# The INSTITUTE of MARINE ENGINEERS

Founded 1889. Incorporated by Royal Charter, 1933

SESSION 1946. *Transactions* Vol. LVIII. No. 8.

Patron : His Majesty The King. President : Sir Amos L. Ayre, K.B.E., D.Sc.


# Air Preheater Design, Construction and Maintenance.


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*Read on Tuesday, May 14th, 1946, at 5.30 p.m. at 85, Minories, E.C.3.*

Chairman : Mr. J. A. Rhynas (Chairman of Council).


***Synopsis.***

*The development is traced of air preheaters from the early designs of some 10 per cent. mean efficiency to modern units arranged for 70 per cent. heat recovery or more. Drawings and photographs show the progress made in the 63 years which have elapsed since the first successful air preheater was fitted to a boiler.*

*The features of recuperative and regenerative air preheaters and the limitations and advantages of each are discussed. Clean heating surface is stressed as one of the most important aims in maintaining air preheaters, and a novel means of overcoming difficulties which arose in certain power stations during the war is described.*

*The paper ends with remarks on the choice of preheaters and some details and illustrations of modern installations on board ship.*


The title of this paper suggests that it is divided under three headings—Design, Construction and Maintenance. There is, however, bound to be considerable overlapping, particularly in the first two, and while the suggestion will be followed generally it is not proposed to mark the divisions.

Design, in addition to its accepted engineering sense of adaptation of means to ends, also means aim or purpose. Let us start therefore by looking at the purpose of air preheaters. Apart from early experiments in the use of heated air for iron manufacture culminating in James Beaumont Neilson's hot blast patented in 1829, the first attempt to add recovered heat to the combustion of the fuel in a boiler appears to be that covered by James Howden's patent of 1860. In this he proposed to use a combined water jet and air-cooled condenser in which the air would perform the double function of partially condensing the exhaust steam and returning the recovered heat to the boiler. The aim was good but the adaptation of the means to the end was impossible due to the discrepancy between the heat content of the steam to be condensed and that of the air for combustion.

The first reference to the modern conception of an air preheater and its purpose is contained in the same patentee's invention of 1882. Claim 1 of that patent condensed reads: "Apparatus or arrangements for supplying air to furnaces of steam boilers wherein the air supplied under pressure by a fan first passes into a casing and in contact with tubes or passages through which the fire gases escape so as to take up residuary heat from the fire gases, and next enters a casing having within it suitably proportioned openings or adjustable valves through which the air under pressure and heated enters each furnace, the parts being arranged and operating for the purposes of increasing the rapidity and efficiency of combustion and diminishing the waste of heat.*"

This still remains the purpose of an air preheater combined with mechanical draught, and the progress which has been made since then is only a matter of degree.

Fig. 1 shows the first application of an air preheater to a boiler. This was in 1883. the boiler being the works boiler of James Howden & Co. The preheater is a tubular one with 28 tubes each 1ft. 3in. long by 3½in. dia., the gases being inside the tubes. The mean efficiency of this preheater could not have been more than about 10 per cent.

Fig. 2 shows the first marine air preheater. This was installed in 1884 in the steamship *New York City* owned by the firm of Scrutton & Sons of London. This air preheater had 120 tubes 2ft. 3ins. long and 3¼in. dia. The efficiency in this case was about 16 per cent., so that even in the first year progress in "diminishing the waste of heat" had already been made.

Fig. 3 shows another design from these early days. In this the casing round the uptake through which the forced-draught fan draws the air before discharging it into the air preheater will be recognized as the forerunner of a similar arrangement which has been rediscovered within recent years.

At the time the air preheater was first introduced marine boilers had no kind of heat-recovery apparatus. The economiser had been known on land boilers for about 40 years, but its bulk and weight prevented its adoption afloat and, in any case, on board a ship a certain amount of exhaust steam was available for feed heating. The air preheater was therefore widely accepted by marine engineers,

*The so-called efficiency of the air preheater provides a means of measuring the performance of the apparatus in "diminishing the waste of heat".

The efficiency on the gas side ($\eta_g$) is the ratio

$$\frac{\text{Actual drop in gas temperature}}{\text{Possible drop in gas temperature}}$$

$$\text{or } \eta_g = \frac{100 \ (T_1 - T_2)}{T_1 - t_1} \%$$

where $T_1$ = Temperature of gas entering preheater.
$T_2$ = " " " leaving "
$t_1$ = " " air entering "

or similarly on the air side the efficiency ($\eta_a$) is the ratio

$$\frac{\text{Actual rise in air temperature}}{\text{Possible rise in air temperature}}$$

$$\text{or } \eta_a = \frac{100 \ (t_2 - t_1)}{T_1 - t_1} \%$$

where $t_2$ is the temperature of the air leaving the preheater.

There are, however, objections to both of these equations. The gas side efficiency even in an ideal preheater can never reach 100 per cent., and the air side efficiency can in an ideal preheater exceed 100 per cent., the reason being that the ratio

$$\frac{\text{Weight of gas} \times \text{specific heat of gas}}{\text{Weight of air} \times \text{specific heat of air}} \text{ or } \frac{W_g}{W_a} \text{ or } \phi$$

is always greater than 1 in boiler practice when all the gas and all the air go through the preheater.

The mean of the gas side and air side efficiencies, which we shall call $\eta_m$, is a truer measure of the performance of the preheater, and this is what is usually accepted as the preheater efficiency. It can be expressed as

$$\eta_m = \frac{(T_1 - T_2) + (t_2 - t_1)}{2 \ (T_1 - t_1)}$$

or bearing in mind that

$$W_g \ (T_1 - T_2) = W_a \ (t_2 - t_1)$$

we have

$$\eta_m = \frac{(1 + \phi) \ (T_1 - T_2)}{2 \ (T_1 - t_1)} \times 100\%$$

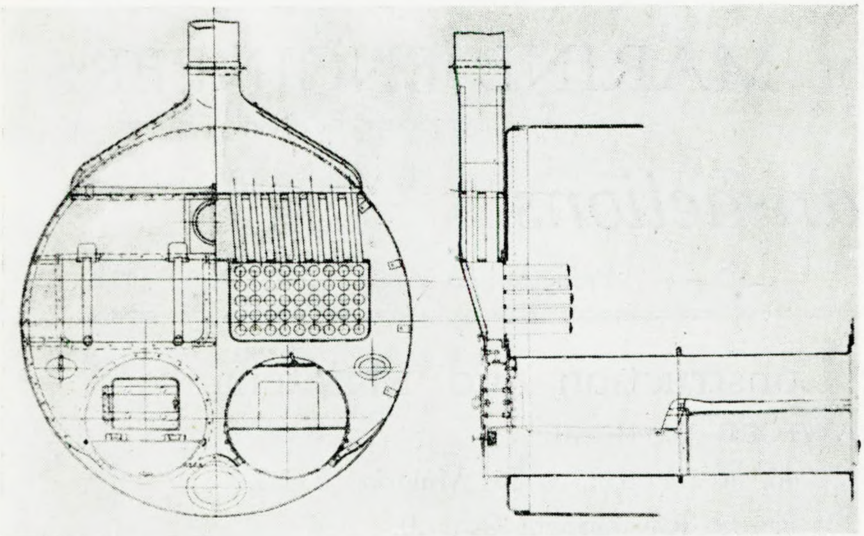


FIG. 1.—*First application of air preheater to boiler.*

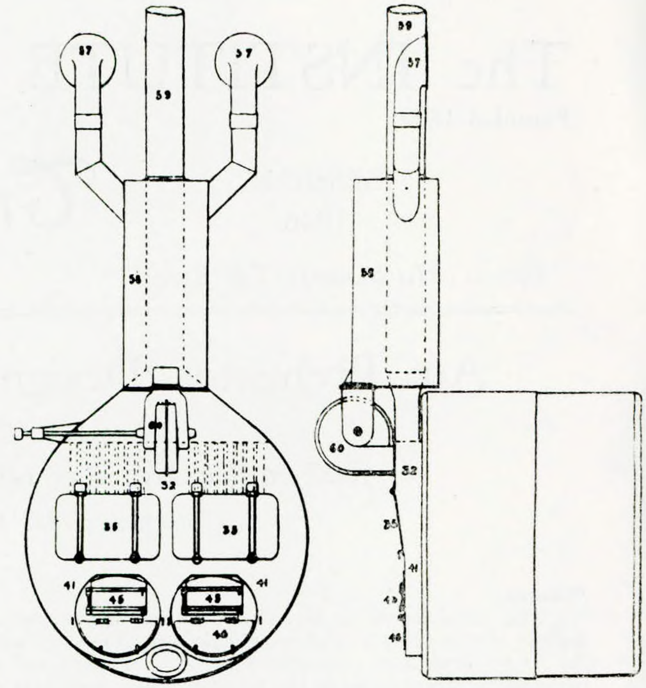


FIG. 3.—*Air preheater supplied by fan drawing from casing round uptake.*

and well over 1,000 were fitted in the first twelve years—a fact which encouraged progress in design.

It was a far cry from these beginnings to the preheater efficiencies of 70 per cent. or more which are now often used, but progress continued to be made by increasing the heating surface, reducing the tube diameters and arranging division plates in the path of the air flow to prevent short-circuiting of parts of the heating surface.

The single-flow tubular preheater had the advantages of compactness and the ease with which it could be applied to Scotch boilers. By the adoption of division plates the length of the tubes could be increased to 4ft. or more, and the preheater could still be accommodated in its convenient position directly above the smoke-box, even on the wing boilers where the head-room was usually restricted. This restriction tended to standardize an air preheater of the dimensions shown in Fig. 4, which is one of 48 on the famous old *Mauretania*. The heat recovery obtained from the improved 4-ft. tubular preheater shown in Fig. 4 was about 25 per cent.

Air preheaters of this performance were the general rule on Scotch boilers from about 1900, and they are still installed in large numbers. The performance could be improved by creating turbulence on the gas side, and this could be obtained by fitting retarders in the tubes or by changing the design of the heating surface itself. Experiments with undulated plates were carried out, and the result was the turbulent-flow air preheater which fitted into the orthodox position on the Scotch boiler and gave a heat

