiler; it was possibly in some respects easier in the cylindrical boiler, due to the facility afforded the engineer to climb into the water side of the cylindrical boiler but not inside the tubes of a water tube boiler, but it was by no means difficult in the water-tube boiler, from his own considerable experience. As regards the brickwork, in the case of the "Duke of Lancaster" when the mechanical stokers were installed there was little new brickwork when she started and it was understood that much of the original brickwork was still in use, i.e. original brickwork with hand fired furnace.

He would reply fully to Mr. Ridings in writing; meanwhile he did not think he had stated anything in the paper that should give other than a true value to the Scotch boiler in combination with the mechanical stoker on account of that boiler's large reserve of water and low cost of upkeep. They were continuously endeavouring with both the water-tube boiler and the mechanical stoker to reduce the upkeep costs, and they visualised the coming position when the first cost of this type of steam generating plant would be no more and its upkeep cost if anything less than that of the cylindrical boiler. Time and experience were necessary to attain that end.

Mr. Ridings considered the Bennis stokers a success in the Manchester liners; nothing he (the Author) had said in his paper was to the contrary. Those installations represented one of the forms of progress that all could appreciate. Referring again to the general feature of the situation, it was important to realise that the introduction of mechanical firing must take a considerable time to prove itself. It would be desirable and even necessary to obtain further experience even with the installations in the Manchester liners before it could be said that they were going to achieve an adequate return for their first cost in subsequent service.

As regards comparative figures for overall efficiency, he had rather tended to keep out all figures from the paper because they were controversial and apt at times to be misleading. Apart altogether from the price of fuel there was a definite improvement in overall efficiency with mechanical stoking as compared with hand firing. He very much welcomed the remark by Admiral Parnall that if they paid a little more attention to the purity of the water supplied to the boiler they would save cleaning and upkeep costs. Mr. Kent had asked whether the mechanical stoker could use varieties of types of coal. The next speaker had answered that question. He wanted to emphasise the point that the coal industry, the shipowning and shipbuilding industries had to plan together if they were to continue the use of coal as fuel. For use with mechanical stokers they required a coal of not less than 15 per cent. volatile, preferably smalls, up to 1in. or 1½in. in size.

In the "Beaver" class the upkeep costs of the mechanical stoker was stated to amount to about 2d. per ton of coal burnt. That might be taken as a fairly representative figure for the upkeep cost of the mechanical stoker.

Mr. Kent had spoken about keeping a sense of proportion in regard to the use of automatic feed water regulators and automatic devices generally. Might he suggest that if they wanted to progress in the art of steam generation they had to progress in the mechanical method of doing it. If they were going to adhere to hand firing and control, then he did not think they would advance sufficiently to compete with any other form of propulsion. These criticisms reminded him of the early days of the water-tube boiler in the Navy, when one objection put forward was to the effect that if an automatic feed water regulator was fitted with the water-tube boiler there would not be sufficient work to keep the fireman fully alert to his duty. The Author did not think the criticism was worth following up, because if efficient control of the feed water supply was desired they might just as well take advantage of an automatic control system which was available for assistance to the operating engineer and the benefit of the steam generating plant. The automatic feed water regulator was undoubtedly a considerable help and it could even be a benefit to the cylindrical boiler.

He felt diffident in answering Mr. Gamble. In the early days when they were calling for large size coal for hand-fired water-tube boilers the coal industry had only to raise the coal from the pit and send it afloat. That was not a paying proposition to the shipowner to-day. Shipping was one of the biggest trades of this country, and the problem must be studied as it faced them to-day. As regards the varieties of coal which the mechanical stoker would deal with, it had been the endeavour of the makers from the outset to put on the market a mechanical stoker that would deal as nearly as possible with all kinds of coal met with all over the world, but there were of course some kinds of coal that would be more troublesome than others to the mechanically fired grate. There had been occasions when with hand-fired water-tube boilers, difficulty had been experienced in burning the best Welsh coal as supplied to H.M. Navy. It was only to be expected that even with mechanical stokers of any one kind fitted in a particular vessel it would not be possible to deal with every kind of coal in the world, or even in this country. As regards coal of 13,000 B.T.U. being considered a low grade fuel, it was not perhaps strictly correct to speak of a coal with that B.T.U. figure as one of low grade. One might have shipped into bunkers a 13,000 B.T.U. coal with a good many foreign substances, i.e. incombustible matter, in it. The trial of the chain grate stoker for marine purposes had been in evidence for many years, and it had been tried on the other side of the Atlantic in the lake steamers. He did not know of any instances of this type of stoker having been usefully employed afloat for open sea work. It did not lend itself quite so well to the limited space as did the retort type stoker. If a chain grate stoker could be fitted for marine purposes and deal with a large variety of coal it would soon find a market, but experience up to the present had shown that this was not at present economically attractive or possible.

As regards the use of the steam jet, to give humidity to the air supplied for combustion with different furnace grates the steam was used at very small pressure only and was a fraction of 1 per cent. of the total steam output of the boiler so far as the Author's experience and information extended. Certainly it could not be recommended if the percentage increased unduly.

With regard to comparisons for which Mr. Sellex had asked, the whole trend of the paper had been to indicate that there had been advantage in the fuel consumption per s.h.p. or fuel per mile of sea service with the use of the mechanical stoker as far as it could be compared with hand firing in similar ships. It would be realised and conceded that strictly accurate comparative figures were difficult to obtain but if as a result of extended sea service for particular or general routes the mechanical stoker continued to be selected it would only be due to economic advantage.

He thought that Mr. Hardy had been rather hard on him when he suggested that he had disposed of the pulverised fuel question in a cursory manner; he had tried to put the situation in a few words only, but still briefly and accurately as it appeared to him. The Author had visited a number of ships with pulverised fuel firing, including the "Mercer", and Messrs. Babcock & Wilcox had put down a marine boiler at Renfrew fitted for burning pulverised fuel and had demonstrated to many visitors that such a system was possible; but it could only be concluded that the initial cost, weight, and space required for pulverised firing equipment in the marine world were against its adoption. He was in agreement with Mr. Hardy's remarks regarding the water-tube boiler. He thought an attractive proposition which included a water-tube boiler with a mechanical stoker could be produced which would be suitable for a tramp steamer for round the world service, the cost and upkeep of which should not be much if anything in excess of that with a cylindrical boiler and mechanical stoker, making possible to the shipowner the advantages in economy in fuel, weight and personnel.

Mr. Williams had asked what would be the weight of a mechanical stoker for an ordinary tramp. He did not think it should be considerable. With the cylindrical boiler the extra weight over the hand-fired furnace might be anticipated to be only a small percentage of the total boiler weight. The water-tube boiler would save so much weight as compared with the Scotch boiler that the total weight of boiler and mechanical stoker would show in favour of the water-tube boiler and stoker.

A vote of thanks was enthusiastically accorded to the Author, on the proposal of the Chairman.

By Correspondence.

Mr. E. G. Warne (Member) in a written contribution expressed his opinion that in no other country had such efforts been made to prolong the use of coal as in Great Britain, and by his paper Engineer Rear-Admiral Whayman had made it clear that he was a most able exponent of the methods employed in up-to-date coal-firing practice. Those methods, however, appeared to involve the installation of much expensive mechanical apparatus, while the fundamental difficulties associated with the generation and utilization of steam were not in the end lessened thereby. He would like the Author to reconcile his statement regarding the use of inferior quality coal in the "Duke of Lancaster" with the remark that the calorific value of the fuels used was of the order of 13,500 B.T.U. That surely would represent anything but inferior coal, and what would be the price of it per ton?

With disarming frankness the Author stated at the outset that reliability, effective performance and competitive first cost would determine the source of power chosen. Reliability would seem to imply the provision of four boilers in the "Princess Maud" when three would suffice unless there had been some miscalculation in the steam requirements for service conditions and effective performance in the "Duke of York" was enhanced by the provision of two grit arresters which were apparently almost as large as the boilers themselves.

The Southern Railway, as the Author had mentioned, had chosen steam plant and mechanical stokers for the three new (or as "new" as made no matter to a railway company in this country) train ferries, the trials of the "Twickenham Ferry" —carried out in 1934—having been conducted with Betteshanger smokeless washed smalls of 14,000 B.T.U. Again, what would be the cost of this coal per ton, assuming that it had a sale in the open market as a fuel for any but the most specialized form of ship?

The Danish State Railways, on the other hand, found that oil engine propulsion was more suitable for their train ferry requirements than steam plant. They were not, perhaps, prepared to undertake the careful calibration of coal knobs that would facilitate the efficient performance of mechanical stokers in a steamer, but it must not be forgotten that they, also, had first investigated alternative methods of propulsion before deciding that they had no use for coal in any shape or form.

The Author's Written Reply.

The Author finds himself committed to a written reply to Mr. A. Ridings, but after reading carefully the manuscript copy of Mr. Riding's contribution to the discussion there seems little to add to the reply given at the meeting.

Mention of the Bennis stoker with the cylindrical boiler was included in the paper to add importance to the close study of the application of mechanical firing for marine purposes, and Mr. Ridings' remarks in respect of the cost of the installation will be confirmed by the extended use of the stoker with the Scotch boiler.

The same applies as regards upkeep costs.

It will be pertinent, however, to point out in respect of increased evaporative capacity that this figure is given in respective cases in comparison with the rating of the boiler or boilers when hand fired. Speaking generally, it would be expected to find that the hand-fired water-tube boilers in the "Duke of Lancaster" were originally working at a higher rating than the hand-fired Scotch boilers in the "Manchester Hero", and the advantages of the introduction of mechanical firing in respect of any increase in rating may still be with the water-tube boiler on account of its greater flexibility.

With regard to the question of efficiency—i.e. the overall efficiency of boiler, superheater, air-heater and stoker—this can be raised even higher than the figure quoted by Mr. Ridings, viz. 82 to 84 per cent., provided weight, space and other conditions allow and if high fuel economy is considered of major importance.

The use of "crushers" seems to the Author a debatable point and it is considered that any treatment of the fuel of this kind should be carried out on shore before bunkering.

In answer to Mr. Ridings' question as to the overall thermal efficiencies including lighting up, banking and port use the Author is not in possession of such comparative figures, but it is known that there has been a saving in the amount of fuel used as a result of the introduction of the mechanical stoker. The mechanical stokers have been fitted in the L.M.S. Railway cross-channel steamers having in view all the various coal fields from which supplies might have been obtained—and it is understood all types tried have been found usable—but naturally the coal selected is that found most suitable in respect of service results and first cost.

The Author would like to suggest to Mr. Gamble in answer to his question as to who is going to pay for the cost of grading the coal supplies, that this cost, as with all other commodities, will be paid by the buyer or consumer. There seems no reason why coal should be different in this respect from other commodities, but the price and quality must be competitive and the shipowner and marine engineer will not use coal as fuel if oil better meets their requirements.

To Mr. Warne's written contribution much is answered in the paper itself, the discussion and the Author's reply.

In answer to the remark as to the number of boilers fitted in the L.M.S. Railway steamer "Princess Maud", does not this resolve itself into a matter of the best rating at which to work the boilers in conjunction with opportunity and facilities for cleaning?

The reliability of the boiler installation is substantially the same in the two cases, but considerations of service upon which the vessel is to be employed must be taken into account.

Again also the decision to fit grit arresters is taken upon the overall design of the plant and the sea service to be performed, and whether it is better to install six boilers without grit arresters or four boilers with grit arresters so that the higher rating may be used without disadvantage to passengers.

Finally, in respect of the choice of fuel, whether oil or coal, it seems to the Author that if the use of oil is profitable it will always be used even if only on account of its advantage in cleanliness, and the advantages in the use of coal must be made substantial if its use is to continue.

Presentation to Mr. John H. Silley, O.B.E., Past President.

A Special Meeting was held in the Lecture Hall of The Institute on Wednesday, 22nd April, 1936, at 6 p.m., when Mr. George Adams, Vice-President, on behalf of the Council and Members, presented to Mr. John H. Silley, O.B.E., Past President, an oil portrait of himself. Mr. H. S. Humphreys (Chairman of Council) presided, supported by Messrs. R. Rainie, M.C. (Vice-Chairman of Council), A. Robertson, C.C. (Honorary Treasurer) and the Secretary. A pleasing circumstance was the presence of Mrs. Silley, who accompanied Mr. Silley on the platform, whilst among the unusually large audience were several members of their family, including Mr. G. F. Silley (brother), Mr. and Mrs. H. A. J. Silley (son and daughter-in-law) and their two children Master Richard J. and Miss Elizabeth Ann Silley, Mr. and Mrs. A. K. Scott (son-in-law and daughter) and Mr. B. L. Silley (son).

Mrs. Silley receiving a bouquet from Miss Elizabeth Ann Silley.

The Chairman, before opening the proceedings, called upon little Miss Elizabeth Ann Silley, who thereupon came forward and presented on behalf of the Members a bouquet of roses to Mrs. Silley. This little ceremony evoked much applause, to which Mrs. Silley gracefully responded.

Proceeding, the Chairman said that it was his privilege, as Chairman of Council of The Institute of Marine Engineers, to preside at that gathering. It was his intention to be very brief in his opening remarks, not through lack of knowledge or appreciation of the sterling qualities of Mr. John Silley, but in order not to overlap any remarks which Mr. George Adams might wish to make in his Presentation Address.

As they knew, they had met that evening for the presentation to Mr. Silley of a portrait of himself in oils, as a small token of esteem and gratitude for the great work which he had done for the marine engineering profession. It was only fitting that one of their oldest Members and Vice-Presidents should make the presentation and the Council were happy in their suggestion that Mr. George Adams should do this, particularly as he had done so much good work for the Guild of Benevolence. He therefore had the greatest pleasure in calling on Mr. Adams to make the presentation on behalf of The Institute of Marine Engineers.

Mr. George Adams, rising amid applause, said that they were gathered there that evening on what might be termed an unique occasion, marking as it did a milestone in the annals of The Institute of Marine Engineers.

They had met to place on record an appreciation of one of their Members, Mr. John H. Silley, who as a young man 44 years ago, on completion of his apprenticeship in the West Country as an engineer, came to London to commence his life's work. Fortunately for him, and for them, he became attracted to The Institute of Marine Engineers, then situated in the Romford Road, Stratford, and joined it as an Associate and afterwards as a full Member. In due time he secured a seagoing appointment as a Junior Engineer and worked up through the various grades to the position of Chief Engineer in the same Company.