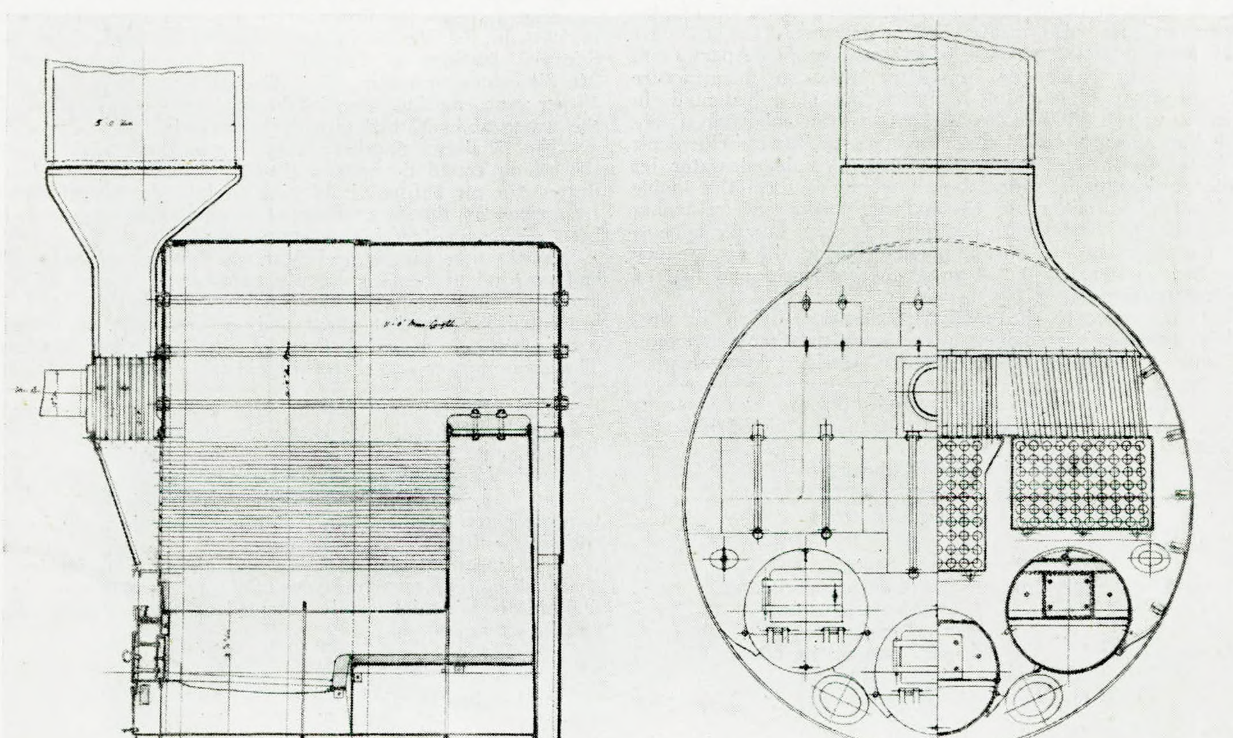


FIG. 2.—*First marine air preheater.*

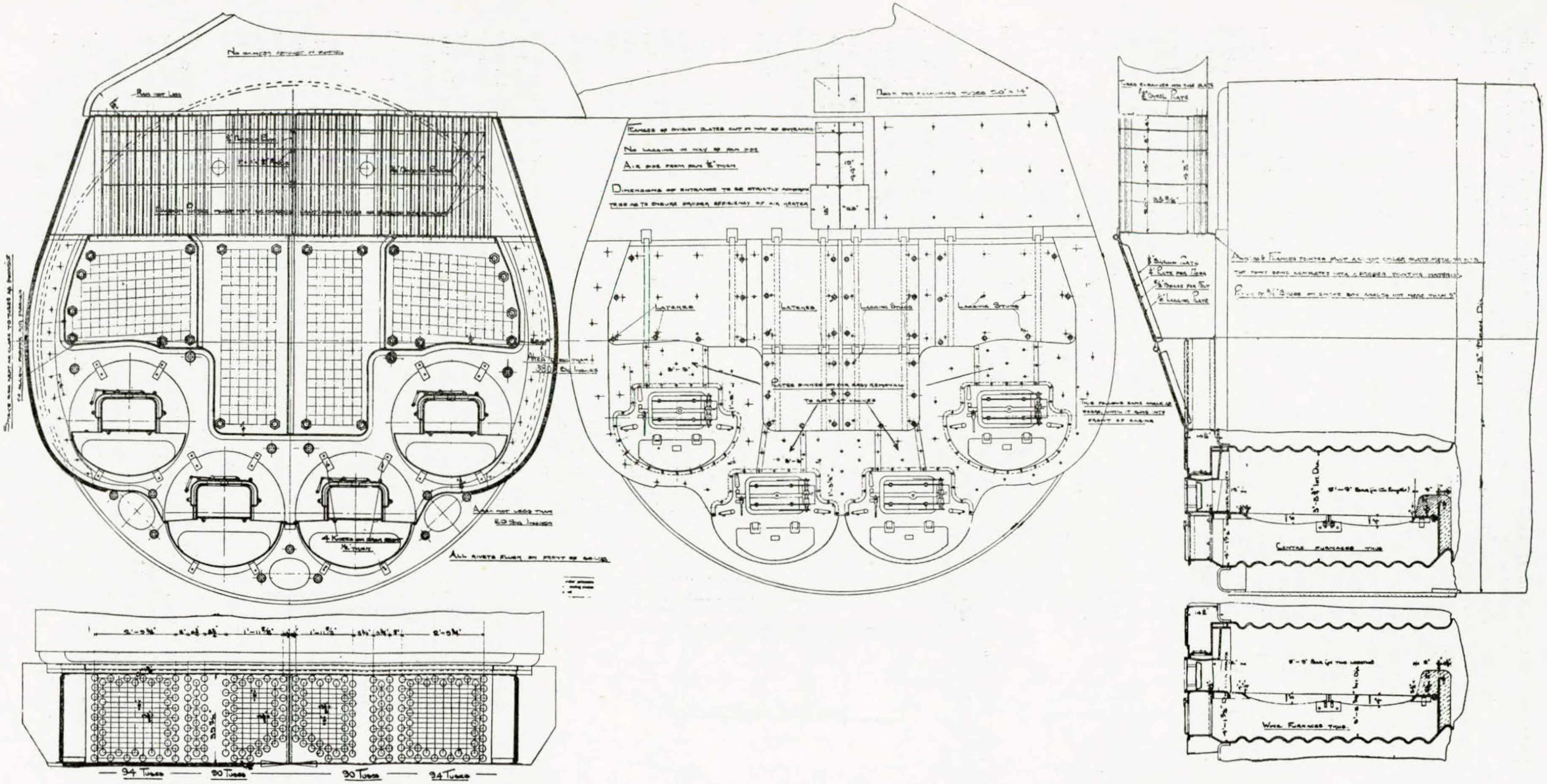



FIG. 4.—*One of forty-eight air preheaters on the old "Mauretania".*

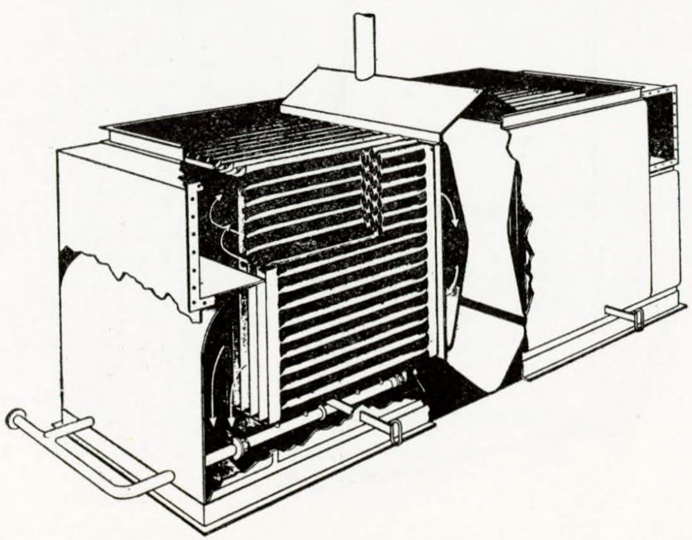


FIG. 5.—*Turbulent flow air preheater.*

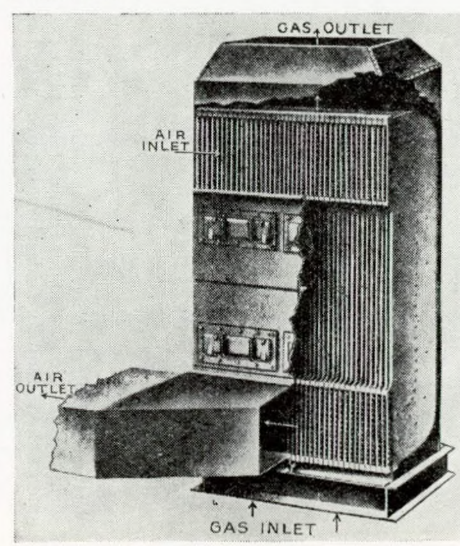



FIG. 6.—*Usco preheater.*

recovery some 50 per cent. greater in the same space as that occupied by the standard 4-ft. tubular preheater. A typical turbulent-flow air preheater is shown in Fig. 5. In this, the sinuous gas passages induce turbulence, and the air can have single, double or triple flow. In the example illustrated double flow is shown. Fig. 6 illustrates a preheater with closely-spaced plain plates, but this type does not appear to have been used to any extent at sea.

It was, of course, possible or necessary in some ships to put an air preheater in the uptake casing, and this might serve two

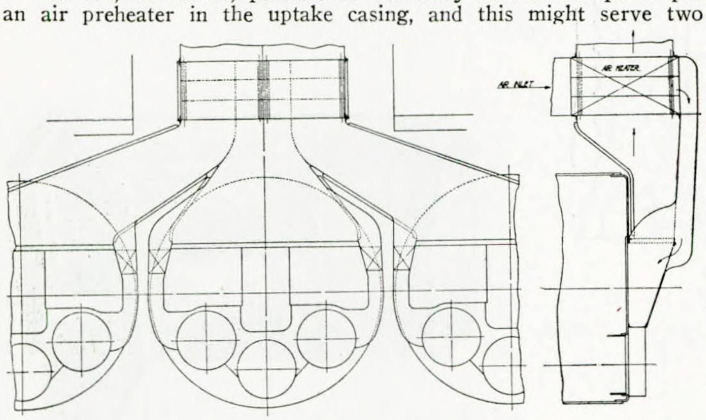


FIG. 7.—*Air preheater in uptake.*

or more boilers (Fig. 7). Once the air preheater had left the original position, changes could take place in the tube arrangements and multiflow designs became possible. Figs. 8 and 9

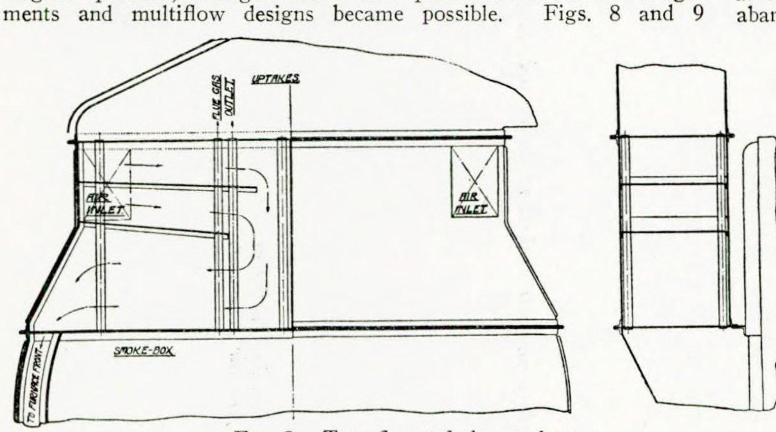



FIG. 8.—*Two-flow tubular preheater.*

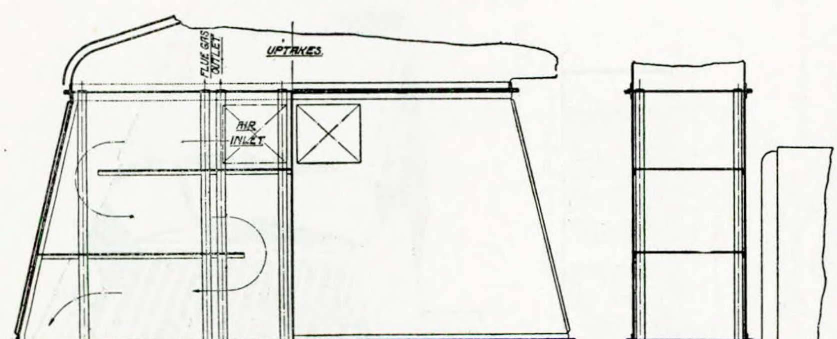



FIG. 9.—*Three-flow tubular preheater.*

show respectively double-flow and triple-flow preheaters accommodated in the usual position above the smokebox. These, however, were rather unusual, and on coal-fired boilers, especially in the earlier days, air temperatures much higher than those obtained from the normal preheater were frowned upon in case trouble might arise when burning certain classes of coal with ash having a low fusion point.

The growing use of oil fuel, however, had a considerable effect on air-preheater design, just as the use of pulverised fuel had the same effect in land practice. No restriction of air temperature was imposed by furnace conditions, and designers began to exploit this relaxation in marine boilers designed for oil firing only, by going in for progressively larger air preheaters with higher and higher heat recoveries. These large air preheaters have tubes 2½in. to 3in. dia., 10 to 14 B.W.G. thick, and anything up to 20 or 30 ft. in length. The tubes are expanded into tube plates supported at the top and bottom of a casing constructed of thin plates stiffened as required by a structural frame. The gas passes upwards through the tubes. The air to be heated enters one side of the casing below the tube plate at the cold end, and passes back and forth around the tubes, being discharged through the casing beside the lower (hot end) tube plate. The air is constrained to flow back and forth several times in its passage by suitably disposed division plates and has thus a combined cross and contra flow. These high recoveries unfortunately led to various difficulties in operation which are mentioned later, and the result has been that very large tubular preheaters with efficiencies of 65 to 70 per cent. are now seldom built, and many engineers consider it unwise to design a tubular air preheater having an exit gas temperature lower than 350°F. or even 400°F. as recommended in the recent symposium on water-tube boilers held under the auspices of the Institution of Naval Architects. In the design of the smaller tubular preheaters soot blowers were hardly ever incorporated, but with the longer tubes of later designs it was found necessary to include these, and most modern preheaters should have arrangements for soot blowing. The effectiveness of soot blowers on long tubes, however, is questionable.

So far the tubular preheaters discussed have been designed with the gases inside the tubes and the air outside. The opposite arrangement was tried many years ago on cylindrical boilers and abandoned. Recently it has been revived on water-tube boilers, mainly perhaps because such a design lends itself to a compact arrangement of tubes which may be tucked neatly into corners of the boiler casing, thus saving headroom. Such air preheaters are usually arranged with the air tubes horizontal, and the gas flows around and among them in the vertical direction. The result may be a fairly deep bank of tubes, the surfaces of which have to be kept clean by soot blowers installed in suitable positions, and the prevailing tendency in design is therefore to keep the horizontal banks shallow, sacrificing heat recovery accordingly.

All the preheaters mentioned have been developments of the original tubular preheater box designed by James Howden in 1882, and have made use of the recuperative principle in which the heat from the hot gases on one side is conducted through the metal of the tubes or other heating surface to the cold air on the other side. As has been indicated, difficulties in operation arise when this principle is carried too far, and the safe limit to which the gas temperature may be reduced has already been mentioned.