Always keeping in close touch with The Institute through its TRANSACTIONS, in 1901 while at sea Mr. Silley was successful in gaining the Denny Gold Medal Award for his paper on "Treatment of Boilers under Forced and Induced Draught". He relinquished his position at sea in order to start, with Mr. John Weir, in a business as Engineers and Ship Repairers, which subsequently developed into the Company of which Mr. Silley was now Chairman. For services rendered by his Company during the stress and strain of the late War, Mr. Silley was awarded the distinction of Officer of the Order of the British Empire by His Majesty's Government.

After 43 years of membership, during which period Mr. Silley had continued his interest in the

The portrait of Mr. John H. Silley, painted by Captain Maurice Randall, which was presented to him at the Meeting on April 22nd, 1936. The inscription reads:-"John H. Silley, Esq., O.B.E., President 1934-5. Presented to him by the Council and Members as a mark of their esteem and appreciation of his outstanding services to The Institute of Marine Engineers."

activities of The Institute, he was unanimously elected as President, the highest office The Institute could invite him to hold. His work in this office was carried out with a zeal and fidelity which had contributed largely to the advancement of The Institute and the membership, particularly by his keen interest in the Council's deliberations which led to the recent important amendment of the By-Laws.

Through Mr. Silley's earnest belief in the advocacy of all good causes, the formation and wide scope of the Guild of Benevolence appealed very strongly to him, and through his activities and personal efforts a substantial capital had been raised and the Fund placed on a good financial foundation.

Thus it seemed to the Vice-Presidents and Members of Council that they and the Members of The Institute could appropriately offer to Mr. John Silley some acknowledgment in appreciation of the services rendered by him to The Institute during the past 43 years, culminating in his tenure of the Presidential Chair, and by a unanimous resolution the Council adopted a proposal that a portrait in oils of himself be presented to Mr. Silley. On being approached in the matter Mr. Silley was pleased to approve of the proposal, and expressed his willingness to sit for his portrait, and Captain Maurice Randall, whose works of art were well known to them all, was invited to paint the portrait.

They were very pleased that Mrs. Silley had graciously accepted the Council's invitation to be present that evening, for they fully realised the source whence, throughout his career and especially during the time of illness, Mr. Silley had derived much help and inspiration, and it was fitting that Mrs. Silley should share in the happiness of that function, and they trusted that to her and her family this portrait would remain an abiding token of the esteem and high regard in which Mr. Silley was held by his fellow members of The Institute of Marine Engineers.

He now had the greatest pleasure, in the name of the Council and Members of The Institute of Marine Engineers, in asking Mr. Silley to accept the portrait.

Mr. George Adams delivering the presentation address.

The inscription read:—

"JOHN H. SILLEY, Esq., O.B.E.,
President 1934-5.
Presented to him
by the Council and Members
as a mark of their esteem and appreciation of his outstanding services to The Institute of Marine Engineers".

To Mr. Silley's sons, aye and his sons' sons, might it ever be an inspiration, stimulating them to follow the high ideals of their predecessor. (Loud and prolonged applause).

Mr. John H. Silley, replying, said that he would like first to thank the Members of The Institute for the splendid painting which Mr. Adams had just presented to him and he wished to thank Mr. Adams most heartily for the kind remarks he had made concerning him. He would like also to express his appreciation to the Council for inviting his wife to be present that evening, which to him was a most important occasion.

The presentation.

As he stood there, his thoughts carried him back 44 years ago to the time when he left a small town in the West Country, fired with the ambition to become a marine engineer, and taking with him the prayers and good wishes of the lady who was now by his side.

In those days they had not the opportunities of technical education that the young engineer had to-day, and it was extremely fortunate for him that he came under the influence of the comparatively new Institute of Marine Engineers which had only been in existence some three years. It might also be rather a coincidence that when he came to London to join a ship—which, by the way, never sailed, and the owning Company went out of existence—the Superintendent of that Company was Mr. Asplan Beldam, the first President of The Institute of Marine Engineers.

He was, therefore, for the first and only time in his life, out of a job. For some weeks he spent the greater part of his time endeavouring to find another berth, and fortunately for him he spent his evenings at 59, Romford Road, the premises of The Institute. He well remembered the great impression The Institute created on his mind. He appeared to be in the presence of very able and serious-minded scientists, and he was afraid this created in him a feeling of inferiority complex. He soon realised, however, that he had quickly to make up for lost time and he scrutinized every TRANSACTION and Paper that could be found in the Library of The Institute. He also undertook a special study in higher mathematics and mechanical drawing at the Carpenters Institute, which, to the best of his knowledge, was the only place available in those days for this branch of education.

After a few weeks he was fortunate enough to obtain his first appointment as a junior engineer at sea with a firm, the principal of which, Mr. John Corry, a few years later, became the President of The Institute. He little realised at that time that 42 years later, he, himself, was to fill that honoured position and to follow in the footsteps of so many distinguished men in the shipbuilding, engineering and shipping world.

Engineering had made tremendous strides since then; he knew that he considered himself extremely fortunate in going to sea with one of the first triple expansion engines, and it was truly remarkable when one looked back to see the enormous progress which had taken place in marine engineering since those days. One often heard people quote "the good old days of marine engineering", but on looking back he said to the young men of to-day that for all the romance that had been taken out of marine engineering it was nothing compared to the opportunities which young engineers had before them to-day, and would, he thought, have more so in the future.

Without doubt a higher standard was required to-day, and The Institute and kindred institutes were making great efforts to create the necessary standard with a corresponding higher status for the marine engineer. He knew that it was the wish and the policy of the Council and the leaders of The Institute to do all in their power to help the young men to obtain that status, but it was only to be done by hard work, efficiency, and determination and he had no hesitation in saying to the young men of to-day—and he said this after 50 years' experience in engineering—that there were still great opportunities open to them if they were prepared to take advantage of them.

The members of The Institute had lived to see raw coal almost disappearing as a fuel for marine purposes, especially in large ships. The chemists and engineers of the future who would produce a fuel from coal from which the incombustibles and marketable by-products had been removed at the pithead and give them a fuel which would compete or combine with liquid fuel, would render one of the greatest services, not only to the economic life of this country, but to the safety of the Empire.

One thing of which he felt proud was in having been privileged to assist a very large number of men to learn the practical side of their profession, and there was nothing which gave him greater pleasure than to hear, as he did from time to time, that young men who had been through his Company's workshops had proved successful in obtaining important positions, both technical and administrative.

It was not the lot of everyone to succeed and they could not all go through life without some misfortune. The last few years had brought great hardships to many of their craft through no fault of their own, and he was more than pleased that during his year of office as President The Institute launched their Guild of Benevolence for helping cases of this kind, and he was thankful that he had been able to play some small part in its foundation. (Applause).

He believed the future held still greater opportunities than the past, and he knew that The Institute would do its best in fitting young men for any task they might be called upon to fulfil. It was his sincerest hope that the young engineers of to-day might derive the same benefits which he obtained, and that their careers, with all their trials and difficulties, might be as happy as his had been since he became an Associate of The Institute of Marine Engineers. (Prolonged applause).

Mr. R. Rainie said that it was not inappropriate that at that gathering which had honoured a member who had passed through all grades to the highest office, he should make some remarks on The Institute and the Guild of Benevolence which it had fathered, his reasons being that two great projects were brought into working shape during the year that Mr. Silley was their President and the presence with them of Mr. George Adams, one of their honoured Vice-Presidents who had been so closely associated with their activities, and had directed, as Chairman of the General Committee of the Guild, its activities since its inception until the present time.

Dealing with The Institute, he wanted to confine his remarks to its more recent history. He was honoured by the Council with the chairmanship of a committee which thrashed out the new by-laws which, it was the Council's hope, would place The Institute in a position to carry the same weight in deliberations as other chartered institutions and give their members equal opportunity with those of other institutions.

He did not know if marine engineers were pessimists by profession, but he knew that the alterations in the By-Laws were viewed by quite a number of their members, he hesitated to call them Jeremiahs, as By-Laws which would adversely affect the membership of The Institute and lead to its financial deterioration.

The new By-Laws came into operation on the 1st January of that year and it was with great pleasure, and a certain amount of personal satisfaction, that he had the information to give them that instead of the membership falling, it was increasing, being now around the 4,000 mark, and that increase included many of the senior members of the profession. Progress in the right direction was being made, and he would ask the many distinguished persons present that evening to bring to the notice of those connected with the profession, when they could, the advantages which membership of The Institute now offered to them.

Turning to the Guild of Benevolence, which had its inception in Mr. Silley's Presidential year, he felt that full advantage was not being taken of what the Guild offered. The approximate membership of the Guild to-day was only 72 life members and 240 subscribing members. Membership of the Guild was not only open to members of The Institute, it was open to all marine engineers who possessed Board of Trade Certificates of Competency. There were some 17,000 to 20,000 of these, and the membership of the Guild, he repeated, was 72 life members and 240 subscribing members. What scope there was for effort!

Mr. Silley had said that when he came to London he found himself for the first and only time in his life out of a job, but there were many of their profession who had had that appalling experience, not once, but many times, and had unfortunately left widows and dependants practically destitute. He had been without a job on several occasions; probably he quite deserved to be, and he remembered that not so many years ago he was in that position for no less than eighteen months and the mental agony of that period was prominent in his mind to-day. That physical privation did not accompany that mental agony he owed to a marine engineer, now one of the best known superintendent engineers in London. That the spirit which actuated him on that occasion should be translated into the organisation of the Guild was a fine thing, and those of their profession who were fortunately in jobs would, he was sure, if the work of the Guild was brought home to them, rally to its support by becoming at least subscribing members of it, and he appealed to all of them to bring the constitution of the Guild and its work before members of their profession whom they controlled or with whom they came into contact. In other words, let them constitute themselves apostles of this good work, and "go out into the highways and byways and compel them to come in".

That The Institute had made progress no one would deny, that the inauguration of the Guild in itself was a successful operation was also undoubted, and in both cases, while they could look upon what had been accomplished with satisfaction, he did not call it great progress. At the same time he did not despair of progress. For organisations such as theirs, as for nations, there was no sin so great as despair and no virtue so vital as courage.

If they had had a measure of success it was good and desirable to remember that nothing succeeded like success in a world which was principally made up of failure, and the measure of their progress would be whether they regarded success as a narcotic or a spur. Let them not, therefore, be too easily contented with their achievements; they had climbed the foot-hills, now let them set their minds and hearts on scaling the mountains. (Applause).

Mr. A. Robertson, after mentioning in humorous vein his relationship to one of the august, bearded scientific gentlemen who constituted the early Council and to whom Mr. Silley had referred, augmented Mr. Rainie's plea for more loyal support of the Guild of Benevolence by quoting some leading financial particulars of the Guild and showing to what extent its good work could be furthered by an increase in the annual subscribing membership.

Upon the Chairman declaring the meeting at an end, Mr. Silley asked that Mrs. Silley and he might be allowed to bid individual farewells to the Members present, including so many of his old friends and colleagues. This pleasing incident, so characteristic of Mr. Silley, concluded the meeting, which will long remain a happy memory to all who were fortunately able to be present.

INSTITUTE NOTES.

CORRESPONDENCE.

To the Editor of the Transactions.

Cylinder Liner Wear.

Dear Sir,—It is probably true to say that no other problem connected with the design and maintenance of Diesel engines has proved so difficult as that of cylinder liner wear. From time to time various theories have been advanced to account for this wear, and, while hesitating to accept definitely any particular one, it is not unreasonable to assume that they are all contributory factors.

Valuable research work ashore has resulted in the production of special metals for liners and piston rings; scientific investigations have revealed the necessity for greater attention to the class of lubricating and fuel oils employed. Despite this added knowledge, liner wear still persists, and is in quite a number of cases excessive.

A study of tramelling records (from various engines) indicates that maximum wear takes place in line with the top ring, and over the first few inches of the piston stroke. With double-acting, four-stroke engines, the writer's experience has been that maximum wear in line with the firing ring on the bottom piston invariably reads somewhat in excess of that on the top. It would be interesting to know whether this is actually the case in other double-acting units.

Records further tend to show that the calibrations obtained from new liners after being in service for one voyage are rather higher than those obtained on subsequent voyages.

From the above it would appear that, after the liner has been run in, the tendency is for wear to be more evenly distributed throughout the stroke, and that the initial treatment may to a great extent influence a very important factor, viz., the period of efficient service before it becomes necessary to renew the liner.

One ventures to suggest that, contrary to the usual practice of boring new liners parallel, it might possibly be an advantage to undersize them slightly, to the extent of a few thousandths (tapered inversely to accepted wear) over say, the first 150-200 mm. of the piston stroke. To allow the piston rings to accommodate themselves to the shape of the liner it would be necessary to increase slightly the clearance gaps.

During the running in process the undersized part of the liner would be subject to the highest gas pressure, and very soon to wear. As this occurred the lower rings would naturally take up more of the load. By this time the entire rubbing surface of the liner would have acquired a working skin and the bore would be practically parallel. It is reasonable to suppose that under these conditions the tendency would be for wear to be more evenly distributed over the whole length of the stroke.

It is suggested that while this slight alteration in the bore would not finally solve the vexed problem of liner wear, it would assist to lengthen appreciably the period of useful service.

Yours, etc.,

L. D. MacBean (Member).

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, 4th May 1936.

Members.

Frederick Victor Bennett, Maxholme, Goitre Fach Road, Killay, Swansea.

Alfred Joseph Buchan, Purification Works, Worcester Park, Surrey.

Thomas Hynd Forbes, P.O. Box 60, New Law Courts, Rangoon, Burma.

John Lawson Gray, 12, Humbert Street, Jarrow, Co. Durham.

Alexander Smith Guthrie, B.I. Engineers' Club, P.O. Box 296, Calcutta, India.

James Wood Harrington, 94, Alric Avenue, New Malden, Surrey.

James Marshall, 11, Liverpool Avenue, Ainsdale, Southport.

Llewelyn Roberts, 62, Radway Road, Hill Lane, Southampton.

John Hodgart Dunlop Traill, 19, Meon Road, Milton, Southsea, Hants.

Mark Lee Watson, 3, Laburnum Villas, Front Street, East Boldon, Co. Durham.

Francis Wigzell, Weardale, Priestden Road, St. Andrews, Fife.