Fortunately, however, for the continued progress in heat recovery by air preheating, the well-known Swedish engineer Frederic Ljungstrom was engaged some twenty years ago in the design of a turbine locomotive. Among the auxiliaries which he visualized for this was an air preheater. This preheater was to be mounted in the smokebox of the locomotive, and was thus cylindrical. He conceived the idea of making the cylindrical heating surface revolve and dividing it so that the gases passed axially through one half while the air for combustion passed through the other half in the opposite direction. The principle involved was that of the old Siemens brick-lined regenerator, but instead of the gas and air being switched alternately in opposite directions through the same passage, the air and gas passages were separate and the heating surface passed round from one to the other, taking with it the heat absorbed from the gas and giving this up to the air. The apparatus was thus a continuous contraflow regenerator.

While this air preheater was abandoned in the locomotive, it was seen to have possibilities in other applications, and it has undoubtedly proved itself satisfactory in stationary and marine installations.

The essential features of this preheater are a rotor carrying the heating surface enveloped by a divided casing which guides the gas and air streams through the heating surface as the rotor slowly revolves, adjustable seals being provided to limit leakage between the gas and the air. The rotor is an open-ended drum divided by radial plates into sectors which contain the heating surface.

In its original form separate from the locomotive, this rotary regenerative air preheater had a vertical axis and it had integral forced- and induced-draught axial fans mounted on a common shaft, the rotor being driven through gearing from this shaft. Fig.

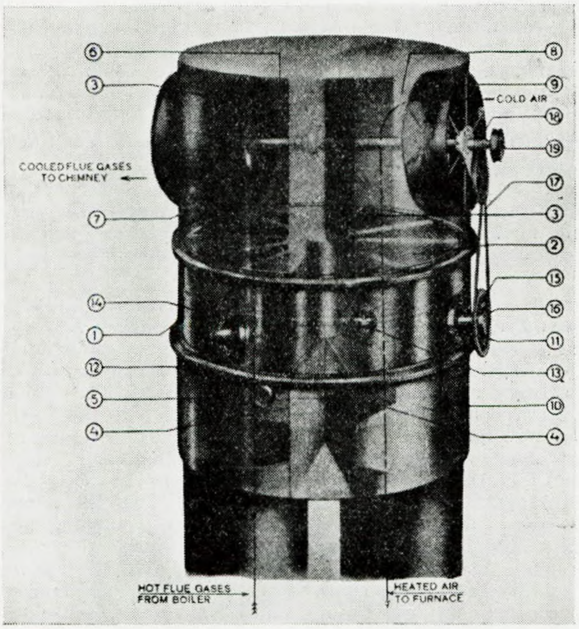



FIG. 10.—*Old C-type Howden-Ljungstrom preheater.*

1. *Rotor*
2. *Heating elements*
3. *Upper partition wall.*
4. *Lower partition wall.*
5. *Lower flue gas chamber.*
6. *Upper flue gas chamber.*
7. *Flue gas fan.*
8. *Upper air chamber.*
9. *Air fan.*
10. *Lower air chamber.*
11. *Driving roller.*
12. *Soot blowing device.*
13. *Guide roller.*
14. *Carrying roller.*
15. *Sprocket wheel.*
16. *Clutch.*
17. *Chain.*
18. *Speed reducing gears.*
19. *Pulley.*

10 shows the apparatus at this stage in its development. It was soon considered advisable, however, to separate the heater proper from the fans, and the result of this step is seen in Fig. 11. In this air preheater at this time, the rotor containing the heating surface was encircled by a hardened race ring supported on three

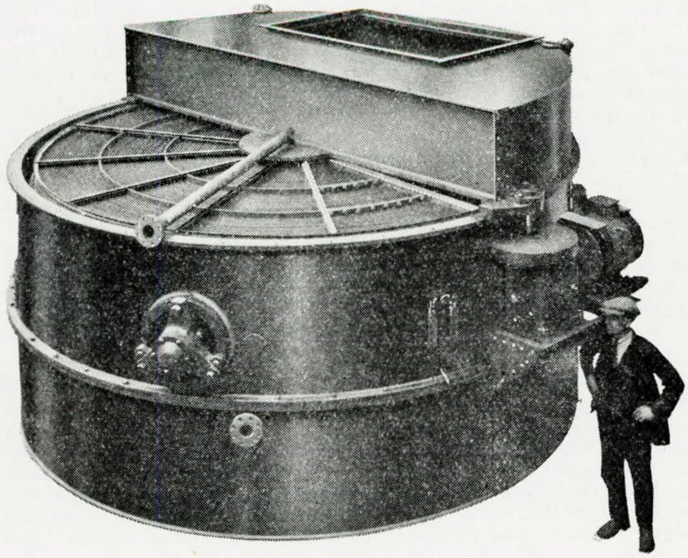


FIG. 11.—*Old CX type Howden-Ljungstrom preheater.*

rollers and centred by three smaller rollers working on its face. The rotor was driven at 4 r.p.m. by a pinion engaging with a rack attached to the race ring or merely by the friction between one of the rollers which was driven and the race ring. The power absorbed, even for large preheaters, was only about ½ h.p.

A parallel step in the development was the design of a preheater with a horizontal axis, which in some cases simplified the arrangement of the installation. In this type the rotor was carried on an axle running in two bearings, one on each end of the casing. The drive was still by rack and pinion, but in this case a pin rack was used in conjunction with a pinion having large teeth, and no lubrication of the rack and pinion was necessary. This type of rack having pins 1-in. dia. proved so successful in service that the same type was adopted in the vertical axis preheater.

The next step in the development was the replacement in the vertical preheater of the race ring and rollers by a central housing containing radial bearings and a heavy thrust bearing to carry the weight of the rotor. Instead of this weight being carried through the casing, which up till this stage had accordingly to be of heavier construction, it was now possible to locate the new central bearing on a beam incorporated in the top of the casing, the beam

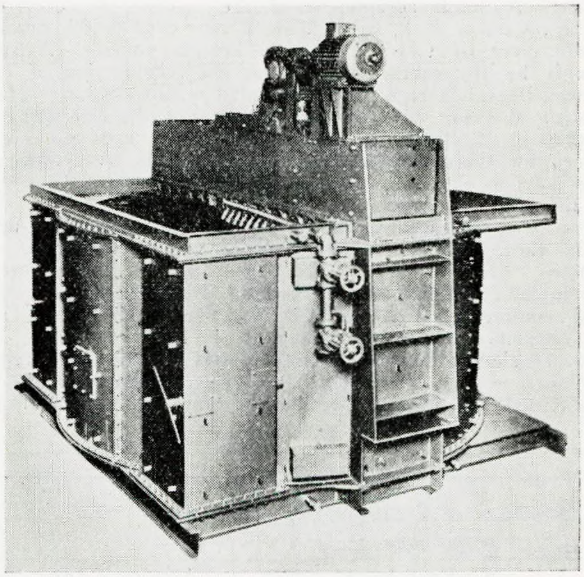


FIG. 12.—*Modern central drive Howden-Ljungstrom preheater.*

transmitting the load direct to the supporting structure. In some cases this central bearing arrangement was combined with a central drive for the rotor, but the peripheral drive through the pin rack

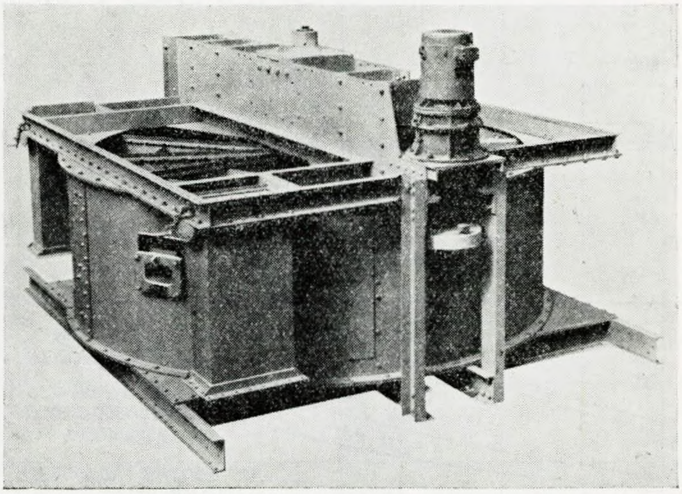


FIG. 13.—*Modern rack drive Howden-Ljungstrom preheater.*

was, and is still, used for marine purposes. Figs. 12 and 13 show the vertical axis preheater as now made with central drive and rack drive respectively.

There are other features of the casing design which will be mentioned later in connection with maintenance, but some remarks on the heating surface itself might now be appropriate.

The original heating surface consisted of mild-steel plates 25 gauge thick (·020in.). The plates were individually packed into the sectors of the rotor, parallel to the chords of the sectors. They were alternately plain and corrugated parallel to the direction of flow of the air and the gas. The heating surface thus consisted of a great number of small triangular passages of such size that the inscribed circle diameter was 6·4mm. The size of the corrugations could be altered to meet different requirements of heat recovery and pressure drop and, as would be expected, the larger the corrugations were made the lower was the draught loss, and also the efficiency of the heating surface.

The next step in the evolution of the design of heating surface was to replace the plain plates by plates having a shallow undulation at right angles to the direction of flow of the air and gas. This corrugated-undulated surface increased the turbulence, and thus the heat recovery, at the expense of a slightly increased resistance. A small adjustment of the spacing, however, would bring the resistance back, still leaving a very considerable advantage from the point of view of reduced heating surface. A further advance in heating surface design was the introduction of double turbulence, if such a term can be applied. After a long series of experiments this was accomplished by changing the direction of the undulations so that these ran at 30° to the direction of the flow. At the same time the corrugations in the other plate were replaced by spacing notches of wider pitch and less depth than the corrugations, the plate between the notches being flat. The double turbulence was obtained by the sinuous passage between the undulations and the plain plate in one direction and by the angle of the undulations to the direction of flow throwing the gases against the notches in the other direction. This type of element is known as the notched-undulated, and it resulted in a very considerable reduction in resistance with a slight increase in heating surface.

Fig. 14 shows the main characteristics of the three types of heating surface. The dimensions have been selected for the same flow rate, and the curves show the resistance and the heating surface for the three types of elements plotted against the mean efficiency of the preheater with a gas leaving temperature of 250°F. The corresponding air leaving temperature is also shown.

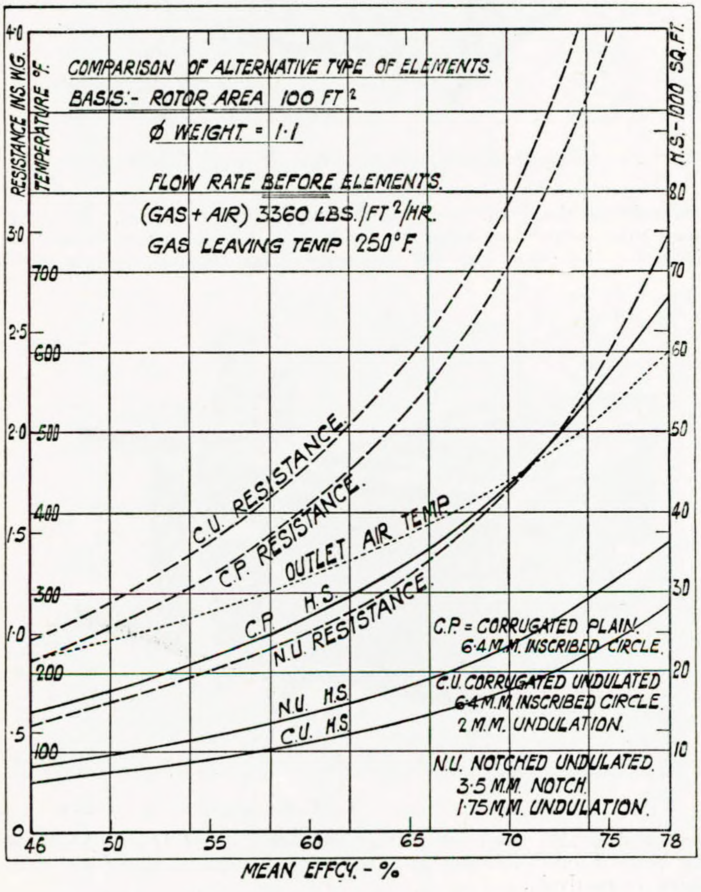



FIG. 14.—*Curves showing characteristics of elements.*

A clearer view of the effect of these steps in the design of the heating surface may be obtained by looking at the performances of the three types on a percentage basis. If the heating surface and resistance of the original corrugated-plain elements were taken as each being 100, then for the corrugated-undulated surface the corresponding figures would be, heating surface 40, resistance 110, and for the notched-undulated the heating surface would be 55 and the resistance 60 in round figures.

The result of all this is that normally the notched-undulated type of surface is now almost universal.

The rotary preheater obviously has moving parts, and this has sometimes been held against it as a disadvantage. On the other hand, the advantages which it offers are very great, and any disadvantage due to the motion is practically eliminated by proper design.

It will have been noticed from the description already given that the rotor, which in modern examples revolves at only 1¼ to 3 r.p.m., is carried on a heavy thrust bearing in conjunction with radial bearings. The operation of the air preheater depends on these bearings, and also on the driving motor and reduction gear. As regards the bearings, the manufacturers of ball and roller bearings can now give very accurately the life to be expected from any particular bearing under specified loading and temperature conditions. Normally the life is taken to be at least 25 years' continuous operation. The loading is known, and the temperature can be controlled by incorporating a simple oil pumping and cooling unit circulating oil through the bearing housing. It is therefore a simple matter to select a bearing to give the life required. Fig. 15 shows the arrangement of the bearing housing and the details of the pumping and cooling unit. The motor is usually rated at 2 to 2½ h.p. to overcome the starting torque, but in operation it absorbs less than 1 h.p. in the largest preheaters, and consequently runs at a light load and causes no trouble. The reducing gear, too, is accordingly lightly loaded. The pin rack mounted on the periphery of the rotor has already been mentioned, and in operation it requires no attention.

In the rotary regenerative preheater there must, of course, always be leakage, but this leakage is there from the beginning and the design of the seals is such that it can be controlled and remain constant throughout the life of the installation. These seals consist of adjustable steel strips on the radial plates and circumferential plate of the rotor. The radial seals bear on sector sealing plates in the casing at each end of the rotor. These sector sealing plates slightly overlap the sectors of the rotor to ensure that there is always at least one radial seal in action on each diameter. The circumferential seals in the same way bear on inside flanges of the casing. Axial seals are also fitted which prevent flow of air between the periphery of the rotor and the casing. There is also a degree of leakage from the air side to the gas side and *vice versa,* due to the entrainment of air and gas in the rotor itself. The speed of the rotor, however, which is determined by the admissible temperature range of the heating surface between the gas side and the air side, is so low that the amount of entrainment is about 1 per cent. With the sealing arrangement properly adjusted and allowing for entrainment, the leakage can be controlled at 6 to 7 per cent., depending on the pressure difference between the air and the gas. This constant leakage has to be taken into account in determining the duties of the draught fans, but it is a known quantity, and by selecting a preheater to give a low resistance the fan power absorbed can easily be reduced to compensate. Fig. 16 shows the sealing arrangements.

The application of soot blowers to the rotary preheater is simplified by the convenient fact that every half minute or less the whole of the heating surface passes across a radial line. A stationary soot blower with a series of nozzles arranged radially will therefore cover the entire surface several times per minute. The blowers, of which there are two, one on either end of the rotor, can therefore be placed within a few inches of the ends of the heating surface, and the full velocity of the steam issuing from the nozzles is utilized in the spaces between the elements, so that these spaces virtually become extensions of the nozzles, and are subjected to a most effective scavenging, especially as the height of the elements is, at most, some 4 or 5ft. Draught gauges are fitted to show the resistance through the rotor, and these indicate the formation of soot, and serve to show at what intervals the blower should be used.

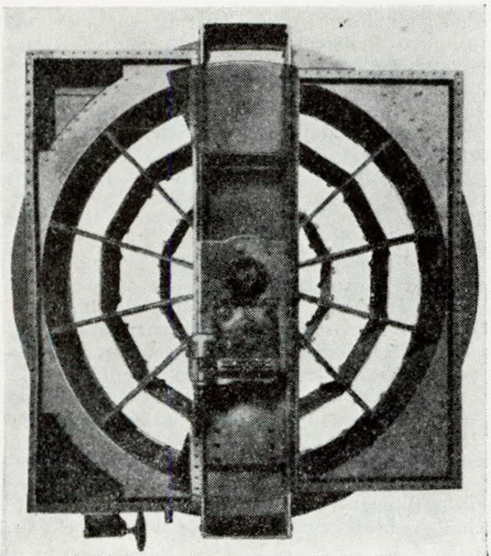


FIG. 17.—*Casing and rotor from above (no heating elements).*

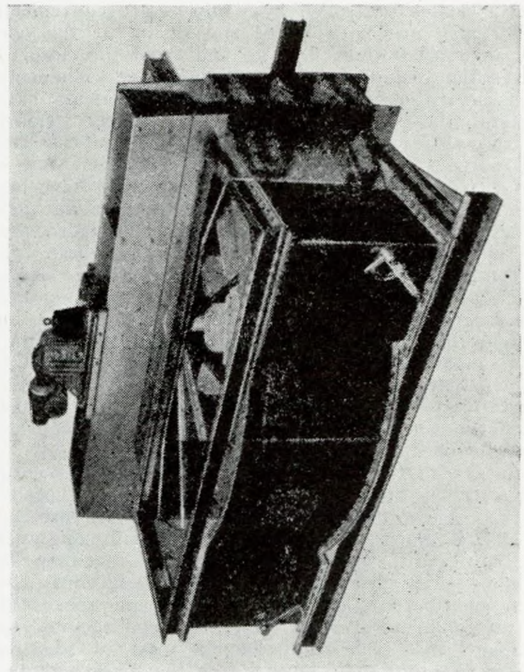


FIG. 18.—*Three-quarter view of casing and rotor with "ghosted" seals.*

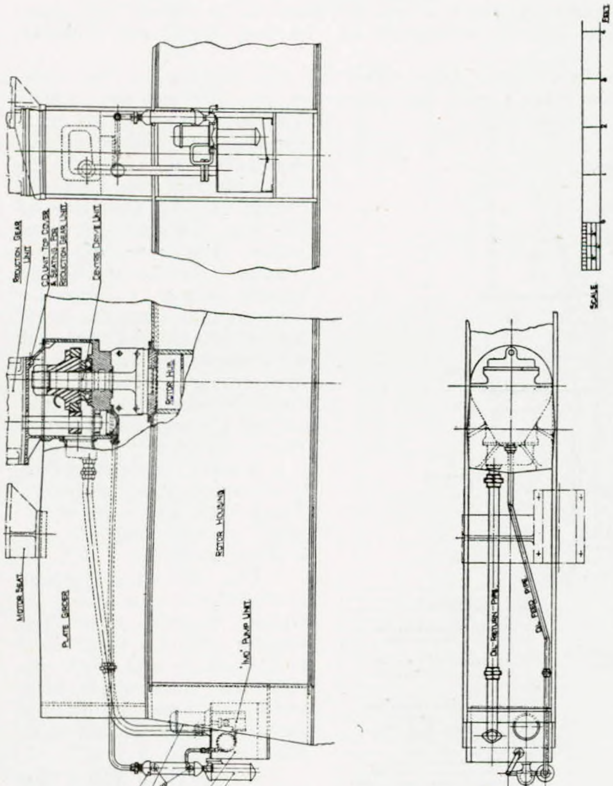


FIG. 15.—*Bearing housing and pumping and cooling unit.*

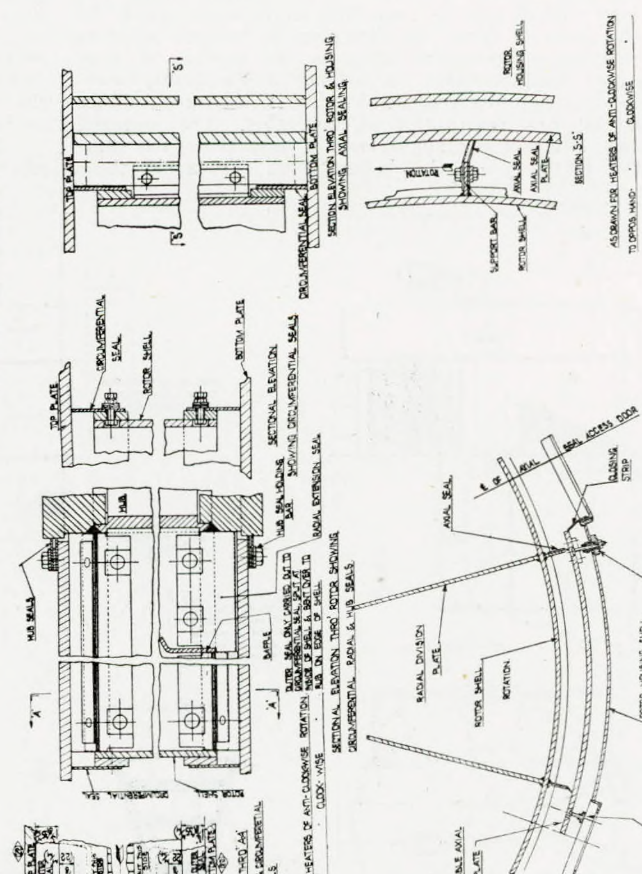


FIG. 16.—*Sealing assemblies for rotary air preheater.*

Air bypasses controlled by dampers are conveniently arranged on the rotary preheater inside the casing at the corners where the rectangular air ducts lead to and from the circular rotor. Fig. 17 shows the casing and rotor from above. The rotor construction is clearly visible, as the heating elements have not been packed into the sectors, and the radial sealing strips can also be recognized. The air bypasses with the dampers closed are at the top corners. Fig. 18 shows a three-quarter view of the same preheater, in which the various features which have been discussed will be recognized. In this illustration the sealing surfaces at the top, sides and bottom of the rotor are superimposed by "ghosting" on the photograph. It will be realized that these "ghosted" surfaces complement the radial and axial sealing strips. The circumferential flange on the casing, which is also clearly seen both in this figure and the previous one, has the same function with relation to the continuous seal on the periphery of the rotor.

The maintenance of air preheaters on board ship is, on the whole, a comparatively simple matter, provided the design has been carefully considered before the installation is made, and also provided the actual working conditions approximate to those for which the preheater was designed.

In operating the preheaters it is essential to ensure that the heating surfaces are kept clean and free from deposit by the use of the soot blowers, if at all possible. It has already been mentioned that large recuperative preheaters with long tubes are now seldom built, and the main reason for this is that they are so difficult to maintain in a clean condition. The design may show that at the cold end there is a considerable margin above the dew-point in the tube temperature, but this is the end remote from the soot blowers, and it is difficult to keep it clear of soot deposit. The soot forms an insulating layer inside the tubes and diminishes the heat transfer from the gas to the tube. On the air side, however, there is no such layer, and the heat transfer from the tube to the air is not correspondingly diminished. The temperature of the tube at the cold end, therefore, falls, and the margin which was allowed may prove insufficient to keep this temperature above the dew-point of the gases. When the dew-point is reached moisture is deposited, causing a cumulative effect in the deposit of soot. This moisture also combines with the sulphur in the gases, forming sulphuric and sulphurous acids which attack the tube surface and cause corrosion and perforation of the tubes. The resulting leakage adversely affects the draught control, and hence the combustion and the efficiency of the boiler plant. To avoid these hazards it is generally agreed by engineers that the final gas temperature in recuperative preheaters, as previously mentioned, must be kept above 350°F. as a minimum.

Another reason for maintaining clean heating surfaces in operation is the danger of fire. What may start as a comparatively harmless soot fire may raise the temperature of the heating surface sufficiently to cause carburization of the steel and the destruction of the preheater. This phenomenon is, fortunately, of rare occurrence, and can only happen through the deposit of soot being allowed to accumulate. If any suspicion arises during operation that deposit is gathering at the cold end of the tubes in spite of the use of soot blowers, the first opportunity should be taken to inspect the tubes and clear them, either by steam lancing, brushing, rotary tube cleaners, or the use of rods. The opportunity should also be taken to ensure that the tubes are tight in the tube-plates and, if necessary, an expander or even a drift should be used to expand the tube ends and prevent increasing leakage. This is a point which requires careful attention, particularly in preheaters with long tubes, because the difference between the expansion of the hot tubes and the cooler casing may amount to at least ¼in., and with alternate heating and cooling the tubes tend to work loose in the tube plates, and the resulting leakage may be as much as 10 or 15 per cent., or even more.

If there has been choking, it is more than likely that the dew-point has been reached, and there may also be perforation of the tubes involving complete retubing—rather a costly matter—or at best telescoping or welding shorter tubes on the long tubes to replace the damaged parts.

The proper maintenance of the rotary regenerative preheater also necessitates keeping the heating surface clean, but this is a much easier matter for the reasons already explained in describing its soot-blowing arrangements. With oil firing, the use of only the lower soot blower (blowing with the gases) once in 24 hours, or even less frequently, will generally be ample to maintain clean conditions. The cleaning of the heating surface is necessary to keep the resistance to the flow of air and gas low, rather than to avoid the dew-point troubles of the large recuperative preheater. In this respect the regenerative preheater has three outstanding advantages which allow the gases to be cooled far below the minimum already mentioned as the safe limit with tubular preheaters.

In the first place, both sides of the heating surface are alternately in contact with the gases and air, and any soot which may be formed on the heating elements will be equally distributed on both sides, thus affecting the heat exchange in both directions to the same extent. In other words, the rate of heat transfer from the gas to the heating surface is always the same as that from the heating surface to the air, and the temperature of the heating surface remains the mean between those of the air and the gas, and for the same operating conditions it is always higher than that in a recuperative preheater. There can therefore be no local undercooling of the heating surface.

The second advantage is that the relatively dry air which sweeps over the heating surface every half revolution would pick up moisture which might have condensed when the heating surface was in contact with the gases.