Companion.

Frederick William Porter, Ravenswood, Cressington Park, Liverpool.

Associate Member.

Edward Haver, Glenwhelt, Herrington Burn, Philadelphia, Co. Durham.

Associates.

Robert William Coleman, 136, Lewisham Road, Lewisham, S.E.13.

William George Jenkins, 11, The Park, Ishapore, Bengal, India.

John Cairns Mason, 16, Lauriston Place, Edinburgh.

Stanley Alfred Poole, 20, St. John's Church Road, E.9.

Kenneth Oates Robinson, 384, Victoria Avenue, St. Lambert, P.Q., Canada.

Ivor Shelly, Morgans Vale Vicarage, Salisbury, Wilts.

Transfer from Student to Associate.

Ellis Robert Chamberlain, 17, Chalk Road, E.13.

ADDITIONS TO THE LIBRARY.

Purchased.

"Code of Practice for the Installation of Lifts and Escalators". Building Industries National Council, 5 Duke Street, Adelphi, London, W.C.2. 1s. 3d. net.

"The Shipping World" Year Book, 1936. 25s. net.

Report on the Examinations of Candidates for Certificates of Competency in the Mercantile Marine and the Sea-fishing Service for the year ending 31st December, 1935. H.M. Stationery Office. 2d. net.

King's Regulations and A.I. Amendments (K.R. 3/36). H.M. Stationery Office. 2d. net.

Lloyd's Register of Yachts, 1936. 42s. net.

Presented by the Publishers.

First Report of the Pipe Flanges Research Committee. The British Electrical and Allied Industries Research Association, 4s. net. (Copies of this Report may be purchased through The Institute at 1s. 4d. per copy, plus 3d. postage).

World Power Conference: Annual Report for 1935.

The following British Standard Specifications:

No. 664-1936. Cast Iron Shaft Couplings, Rigid Flanged Type with Recessed Bolt-Heads and Nuts (including recommended limits on diameters of line shafting used therewith).

No. 665-1936. Vertical Cross Tube Boilers.

No. 668-1936. Laminated Synthetic Resin Bonded Sheet (Fabric Base) for use as Gear Material.

No. 669-1936. Flexible Metallic Tubing and Connectors for Portable Gas Appliances.

No. 671-1936. Dimensions of Segments for Grinding Wheels.

No. 673-1936. Pneumatic Tools and Accessories.

"Modern Heating and Ventilation", Vols. I, II and III). Edited by Alcwyn A. Jones. The Caxton Publishing Co., Ltd., Clun House, Surrey Street, London, W.C.2, illus., £3 3s. net.

"Practical Hints on the Installation of Heating Apparatus with Brief Notes on Ventilation", by E. G. Blake. The Technical Press, Ltd., 123pp., illus., 2s. 6d. net.

In reading "Practical Hints on the Installation of Heating Apparatus" the reviewer has endeavoured to put himself in the position of a householder having a central heating installation or hot water system in his house, and to such a person this little book should be very instructive.

The author is to be congratulated on putting the subject matter of his book simply and clearly before the reader and at the same time avoiding any reference to technical terms and formulæ which would be found in textbooks dealing with a more advanced treatment of the subject.

Although most of the information contained in this book should be part of the general knowledge of every layman and especially the occupant of any modern private house, it is surprising to find that a great many householders are entirely ignorant as to how a heating or hot water system functions, not to mention any idea of the care and maintenance necessary in order to obtain the best results from their installations, and it is to such people that the reviewer would recommended Mr. Blake's book.

"Dampfturbinenkraftwerke kleiner und mittlerer Leistung", by Dr.-Ing. F. Aschner. Julius Springer, Berlin, 145pp., illus., 7.50 marks.

Modern literature on steam turbines for power stations does not, in the main, deal with small and medium powered plants, and this book is intended to cover that neglected field.

Power station equipment occupies the greater part of the work, but this is prefaced by such matters as consideration of the importance and rating of small power stations, and a comparison, by means of tables, of the electrification of countries in terms of density of population and individual consumption. The thermodynamic aspect is discussed briefly with the help of graphs, and the effects upon consumption of pressure, temperature and vacuum are indicated. Much very useful statistical information is contained in the book.

The work will afford profitable reading to marine engineers, whether employed at sea or on shore. It is, of course, written in German.

"Graphical Solutions", by Charles O. Mackey, M.E. Chapman & Hall, Ltd., 130pp., illus., 12s. 6d. net.

The title of this book is apt to mislead English readers as to its actual contents. The subject matter deals with graphical and mechanical solutions of various equations usually applied to experimental data which confront the engineer. The book is divided into five very suitable chapters, viz.: (1) stationary adjacent scales; (ii) sliding scales; (iii) net work and intersection charts; (iv) alignment charts; and (v) empirical equations—non-periodic curves.

The titles of the first two chapters explain their contents. A very detailed description of the construction of stationary scales is given on page 5, using the empirical equation $h=240\left(\frac{v}{u}\right)^{0.8}$ as an example. This is the film coefficient of heat transfer on the water side of condenser tubes, and a scale is constructed and shown in a diagram giving direct readings of h and $\left(\frac{v}{u}\right)$. At the end of chapted (i) some very interesting examples are given for the reader's own manipulation.

Sliding scales are similarly constructed and described in chapter (ii) and are useful for solving equations containing three or four variables. The Unwin-Babcock formula for the flow of low-pressure steam in pipes $p=0{\cdot}00145w^2\left(\frac{d+3{\cdot}6}{d^6}\right)$ is an example given, together with a diagram of the sliding scale.

Chapter (iii) on network or intersection charts is really a graphical representation of an equation containing three or more variables, e.g. $B.H.P.=\frac{2\pi\ PRN}{33{,}000}$. Numerous examples are given in this chapter, which should be found invaluable to the engineer and research worker.

Alignment charts are another means of graphical representation of an equation with three variables, and in comparison with the special sliding scales described earlier in the book are often easier to construct. Equations of the type $Q=3{\cdot}33bH^{1\cdot5}$ are usefully employed to illustrate the matter in this chapter, the examples being wholly of an engineering character.

The last chapter dealing with empirical—non-periodic curves is of a more mathematical nature than the previous work, but there is no doubt of its importance to problems in engineering.

The book is of general interest to the scientist and of special interest to the engineer who is continually plotting results taken during routine and experimental work. It is well printed, is illustrated with numerous diagrams, has a set of useful examples at the end of each chapter, and has a lot to commend it to every engineer.

"The English-Russian Technical Dictionary". Edited by Adolph E. Chernukin, E.E.R.E. The State Theoretical Technical Publishing House, Moscow, U.S.S.R.

During the past few years there has been a rapidly increasing exchange of technical publications between this country and the U.S.S.R. A demand has evidently been felt in that country for a thoroughly comprehensive English-Russian dictionary and the State Publishing House has produced this 1,200-page work in an endeavour to meet this need.

The dictionary is of unusually wide scope, and the achievement of the Editor in compiling it is exceptional. It must be regarded as an invaluable work in the U.S.S.R. and, although a Russian-English dictionary would naturally have a wider appeal here, there are doubtless many in this country to whom it will be of great use.

The printing is excellent and, whilst the paper and binding are not of the quality to which English readers are accustomed, it is quite a serviceable production.