In the third place, the heating surface is not the partition between the air and the gas, and if corrosion were ultimately to start no cross leakage would take place as a result of that corrosion. The

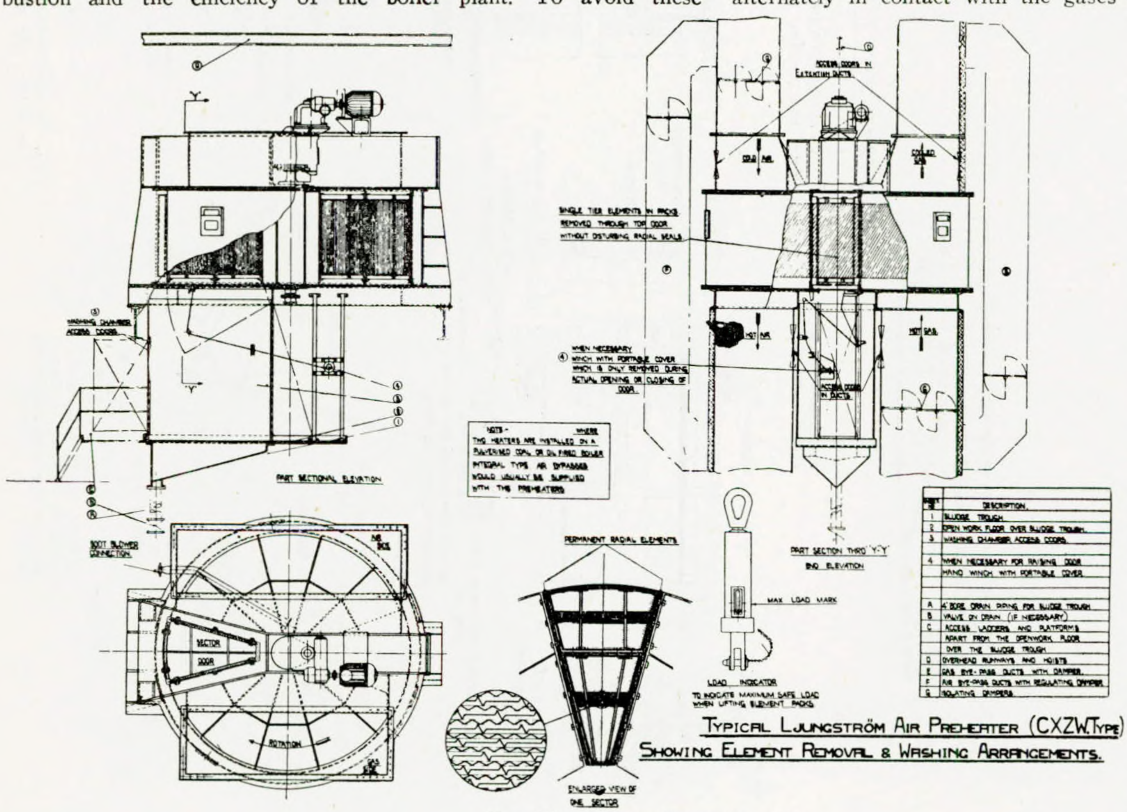



FIG. 19.—*Removable sector plate.*

draught control, and hence the boiler capacity, would be unaffected.

These facts, and especially the first, allow the rotary regenerative preheater to be designed and operated so that the mean temperature of the heating surface at the cold end is only a few degrees above the dew-point, with the assurance that it will not fall lower and, therefore under ordinary conditions, will never reach the danger zone.

This assumes that the boilers are operating at the designed load. On low load the temperature of the gas leaving the boiler

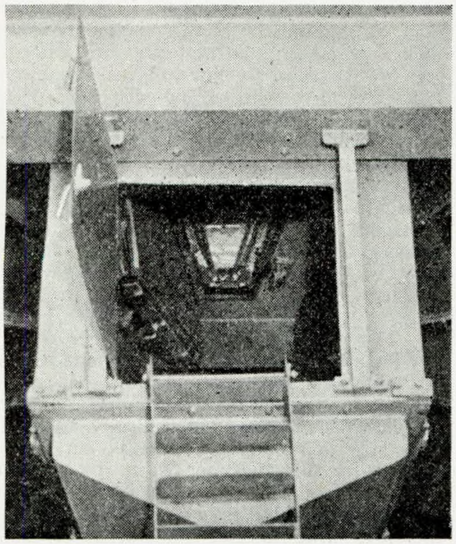


FIG. 20.—*Photograph of removable sector plate.*

falls, and the temperature of the heating surface is reduced. This applies to recuperative and regenerative preheaters alike. With the regenerative type, however, the operator has the advantage of knowing the temperature of the heating surface, and he can control this temperature by maintaining a minimum "combined" temperature. This "combined" temperature is the sum of the exit gas temperature and the entering air temperature. The minimum varies with different types of fuel and conditions of installation, but usually the sum should not be allowed to fall below 330°F., which is equivalent to air entering at, say, 90°F., and gas leaving at 240°F. This control is effected by operation of the air bypass dampers, and is usually necessary only on low loads or when starting up. Such control can, of course, be exercised with recuperative preheaters too, but there is always uncertainty in estimating the tube temperature in these.

The seals in the regenerative preheater should be inspected and adjusted if necessary when opportunity occurs, and the automatic lubrication system should be inspected from time to time to ensure that it is functioning properly, and that the oil is effectively cooled.

Although it is not strictly a marine matter, it might be of interest to refer to conditions which arose during the war in certain power stations with boilers fired by mechanical stokers. These conditions raised very difficult problems in maintaining the boiler availability. In these installations the abnormally high dew-point temperatures occurred due, it was recognized, to the gases containing an excessive amount of sulphur trioxide. It was at first suggested that the sulphur content of the fuel had something to do with this, but as the same fuel in other plants did not produce the same con-

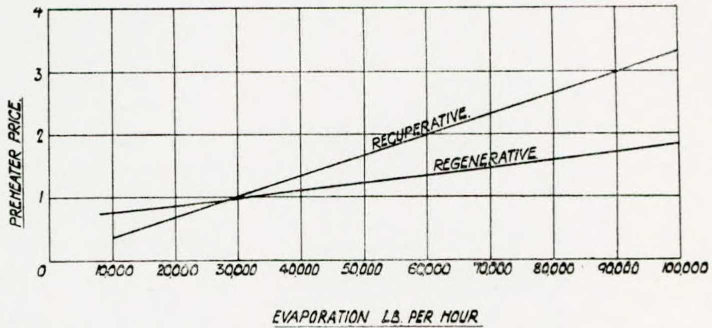



FIG. 21.—*Costs of recuperative and regenerative preheaters for different evaporations.*

ditions it was clear that the fuel alone was not responsible. Harlow* submitted evidence to show that the oxide film on high temperature superheater tubes could act as a catalyst in the conversion of sulphur dioxide to sulphur trioxide, thus increasing the sulphuric acid content of the gases and raising the dew-point to the abnormal extent found in these cases.

This high dew-point caused trouble in economisers and air preheaters where a hard bonded deposit was formed, and in some cases it even affected the last passes of the boiler. This did not yield to soot blowing, and the availability of the boiler plant was seriously impaired. It was found, however, that this hard deposit yielded to washing after soaking with a solution of soda ash in hot water. The problem, however, was to do this with the boiler still on load. As far as the rotary preheater was concerned the solution of the problem was fairly easy when some modifications to the casing and the packing of the elements in the rotor had been made. The object of these modifications was to make the heating surface accessible either for removal and replacement or for washing without interrupting the flow of gas and air through the preheater. The sector sealing plates in the normal preheater slightly overlap each sector of the rotor as this passes between them for the reason already indicated in the explanation of the

*"Causes of High Dew-point Temperatures in Boiler Flue Gases" by W. F. Harlow, Wh.Ex., A.M.I.Mech.E.

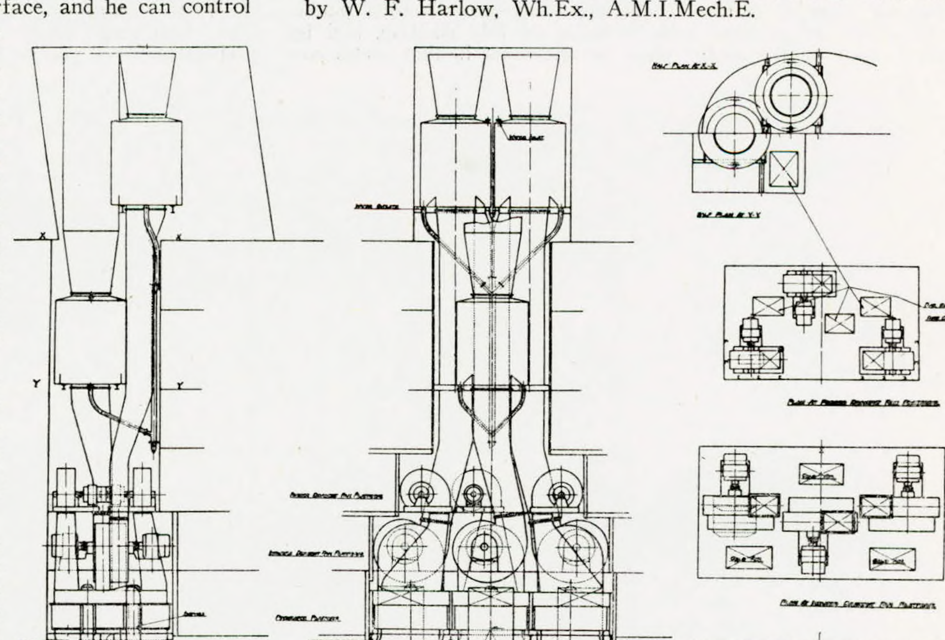


FIG. 22.—*"Asturias" and "Alcantara".*

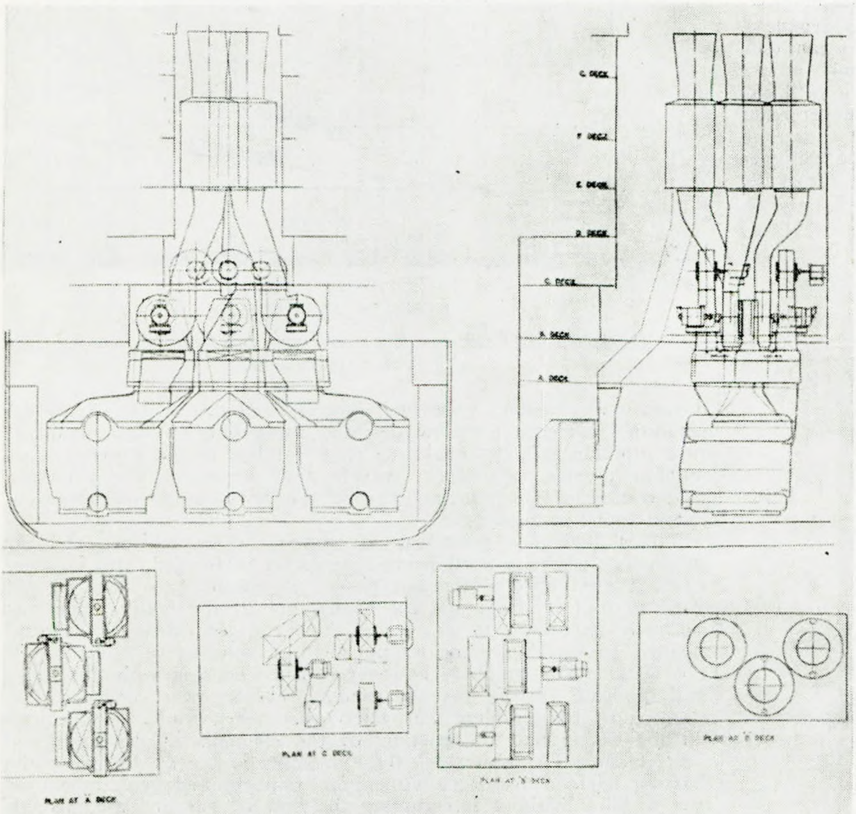


FIG. 23.—*"Andes"*.

sealing arrangements. It will therefore be clear that as the rotor revolves, each sector is successively momentarily sealed from both gas and air when it is directly between the sector sealing plates. The rotor can be stopped with a sector in this position, and by opening a door on the sector plate the elements in that sector are easily accessible. With the heating elements packed in interchangeable containers which fit the sectors it is a simple matter to remove these containers, replacing them by other containers with new elements. The removed elements can then be cleaned at leisure and kept to repeat the process should the hard bonded deposit again be formed.

An alternative process which has also been carried out with success in certain power stations where these peculiar conditions arise, is that of washing the heating surface without removing it from the rotor. This is done by soaking the sectors with soda-ash solution and then washing with hot high-pressure water. In this case the lower sector sealing plate is also opened and a hopper below collects and disposes of the washing water. Fig. 19 shows the details of the door in the sector plate and the removable containers carrying the heating elements, while Fig. 20 is a photograph of the arrangement. As has already been inferred, these conditions have not arisen at sea, but it is hoped that the reference to them here is justified as showing how the special features of the rotary regenerative preheater may be adapted to meet very difficult conditions raising problems which cannot be solved in the recuperative type.

The choice of the correct type of preheater for any installation depends upon the performance required. For high heat recoveries and low exit gas temperatures the rotary regenerative type offers great advantages, and its choice is correct, technically, for such conditions. The size and output of the boiler, however, has a bearing on this question, as the first cost of a rotary preheater in small installations is influenced by its mechanical features. As the size of the preheating plant increases with the size and output of the boilers, the effect of the additional cost of the mechanical features becomes less and less, and for boilers of 25,000 to 30,000lb. evaporation per hour the costs of the rotary preheater and the recuperative preheater are about the same. Above this size of boiler the difference in cost becomes more and more marked in favour of the regenerative preheater, as is seen in Fig. 21, which gives the relationship between the costs of the two types of preheaters for different evaporations. The following table compares recuperative and regenerative preheaters for a marine boiler of 60,000lb. evaporation per hour:—

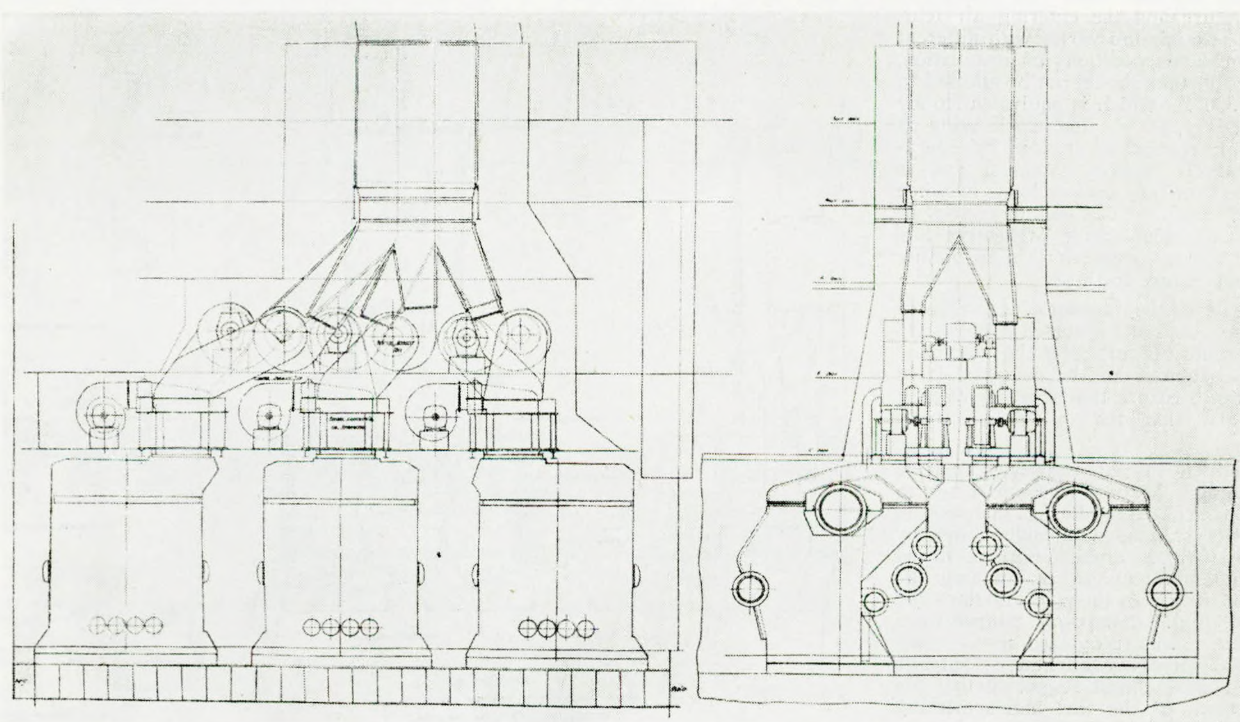


FIG. 24.—*"Awatea"*.

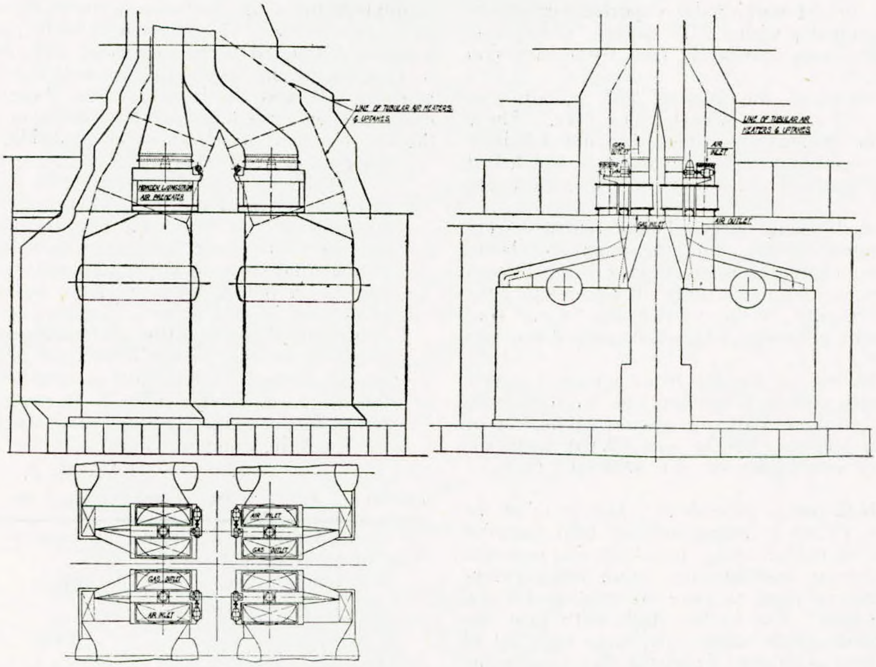


FIG. 25.—*Recuperative preheaters replaced by rotary preheaters with closed stokehold forced draught.*

| Preheater. Type. | Tubular Recuperative. | Rotary Regenerative. |
|---|---|---|
| Weight, tons ... ... | 31 | 12 |
| Space occupied by heating surface, cu. ft. ... ... | 2,200 | 250 |
| Price ... ... ... | 1·5 | 1 |

Near the beginning of the paper some early applications of marine air preheaters were described. It might be appropriate, in conclusion, to refer briefly to one or two modern installations. Fig. 22 shows the arrangement of the uptakes on two sister ships which have been in operation for about twelve years. The rotary air preheaters between the boiler tops and the induced-draught fans are clearly seen. The forced-draught fans are placed above the induced-draught fans and up in the funnel the wet vortex dust collectors are situated. Fig. 23 shows a similar arrangement in the Royal Mail liner *Andes,* while Fig. 24 shows the arrangement on the s.s. *Awatea.* In all these installations the gas leaving temperature is about 240 to 250°F.. and the heat recovery or gas side efficiency is between 65 and 70 per cent. Fig. 25 shows the outline of an installation of tubular air preheaters in which troubles such as those already described have been experienced. Rotary preheaters to replace these are also shown on the drawing. In spite of the obvious reduction in the space occupied by the rotary units, the exit gas temperature from them is some 100°F. lower than that from the tubular preheaters.

## Discussion.

**Mr. G. H. Harford** (Visitor), opening the discussion, said that the paper afforded an opportunity of bringing to the notice of the marine engineering world the advantages of preheating, which had been known in land practice for many years. It was difficult to understand the reluctance of marine engineers to adopt preheating, as was shown in the symposium in 1944, in which only a small percentage of the papers read proposed preheaters. The general feeling in those papers was that, not only were final gas temperatures of 300° F. tolerated, but temperatures of 400° F. were encouraged by the shipowners themselves, as well as by the boilermakers. In view of the reduced oil-carrying capacity necessary for any given trip, and therefore the increased profit-earning capacity of the ship, he would very much like to hear the author's opinion as to why this had not been so readily adopted in marine practice.

The author had referred at some length to the number of preheaters, he mentioned one thousand, installed in the first twelve years after they were adapted for use in marine work. Perhaps he could give some indication of the numbers installed in marine practice in, say, the twelve years before the war, and the preponderance of regenerative to recuperative types of heaters.

He had also mentioned the problem of fouling in land practice, and suggested that the recuperative heater could not overcome these difficulties, and had shown most excellent ways of doing so in the regenerative type of heater. Had this method been successful in cases of severe fouling? In his (the author's) opinion was it not better to tackle the cause of this trouble and eliminate it rather than to effect a cure?

Finally, in Fig. 21 showing the cost of the regenerative and recuperative heaters, which the speaker thought referred to the tubular types of heaters, he had shown the discrepancy in price between the two types, which showed up very much in favour of the regenerative type at the higher sizes of boilers. If one exterpolated that curve to, say, a boiler of 300,000lb., the figure for the regenerative type of heater would be of the order of 4½ units, and for the recuperative type of heater of the order of 10 units. As very many boilers of this size were being installed in land practice to-day with recuperative plate heaters, it was rather difficult to understand why neither the boilermaker nor the user had taken advantage of the price of the regenerative type of heater.

A hearty vote of thanks to the author, proposed by **Mr. A. F. C. Timpson, M.B.E.** (Member of Council), was carried with acclamation.

### BY CORRESPONDENCE.

**Mr. F. R. Le Pla** (Member): With reference to the section of the paper dealing with acid dewpoints and corrosion of preheater elements, the writer would very much appreciate any further views the author might have, or which might be brought out in the discussion, concerning the origin of the $SO_3$ which was usually present in the flue gases passing through preheaters in which excessive corrosion of elements was taking place.

It was probably well known by now that if the cause of $SO_3$ production in boiler flue gases could be definitely established and eliminated, then a large step forward would have been taken in preventing preheater corrosion from acid dew-points.

At the two power stations with which the writer was directly connected, there were similar makes of boilers all fitted with rotary regenerative preheaters. "A" station, in which the boilers were fired with retort-type stokers, was almost continually experiencing severe corrosion of the preheater elements, whilst "B" station, which was fired by travelling-grate stokers, was completely free from corrosion troubles.

The average sulphur content of the fuel at "A" station was 1·6 per cent. whilst that of "B" station was 1·1 per cent. These figures tended to show that the sulphur content of the fuel definitely had some bearing on the high acid dew-point temperatures which had been found present in the flue gases of the boilers at "A" station but not at "B".

The percentage washed slack being burned in the retort stokers at "A" station was approximately 50 per cent., the remainder being dry slack. At "B" station the percentage washed slack being burned on the travelling-grate stokers was approximately 70 per cent. This might, of course, have some bearing on the subject due to one coal giving off a greater percentage of grits which would be passed through the boiler with the flue gases.

It was appreciated that, having on the one hand a power station with preheater corrosion trouble and on the other, one without, both burning very similar South Yorkshire coals, the answer might not be far away. In fact, the main question briefly was—What were the most favourable conditions for production of $SO_2$ without $SO_3$?

**Mr. E. F. Spanner, R.C.N.C. (ret.)** (Member): The problem of designing effective means for securing interchange of heat between a stream of hot gas and a flow of cold air was one which was common to a large number of commercial undertakings, from recuperators used in various types of industrial plant to pure air heating for the drying of foodstuffs and the like. The author dealt with heat exchange apparatus for the purpose of preheating air, to be supplied to boiler furnaces, by means of heat abstracted from the flue gases coming from the boilers.

In the latter part of his informative paper the author made an excellent and authoritative case for rotary preheaters, but, at the same time, he agreed that there were a large number of different types of boiler installation for which it was neither convenient nor economical to provide rotary preheaters. Attention must, of necessity therefore, be directed towards the use of preheaters of the tubular recuperative type.

In a paper *"Some Simplified Heat Transfer Data", Dr. Margaret Fishenden and Dr. Saunders had recently published some very interesting curves clearly indicating that in preheater tube banks the external tube surface was well over 50 per cent. more effective in securing heat transfer than was the internal tube surface.

This might well have been expected since gas or air flowing through a tube was moving parallel to the wall of the tube and could not be so effectively heated or cooled as would be gas or air eddying through a nest of tubes and moving more or less at right angles to the tube surfaces.

In such preheaters as were shown in Figs. 1 and 2 it was obvious that the arrangement was not scientific because there was lack of balance between the efficiency of the heating surface inside and outside the preheater tubes. Such lack of balance became even worse with two-flow or three-flow tubular heaters such as were shown respectively in Figs. 8 and 9. In fact it would appear that a three-flow arrangement which forced the air eddying around the outside of the tubes to pass through roughly three times the length of passage which had to be traversed by the hot gases going through the tubes—this despite the fact that for scientific efficiency the relative lengths of passages should be reversed—was extremely faulty in both conception and arrangement.

Retarders could not greatly improve heat transfer inside a plain tube since, at best, a retarder caused only a proportion of the gas passing through the tube to move more quickly than it otherwise would *along* the inside surface of a tube. A retarder could not possibly cause the gas inside a plain tube to move at right angles to the surface of the tube, *i.e.* to impinge upon the tube wall.