"Engineering for Nautical Students", by W. A. Fisher. Brown, Son & Ferguson, Ltd., 140pp., illus., 5s. net.

The Author, lecturer in Engineering and Mathematics in the School of Navigation, Royal Technical College, Glasgow, has produced an excellent book primarily designed for the use of cadets and apprentices and second mates of the Merchant Service. In 1935 the Central Board for the training of officers of the Merchant Service included the subject of marine engineering in their syllabus for the instruction of apprentices and this book endeavours to cover the work set out in this syllabus.

The book has been divided into three sections corresponding to the three years' course. The first section, on the first year's work, commences with a chapter on the use of drawing instruments and scales, with rules for the correct projection, and dimensioning of machine drawings, and a few examples of simple engine parts illustrate the text. Simple ideas are given upon the working of steam reciprocating engines and upon the construction and working of marine boilers. The second years' work includes elementary notions of steering gears, turbines, Diesels, refrigerating engines, pumps, propeller shafting and reciprocating engine details, while the third years' work is confined to electricity with a simple reference to wireless and its application to direction finding.

The book is written in a very simple, although somewhat staccato style and is very fully illustrated with good clear sketches.

Students studying for the Board of Trade Masters certificate will find much useful information to help them in their study for the examination paper in marine engineering.

"Examinations", by William John Galbraith. John Bale, Sons & Danielsson, Ltd., 83-91, Great Titchfield Street, London, W.1, 175 pp., 8s. net.

This book is of special interest at present when the value of examinations is the subject of so much publicity. It deals principally with the examinations for Certificates of Competency conducted by the Mines Department of the Union of South Africa, the possession of which is compulsory for those holding leading positions in any mine in the Union.

The Author has produced the book as a worker in a worker's mood and gives many instances touching the point of view of the practical mechanic to the certificated manager in authority over him.

Many incidents are quoted to prove that the examination system is detrimental to the experienced practical worker, but favourable to the technically educated candidate with little or no practical experience who by the "cramming" system has gained the facility to answer the set questions. The examiners are charged with incompetence, discourtesy and corruption, and if the facts are as stated they are a damning indictment of the examination system in force in the Union. Several cases are given of expensive mistakes made by mine managers which it is claimed would not have been made by practical men.

The psychological effect of failure in the examination on a candidate is drawn in vivid lines, but it is hoped that the calamitous results following some such failures are exaggerated. The reader is left with the impression that the Author has such a feeling of bitter injustice as to warp his sense of discrimination.

Many cases are quoted of famous men who were dullards and worse at school and of brilliant scholars who were failures in life to support his opinion of the utter uselessness of written examinations.

The Author makes a full survey of the many variations of Examination proposed by educationalists, but admits that he can see no prospect of any of them eliminating the inherent defects of all examinations. Mention is made of the possible use of clairvoyance in lieu of written examinations, which would certainly be a startling innovation to educationalists.

The book is a challenge to existing methods and worthy of perusal, especially by a young engineer contemplating advancement in his profession in South Africa.

"Oldenbourg's Practical Charts: Tables for Heat Engineers: Steam Boiler Operation". Technical Press, Ltd., 7s. 6d. net.

The demands of modern industry have forced engineers to discard the old empirical methods in favour of accurate calculations on a strictly scientific basis, but many must grudge the time that has to be spent at the office desk in order to arrive at the necessary information.

This book will save a great deal of this work in as much as it presents, in a series of graphs, the results of accepted formulæ bearing on the various problems with which the engineer is faced. The forty graphs which it contains are easy to read, amply explanatory and cover furnace control, steam generation, boiler water and fuels and include an especially valuable conversion chart of British and metric units. The complicated formulæ which are involved in the science of modern boiler operation are given and cover solid, liquid and gaseous fuels. Time will undoubtedly be saved by the use of the graphs and the danger of mistakes in calculation avoided. The same problem can be solved by the use of more than one graph, depending upon the data available and the reader is thus offered fresh avenues of research.

The explanations are given in three languages—German, English and French—and should undoubtedly be of considerable value, especially to those who favour the graph method of calculation. The book will prove an asset to the technical library of the power engineer, fuel technologist and boiler plant designer.

"Technical Education: An Immediate Programme". A report of the Education Committee of the New Fabian Research Bureau drafted by Barbara Drake and Tobias Weaver. Issued by the New Fabian Research Bureau, 36pp., 6d. net.

This report is in two parts: *Technical Education To-day* and *An Outline of Policy.*—The first part opens with an outline of the historical development of technical education and then describes the organisation existing at the present time in respect of junior and senior full-time and part-time day and evening courses in technical colleges.

The authors have seen clearly that the growth of technical education provision has been somewhat haphazard and that the existing organisation necessarily reflects this. They have also seen that the protagonists of technical education have throughout striven to get away from narrow vocational practice and have steadily aimed at the provision of the individual with *education* in the fundamental principles underlying industry as well as with a continued education to widen his interests and his powers.

It gives relevant statistical information which shows how small is the total provision for technical education in our industrial country.

In a brief section on examinations the authors do not, we feel, sufficiently emphasise the fact that whilst examinations played a very important part in encouraging the establishment of classes there has been a steady trend away from the purely external examinations with the rigid dictatorial syllabus to the internal assessed examinations based on courses designed and approved to meet the needs and conditions of local industries.

The second part outlines an educational policy under the sub-headings of *Technical Education at the Secondary School Stage, Co-operation with Industry, The Case for Day Continuation Schools, The Organisation of Part-time Courses, The Status of the Higher Technical Institutes,* and a *Rational Policy of Recruitment.* At the end of each of these sections the Committee makes a series of recommendations.

This part of the report is extremely interesting and stimulating whether one agrees with the recommendations or not. There is advocacy of a wider development of the junior technical school to the "technical secondary" type which has already been advocated strongly by the Association of Principals and Teachers in Technical Colleges. There are valuable suggestions for the closer co-operation of industry, nationally and regionally and interesting recommendations on the question of recruitment.

The report is very well worth reading and should be of great interest to all industrialists particularly at this epoch when industry as a whole realises the shortage of its skilled workers even though it may not fully realise the cause.

"Alternating-Current Machines", by A. F. Puchstein and T. C. Lloyd. Chapman & Hall, Ltd. 582pp., illus., 25s. net.

This textbook is primarily suitable for students taking a degree or diploma course or for those studying for The Institute's Examinations, and in this respect the book is technical rather than practical. From a technical point of view the book is very good. Fundamental problems of alternating current are explained. A knowledge of calculus is an advantage, but this is not essential for the understanding of the principles contained in the subject matter. Numerous numerical examples are given, and an excellent bibliography.

The book deals very fully with the technical problems of synchronous and induction motors and rotary converters. Transformers and repulsion and series type motors are also dealt with. The problems of mercury arc rectifiers are treated very shortly. Methods of testing and analysis of the results for the various machines are given.

The book was not written from a practical point of view and consequently, in general, there is little or no information to assist the electrician at sea in the maintenance and operation of alternating current machines in service.

With alternating current a large number of the smaller auxiliaries are repulsion and series type machines, and in this respect the sea-going electrician will be assisted by the information in the book. Generally at sea there will always be a number of important auxiliaries of a variable speed nature. These auxiliaries, known as a.c. commutator motors, require a fair amount of supervision and maintenance. Unfortunately the book gives very little of the way in which this type of machine works, there being no information regarding supervision and maintenance.

JUNIOR SECTION.

Marine Superheaters.

A paper on the above subject was read by Mr. J. H. Wheadon (Member) at a meeting of the Junior Section held in the Lecture Hall of The Institute on Thursday evening, 23rd April. Mr. E. R. Chamberlain (Student) occupied the Chair.

The paper, which was a model of its kind, provoked a useful discussion in which several of the senior members present took part. General agreement concerning the high value of the paper has been confirmed by a decision of the Council to publish it in the July Transactions.

BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examinations for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

For week ended 26th March, 1936:—

Name.	Grade.	Port of Examination.
Robinson, Joseph W. ...	2.C.	Newcastle
Grice, James W.	2.C.M.	,,
McDonald, Robert	2.C.M.	,,
Codd, Bernhard S.	2.C.	London
McMillan, John N.	2.C.	,,
Wood, Robert	2.C.	,,
Coleman, Robert W. ...	2.C.M.	,,
Bell, Harvey	2.C.	Liverpool
Booth, George F.	2.C.	,,
Bradbury, Frank M. ...	2.C.	,,
Derby, James B.	2.C.	,,
Hislop, Robert McK. ...	2.C.	,,
McKevitt, James S. ...	2.C.	,,
Rimmer, George F.	2.C.	,,
Smoquina, Carlo I.	2.C.	,,
Roberts, Cyril	2.C.M.	,,
Crossan, John McG. ...	2.C.	Glasgow
Gamble, Alexander	2.C.	,,
Gibson, William R.	2.C.	,,
Mason, John C.	2.C.	,,
McEwan, John	2.C.M.	,,

For week ended 2nd April, 1936:—

Name.	Grade.	Port of Examination.
Smith, John	1.C.	Glasgow
Ingram, Alexander A. ...	1.C.M.	,,
Glen, William P.	1.C.	London
Robinson, Edward	1.C.	,,
Cameron, James	1.C.M.E.	Glasgow
Cullen, William	2.C.M.E.	,,
Perry, John E.	1.C.M.E.	London
McCormick, Henry C. ...	1.C.M.E.	,,
Gibbs, Bryan O.	1.C.M.E.	,,
Barron, John S.	1.C.M.E.	,,
Smith, William R.	1.C.M.E.	Glasgow
Collins, Alfred	1.C.	Newcastle
Douglas, John N. P. ...	1.C.	,,
Parker, Frederick S. ...	1.C.	,,
Glen, James C.	1.C.	Liverpool
Herriot, James C.	1.C.	,,
Hubbard, John A.	1.C.S.E.	,,

For week ended 16th April, 1936:—

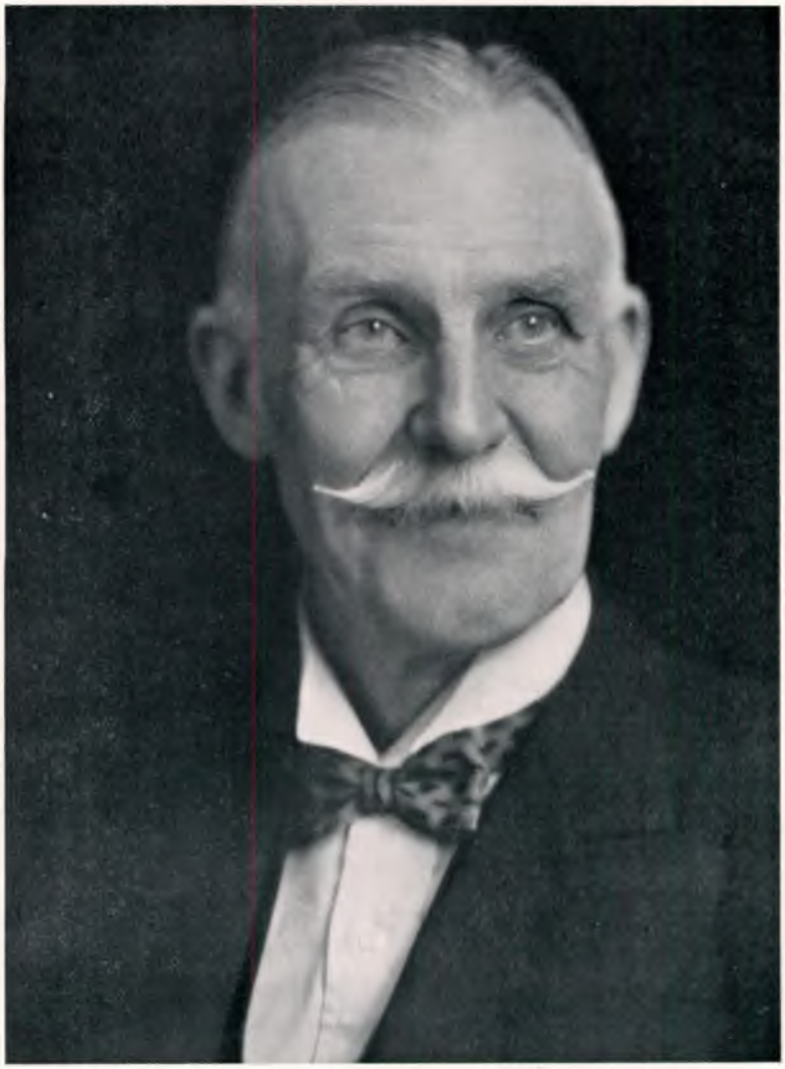
Name.	Grade.	Port of Examination.
Evans, Clifford H. ...	2.C.	Cardiff
Garrett, Francis W. G. ...	2.C.	,,
Morgan, Ronald J.	2.C.	,,
Page, Joseph	2.C.	,,
Jenkins, William T. N.. ...	2.C.M.	,,
Coombe, George	2.C.	London
Dowle, Harold	2.C.	,,
Fowler, John	2.C.	,,
Robinson, Albert E.... ...	2.C.	,,
Sunners, Brian P.	2.C.	,,
Williams, Stanley S. ...	2.C.	,,
Frayn, Clifford C.	2.C.M.	,,
Holt, Leslie E.	2.C.M.	,,
Campbell, Joseph R. ...	2.C.	Newcastle
Collins, James	2.C.	,,
Gauld, Douglas R.	2.C.	,,
Hedley, Arthur B.	2.C.	Newcastle
Pollitt, William	2.C.	,,
Potts, John	2.C.	,,
Thornton, John George ...	2.C.	,,
Whitehead, Alfred	2.C.	,,
Cable, William F.	2.C.M.	,,
Dean, Alan E.	2.C.M.	,,
Haver, Edward	2.C.M.	Newcastle
Little, James Henry ...	2.C.M.	,,
McGahan, Gerard	2.C.M.	,,
Seales, Gordon	2.C.M.	,,
Taylor, Joseph Westoll ...	2.C.M.	,,
Wood, Harry G.	2.C.M.	,,
Fielden, Victor G.	2.C.	Liverpool
Hughes, Hector A.	2.C.	,,
Lawler, James	2.C.	,,
McKellar, Gilbert H ...	2.C.	,,
Nixon, Norman Charles N.	2.C.	,,
Clark, Robert H.	2.C.M.	,,
Hallworth, Henry	2.C.M.	,,
Robinson, Thomas R. ...	2.C.M.	,,
Shelly, Ivor	2.C.M.	,,
Cherrie, John	2.C.	Glasgow
Duncan, Thomas B. ...	2.C.	,,
Johnstone, Norman A. ...	2.C.	,,
McColl, Angus	2.C.	,,
St. Clair-Miller, H. C. E....	2.C.	,,
Wallace, William D. ...	2.C.M.	,,
Wilson, Robert	2.C.M.	,,