The author mentioned in his paper that although tubular preheaters with the air inside the tubes and the gases outside were tried many years ago and abandoned, recently such designs had been revived on watertube boilers. It must be pointed out that so long as plain tubes were used, similar criticism would apply to these new tubular air preheaters as had been applied to the heaters shown in Figs. 1, 2, 8 and 9.

In 1938, on the initiative of the writer, heat transfer tests were carried out at the City and Guilds Engineering College, London, by Dr. Margaret Fishenden and Dr. Saunders on a series of tubes carrying three similar spirally-impressed grooves. It was anticipated that the presence of these grooves would have a beneficial effect on heat transfer since (*a*) gases passing through the tubes would be forced to impinge upon the surfaces of the grooves, (*b*) there would be little or no possibility of the gas flow "coring", and (*c*) the gas would be in a constant state of turbulence from one end of the tube to the other, so that conditions would be favourable to the greatest possible heat transfer. It was the intention that these experiments should determine whether or not the presence of these grooves would indeed give the improvement which appeared probable.

An extract from the report on these tests read as follows:—

"Table 2 shows the results from Figs. 11, 12 and 13, expressed in terms of the lengths of plain and Swirlyflo tube respectively, required to give the same result. The lengths given are those necessary to reduce the gas temperature to 0·5, 0·6, 0·7 and 0·8 of the total drop to the water temperature. The percentage reduction in length made possible by using Swirlyflo, instead of plain tube is also given. Since, over this range of temperature reduction, there is little systematic variation in the percentage length reduction, means have been given for each pair of tubes. It will be seen that the mean length reduction made possible by the use of Swirlyflo tubes is 46 per cent. for the 2¼in. diameter pipes, 26 per cent. for the 1¾in. diameter pipes, and 27 per cent. for the 1¼in. diameter pipes".

TABLE 2.

REDUCTION IN LENGTH MADE POSSIBLE BY USE OF SWIRLYFLO TUBES.

| Temperature drop, as fraction of total drop to water temperature. | Length of tube required, feet. Plain. | Swirlyflo. | % reduction. |
|---|---|---|---|
| *Diameter 2¼in.* (I.D.) | | | |
| 0·5 ... ... ... ... ... | 4·4 | 2·5 | 45 |
| 0·6 ... ... ... ... ... | 6·2 | 3·3 | 47 |
| 0·7 ... ... ... ... ... | 9·1 | 4·8 | 47 |
| 0·8 ... ... ... ... ... | 12·5 | 6·3 | 46 |
| | | Mean | 46 |
| *Diameter 1¾in.* (I.D.) | | | |
| 0·5 ... ... ... ... ... | 3·6 | 2·7 | 25 |
| 0·6 ... ... ... ... ... | 5·0 | 3·6 | 28 |
| 0·7 ... ... ... ... ... | 6·3 | 5·0 | 21 |
| 0·8 ... ... ... ... ... | 9·4 | 6·5 | 31 |
| | | Mean | 26 |
| *Diameter 1¼in.* (I.D.) | | | |
| 0·5 ... ... ... ... ... | 2·6 | 2·0 | 23 |
| 0·6 ... ... ... ... ... | 3·3 | 2·5 | 24 |
| 0·7 ... ... ... ... ... | 4·5 | 3·0 | 33 |
| 0·8 ... ... ... ... ... | 5·8 | 4·1 | 29 |
| | | Mean | 27 |

and established that, so far as these tests gave evidence, spirally impressed grooves had the effect of making the inside surface of the tube along the axis of which gas was flowing, equally as effective

FIG. 26.

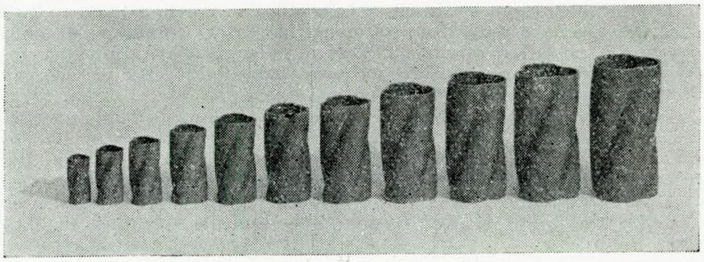


FIG. 27.

*Presented to The Institute of Fuel, 21st November, 1945.

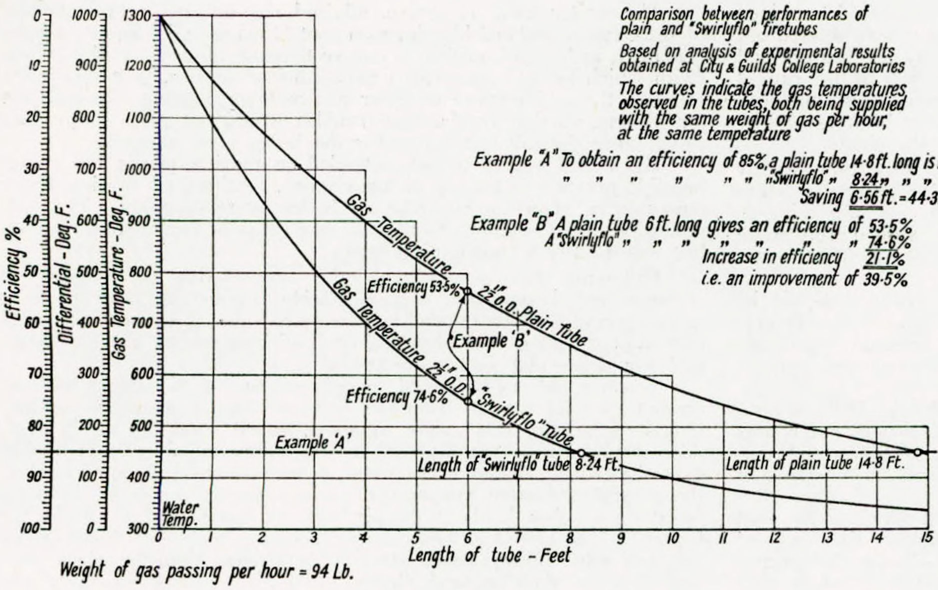



FIG. 28.

for heat transfer as the outside surface at right angles to which gas was flowing.

This result had been confirmed in a number of practical commercial applications of spirally-grooved tubes, and could hardly fail to be of interest to all users and designers of tubular air heaters or recuperators. It offered hope that, by retubing with spirally-grooved tubes, considerable improvement would be secured in the performance of existing preheater units, and suggested that, for new boiler installations, attention must necessarily be given to the merits of spirally-grooved tubes in the interests of economy and efficiency.

Incidentally, study of the information given by the author on page 154 of the paper, and concentrated in Fig. 14, gave excellent supporting evidence of the value of increased turbulence in improving figures of heat transfer in the case of preheaters of regenerative type.

Figs. 26 and 27 showed photographs of a standard range of spirally-grooved tubes from 1¼in. o.d. to 3¾in. o.d.

Fig. 28 which was based upon the experimental results recorded in 1938, gave a comparison between rapidity of temperature drop when gas was passing through a plain boiler tube, and when gas was passing through a Swirlyflo boiler tube.

**Mr. C. P. Parry** (Member): In a paper read at this Institute on 10th March, 1936, the writer offered a complete solution of the problem of maintaining watertube boiler plants in continuous or intermittent service with maximum efficiency and reliability in so far as the cleanliness of the surfaces on the gas side was concerned.

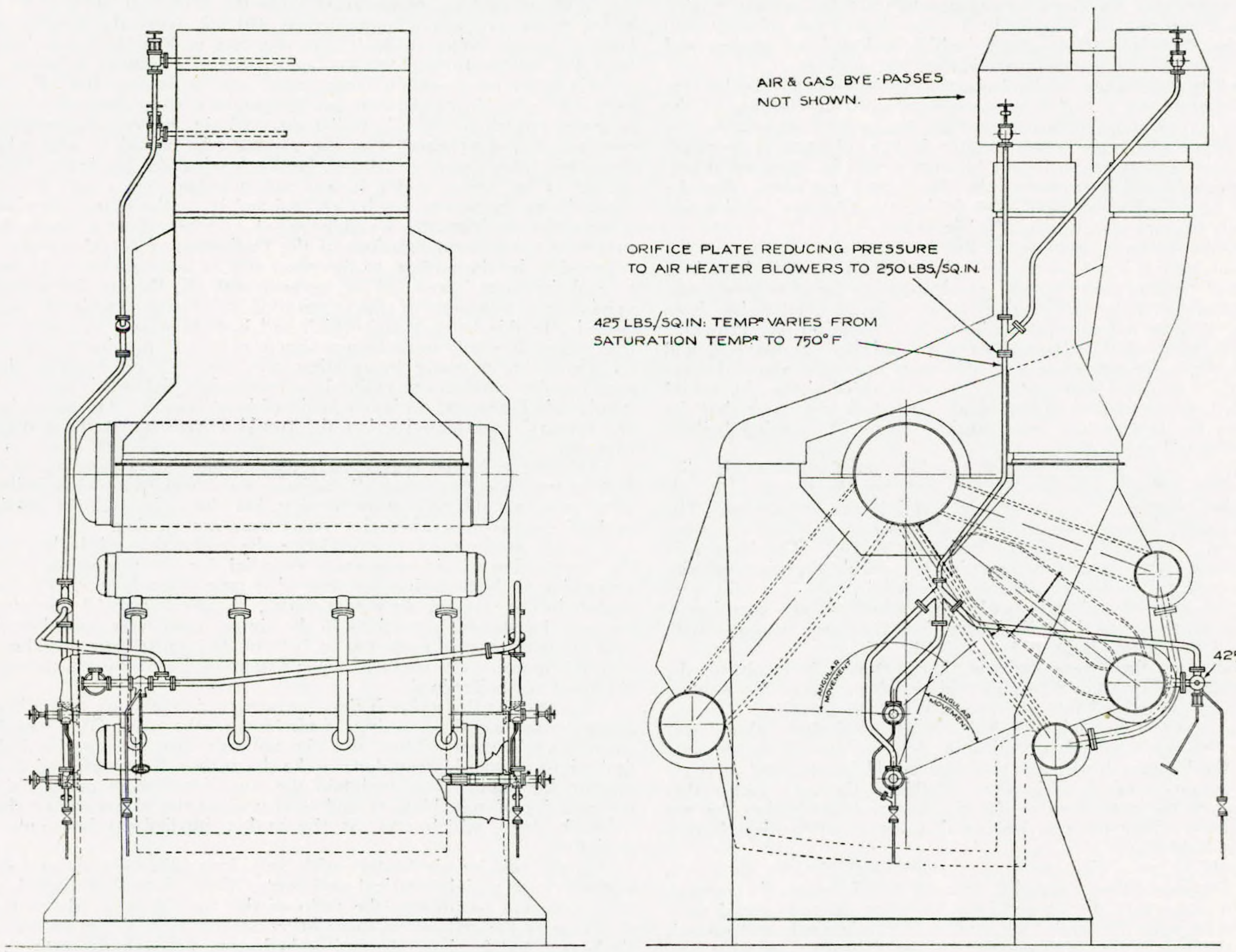



FIG. 29.

In that paper no claim was made that the problem could be solved by the installation of steam soot blowers alone, but it was pointed out how the mal-operation of boiler plants, particularly air heaters and economisers, or imperfections in their design, unnecessarily caused conditions in the whole plant with which soot blowers could not deal. It was also pointed out that unskilfully-applied soot blowers on any part of the plant adversely affected the whole of the plant.

The views expressed in the writer's paper were now widely accepted in marine engineering circles as correct for watertube boiler operation, and the precautionary methods of boiler operation advised, where adopted, gave satisfaction. These methods were merely those obtaining in the best practice with Scotch boiler plants of 50 years ago and since.

The views might perhaps be even more generally accepted by members by reference to the paper on "Water-Tube Boiler Operation" recently read at this Institute by Major W. Gregson of Messrs. Babcock & Wilcox Ltd. This latter paper largely re-stated matters discussed in the writer's paper of March, 1936.

In the appendix to the writer's paper of March, 1936, several land plants with regenerative air heaters were discussed and it was clearly indicated that the writer attributed much of the trouble experienced with the plants to the unskilful manner in which soot blowers were applied to the air heaters.

The writer particularly criticized the counter-draught soot blowers in the gas passages that the air-heater makers then insisted on fitting. The operation of such blowers must elevate the natural dew-point of the boiler gases to anything up to 212° F. whilst they were in operation. Also, as applied by the author's firm, the blowers were too close to the rotors, and the temperature of the gas leaving the rotors was too low for the moisture in the expanded steam to be evaporated before impinging on the rotors. The temperature of the metal being well below 212° F., the rotors functioned as condensers and condensed some more blower steam in contact with the surfaces.

The writer did not refer to regenerative air heaters on marine boilers in his paper of March, 1936. He then knew of only two vessels—the *Asturias* and *Alcantara*—which had such air heaters and they had been in service a comparatively short period.