For week ended 23rd April, 1936:—

Name.	Grade.	Port of Examination.
Ramsdale, Gerald S. ...	1.C.	Newcastle
Gray, James M.	1.C.M.	,,
Potts, Fenwick	1.C.M.	,,
Colquhoun, William M. ...	1.C.	Glasgow
Crockett, Hector B. ...	1.C.	,,
Leith, Allen B.	1.C.	,,
Paton, William	1.C.	,,
Thomson, Thomas	1.C.	,,
Bradley, Alexander	1.C.M.	,,
Whitten, John M.	1.C.M.	,,
Robertson, James	1.C.M.	,,
Daniels, Alfred J.	1.C.M.E.	London
Proudfoot, Joe C.	1.C.M.E.	Liverpool
Gillan, Francis D.	1.C.S.E.	London
Kennedy, Thomas	1.C.M.E.	Newcastle
Mackay, Alexander M. ...	1.C.	London
Powell, Francis J.	1.C.	,,
Neilson, Donald R.	1.C.M.	,,
Poole, Stanley A.	1.C.M.	,,
Trint, John G. F.	1.C.M.	,,
Bennett, Stanley G.	1.C.	Cardiff
Fry, Robert A. F.	1.C.M.	,,
Brodie, David H.	1.C.	Liverpool
Christian, Frederick ...	1.C.	,,
Fogg, Oliver O.	1.C.	,,
Sherwood, John H.	1.C.	,,
Blight, James A.	1.C.M.	,,
Crowther, Harry	1.C.M.	,,
Hanwell, Hilton B.	1.C.	Newcastle
King, John R.	1.C.	,,
McIntyre, William F. ...	1.C.	,,
Henderson, John G. ...	1.C.M.E.	,,
Gardener, Thomas	1.C.M.E.	,,
Douglas, John N. P. ...	1.C.M.E.	,,
Chambers, Robert H. ...	1.C.M.E.	,,

For week ended 30th April, 1936:—

Name.	Grade.	Port of Examination.
Strachan, James C.	1.C.M.E.	Glasgow
Bourne, Frederick	2.C.	Newcastle
Marr, Richard B.	2.C.	,,
Jones, Ernest Mitchell ...	2.C.M.	,,
Hawke, Herbert J.	2.C.	London
Fairhurst, William H. ...	2.C.	Liverpool
Hall, Herbert C.	2.C.	,,
Smillie, Albert	2.C.	Glasgow
Stewart, Roderick J. ...	2.C.	,,
Brown, Donald M.	2.C.M.	,,
Keane, Thomas	2.C.M.	,,
Sinclair, Arthur	2.C.M.	Newcastle



The late Sir ARCHIBALD DENNY, Bt., LL.D.
(Past-President).

Portrait by H. J. Whitlock & Sons, Ltd.

OBITUARY.

Sir Archibald Denny, Bt., LL.D. (Past-President).

By the death of Sir Archibald Denny, which occurred suddenly on Friday, May 29th, at his home in Queen Anne's Mansions, London, the shipbuilding and engineering industry has lost one of its most popular members and the Institute one of its most eminent and esteemed Past Presidents.

Archibald Denny was born on February 6th, 1860, the fourth son of the late Mr. Peter Denny, himself one of the Clyde's most famous shipbuilders, and the Institute's third President and founder of The Denny Gold Medal. Sir Archibald received his early education at the Dumbarton Academy and at the early age of fourteen was sent to the École Cantonal, Lausanne, where he continued his studies in science, mathematics and languages. His training as a naval architect was begun in 1876 at the Leven Shipyard. Later he studied at the Royal Naval College, Greenwich, and for some time served on the staff of Lloyd's Register of Shipping as a surveyor in Liverpool. In 1883 he became a partner of William Denny and Brothers, and was for many years in charge of the technical and scientific work of the shipyard. During the period in which he was in control, he developed the research side of the firm's business, which has been their special characteristic for close upon 200 years, during which shipbuilding has passed from wood to iron, and from iron to steel. In the development of propelling machinery, Sir Archibald was closely associated with the late Sir Charles Parsons, and it was at the Dumbarton yard that the "King Edward", the first turbine-driven ship for passenger traffic, was built in collaboration with the Parsons Marine Steam Turbine Company. In the New Zealand Shipping Company's "Otaki", which followed, a combined system of turbines and reciprocating engines was tried out. Oil engine development was not neglected by Sir Archibald, and Denny's were early constructors of the Sulzer oil engines. The firm, under his leadership, built many fine ships for both home and overseas service, among which numerous cross-Channel steamers for railway service were noteworthy as embodying many new features of design and practice.

He was created a baronet in 1913, in recognition of a life of public service. The honorary degree of LL.D. had been conferred upon him by Glasgow University two years earlier, and at a later date he received a similar honorary degree from the University of Cambridge. He was for many years closely associated with classification work, and was Chairman of the Technical Committee of the British Corporation Register of Shipping and Aircraft, and Honorary President of that Corporation. On many occasions Sir Archibald served on Board of Trade committees, prominent among which were the Committee on Bulkheads in 1912 to 1915 and the Conference on Safety of Life at Sea in 1913-14, of which two latter bodies he was appointed as Chairman. He also presided over the British Engineering Standards Association, now the British Standards Institution, from 1918 to 1927.

Sir Archibald was keenly interested in general scientific and research work, and was fully alive to the importance of the part which the engineering institutions played in this field. His valuable service to The Institute during his year of office as President—an office which five members of the Denny family have now filled—in 1914-15 was greatly appreciated, and he was re-elected as President for the following year. His interest in The Institute and marine engineers generally was maintained until his death. Sir Archibald was also a member of The Institution of Naval Architects and as a member of the Council and a Vice-President for several years he did much to further the work of that body. He was also a member of the Institution of Engineers and Shipbuilders in Scotland and one of its honoured Past-Presidents, while he was a valued member of the North East Coast Institution of Engineers and Shipbuilders, and of the French Association Technique Maritime et Aeronautique.

When Sir Archibald retired from active work with his firm in Dumbarton he came to live in London, but remained a director of the company. He was in constant touch with the firm's work, and his opinion on technical matters was frequently sought. His activities in London allowed him more time to attend the meetings of the various institutions with which he was connected, and his work will long be remembered by the many friends he made in these and allied spheres. Indeed, possessed as he was of a very charming manner, his friends were almost as numerous as his acquaintances, and he will be missed by a very large circle. For some years his health was not good, but latterly he appeared to have completely recovered, and until only a few days before his death was full of the liveliness and good fellowship which characterised him.

The funeral service, at which The Institute was represented, was held on June 2nd at St. Columba's (Church of Scotland), Pont Street, London, a large number of his friends in the shipping and engineering world being present to pay their last respects.