Following experiences on land plants with regenerative air heaters and their soot blowers, and being concerned with the cleaning of the boilers, the writer endeavoured to convince the owners' representatives of the ill-effects of the air-heater counter-draught blowers, if operated, and was assured that no air-heater blowers would be operated at sea. He had recently had it confirmed, by the vessels' engineers, that the air-heater blowers had not been used during the 12 years' service and that the air heaters were not washed in port.

From the extreme fineness of the gas and air passages in the Ljungstrom rotors, it would not have been wise to install them in a steam vessel without both air and gas bye-passes for emergency use, and it appeared that the fact of air-bye-passes being installed had been the saving of these regenerative air heaters. The writer was informed that boilers were well preheated prior to lighting oil burners, and also the rotors were rotated and so uniformly heated to above the gas dew-point. The gas bye-pass dampers were sealed shut. As would be expected, the operation of the boiler plant had been such that the blowers on the boilers had been capable, alone, of cleaning boilers, superheaters and air heaters.

In view of the author's remarks in his contribution to the discussion on the writer's paper of March, 1936, the illustration (Fig. 29) of the boiler plant in two new vessels building was interesting. The counter-draught blowers, as fitted in *Asturias* and *Alcantara,* were not included. The author might care to state why. The blower in the air passage was apparently intended to provide the high velocity water jet referred to by the author. If used in port it would, presumably, be supplied with saturated steam which, after expansion in the blower nozzles, would be discharged into the rotor passages with a wetness fraction of about 0·14 and at 212° F.

The author's firm were defeating their own ends by fitting the orifice plates in the steam pipes, as without these plates the wetness of the steam discharged into the rotors would be greater.

In the writer's reasoning, if the operation of these plants was on a par with the reported operation in *Asturias* and *Alcantara*—except that the blowers in the gas passages would be operated at sea—then the operation of these blowers would be the only factor that could produce the conditions in the air heaters necessitating the use of the water-washing process, just as they were contributing factors in so many land plants.

It would be noted that the blowers were quite close to the rotors and must commence their operation with saturated steam—the wetness fraction of the steam discharged into the rotor, at sea, would vary from about between 0·14 and 2 per cent.—not continuously wet enough to wash the rotors but wet enough to cause heavy corrosion and fouling.

The writer had, of course, advised the owners' representatives of these two vessels of his views on soot blowing and boiler operation generally, as he was entitled to ensure that the blowers on the boilers (with which he was concerned) gave efficient service. He was interested in the maintenance of clear gas and air passages through the air heaters, so that combustion troubles would not arise to produce other more difficult conditions for the boiler soot blowers.

He would regret to see extended to marine plants the reprehensible practice, obtaining in many power stations, of turning water lances on to superheaters whilst the boilers were steaming. The mal-operation of air heaters was not the only cause of combustion troubles but was usually a contributing factor.

Following the results with the regenerative air heaters in *Asturias* and *Alcantara,* it was reasonable to anticipate that all boiler firms making and recommending three-pass tubular air heaters would now support, instead of obstruct, the judicious use of air bye-passes and would see that such were provided.

Steam could not be raised to full pressure on any boiler without condensation of vapour from the gases in the air heaters occurring, unless the air for combustion was bye-passed from the air heaters. Also, depending on the ratio of the mass flow of air to that of gas over the critical air-heater surfaces, condensation of vapour at below the natural dew-point temperature of gas leaving the boiler must go on at light boiler loads if the air was not bye-passed from the air heaters. The chemical elevation of the dew-points of boiler gases left him quite unimpressed. It was elementary that the gases were cooled below their natural physical dew-point during steam raising and manœuvring periods if means were not taken to prevent it.

He knew of no case of corroded air heaters where the gases had not been, at times, cooled below the natural dew-point.

The critical surfaces of air heaters were those near the cold air inlets and the ratio of mass flow referred to was as high, in some tubular air heaters, as 40 to 1.

With an exit gas temperature from the boilers of about 650° F. and a mean exit gas temperature of 240° F. from the tubular air heaters at full boiler loads it was reported to him that, in winter-time, the temperature of the gas leaving the tubes closely adjacent to the air inlets on a certain large vessel was as low as 160° F. At very low boiler loads the exit gas temperature from the boiler must be much less than 650° F., whilst the cold air temperature remained constant, and it appeared that the gas must be cooled to well below the natural dew-point of 120° F. before leaving the particular tubes. In the vessel under notice it was not possible to bye-pass the air from the air heaters at any boiler load and if, as the writer surmised, it was the performance of this vessel and her sister vessels that prompted the recommendations of the Institution of Naval Architects referred to by the author, to the effect that it was unwise to attempt to cool the gases below 350° F. or even 400° F., then in the writer's opinion the members of the Institution of Naval Architects were misled. In this large vessel which had both F.D. and I.D. fans for the boilers, it would have been a simple matter to provide means for completely or partially bye-passing air from the air heaters, thus enabling the engineers to maintain a reasonably high efficiency of the tubular air heaters at all boiler loads without trouble. He so advised the owners' representative but the troubles went on at the owners' expense.

Of course, in the regenerative air heaters the ratio of mass air flow to mass gas flow over all surfaces was about unity when boilers were steaming and the rotors moving, but the ratio could be infinite on half the surfaces when the rotors were not moving.

In his reasoning and experience the preheating of boilers and the bye-passing of air were more essential for the protection of regenerative air heaters than for any other type of air heater. Further, neglect in not rotating the rotors during steam-raising and manœuvring was disastrous, as portions in the air passages were cooled to the cold air temperature from top to bottom, and must cause condensation of vapour on the surfaces when first moved into the gas passages at almost any boiler load.

It was clear that other boiler contractors did not share the author's doubts regarding the cleaning of air-heater tubes over 20ft. long by steam soot blowers. They, like the author's firm, now realized the limitations of soot blowers but, unlike the author, they preferred so to operate the plants as to maintain the conditions on all parts within the capacity of soot blowers and to dry clean the plants rather than to wash them, which was, as the author implied, at best only a palliative.

In the tubular air heaters with very long tubes the air and gas motions were mainly vertical and contra flow. Practical considerations appeared to prevent the ratio of the mass flow of air to that of gas over the critical surfaces being as low as in the regenerative air heater, but in those the writer had seen, although the ratio was much less than in the three-pass tubular air heaters, it was not as low

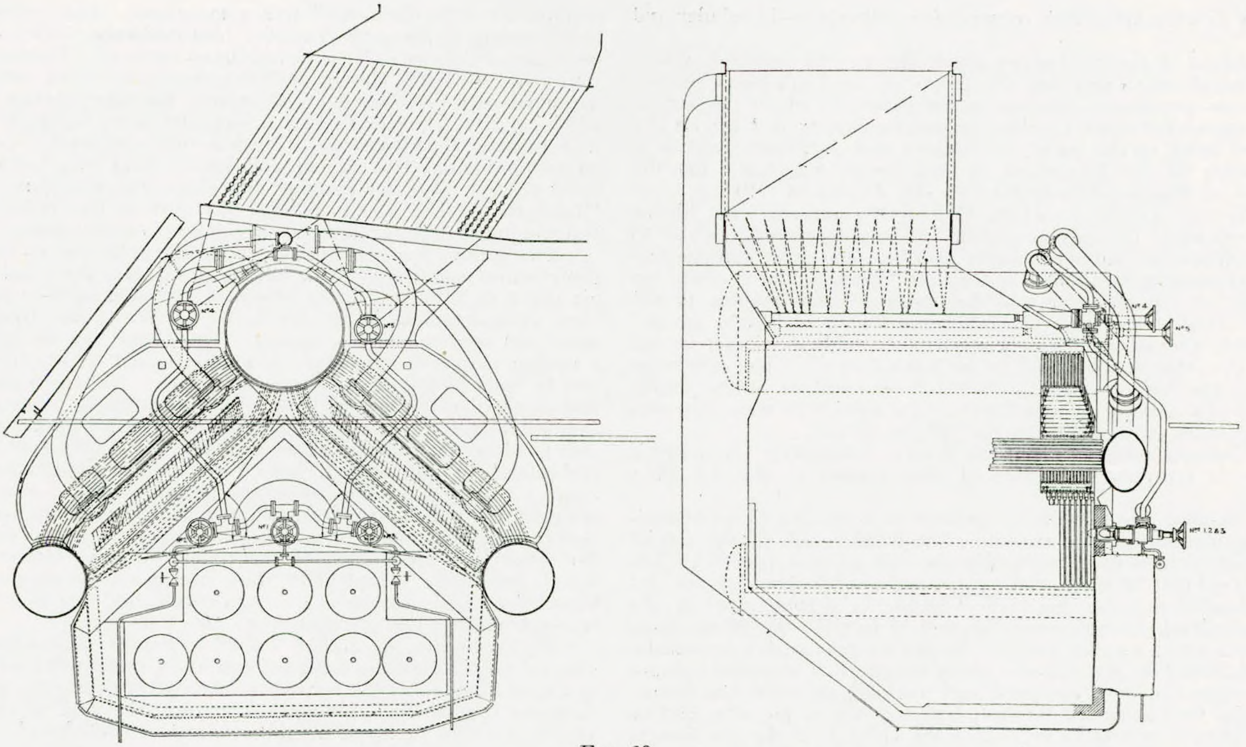


Fig. 30.

as was practically possible. It appeared to be obvious that the less the ratio of the mass flow of air to that of gas over the critical surfaces of an air heater, the lower the load would be at which the boiler plant could work without condensation of vapour from the gases occurring in the air heater, with the air not bye-passed. The provision of large external water downcomers in recent designs of boilers would tend to diminish the severity of the attacks of "airheateritis" resulting from inattention to the air bye-passes as well as to ease the duty of the feed-water controls.

In the last ten years the author's firm had been forced to abolish counter-draught soot blowing although the author resented the writer's comments on this in 1936. The author did not mention the precautionary methods of boiler operation discussed in the writer's paper of March, 1936. The author might possibly read another paper in 1956 advocating all the protective measures of operation for regenerative air heaters that the writer succeeded in establishing for the last twelve years in *Asturias* and *Alcantara,* and might then realize that emergencies need not arise for gas bye-pass or washing appliances, either of which could be so operated as to produce great troubles.

In Fig. 17 (reproduced here as Fig. 30) of the writer's paper of March, 1936, an Admiralty boiler with Howden turbulent air heater was illustrated. Members might be interested to refer to the remarks accompanying the illustration in that paper, viz.:—

*"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 on these tubes during light steaming rates.

[After extensive trials of a warship equipped with boilers of this type, signs of corrosion were noted on 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]"

It should now be noted that the air and gas passages through these air preheaters were 8ft. 4in. = 100in. long. The ratio of the mass air flow to that of gas over the surfaces was infinite at any vertical cross plane. In any inch of the length of the passages the ratio was 100 to 1. In half an inch it was 200 to 1. It was reasonable to conclude that the air must be partially bye-passed from this air heater at full commercial boiler ratings.

## The Author's Reply to the Discussion.

With regard to Mr. Harford's remarks, the author was sorry if he did not make it clear that air preheating, which was first used commercially in marine engineering, had continued to be used at sea to an ever-increasing extent, and there were very few shipowners to-day who did not use it with steam machinery. It was true, however, that while for the last twelve years there had been 1,000 to 1,500 air preheaters installed annually, these were mainly of the short tubular type illustrated in Fig. 4 and were applied to Scotch boilers. The advent of the water-tube boiler, with its higher ratings, larger gas quantities and high exit gas temperatures, stimulated interest in heat recovery, resulting first of all in the use of large tubular air preheaters. These, however, on the whole, had not been successful. The rotary preheater, on the other hand, was now being used to an increasing extent on such boilers, and marine engineers were becoming more and more familiar with its advantages. Since the end of the war, ships aggregating about 175,000 h.p. had been built or were building with rotary air preheaters.

The methods of overcoming the fouling difficulties which sometimes occurred in land plants had been successful in severe cases, but the causes of the fouling did not come within the scope of the air preheater manufacturer, who had to do his best to tackle the conditions as he found them. This was a short-term policy and it would, of course, be better to eliminate the cause. To do so was the long-term policy and this was mainly a problem for the boilermakers and stokermakers. The Boiler Availability Committee, composed of operating engineers and boilermakers, was doing valuable work on these problems. The Short-Term Sub-Committee were concerned with improving availability under existing conditions, and the Long-Term Sub-Committee were trying to tackle the problem of burning fuel without making boilers into sulphuric acid factories.

With regard to Mr. Harford's last point, the answer would appear to be found in the fact that of the 61 air preheated boilers, with a total evaporation of over 12,000,000lb./hr., recently ordered for power stations, 36 were fitted with rotary regenerative preheaters while the remaining 25 were fitted with recuperative preheaters—12 tubular and 13 plate.

The origin of the $SO_3$, about which Mr. Le Pla enquired, was a question which was exercising the minds of most engineers dealing with flue-gas problems. Harlow in his paper, to which the author referred, gave what seemed to be a reasonable answer, and Mr Le Pla might also refer to the paper by Rylands and Jenkinson read at a joint meeting of the Institution of Mechanical Engineers and the Institution of Electrical Engineers on 4th November, 1943.

In the two stations to which Mr. Le Pla referred, the higher sulphur content of the fuel at station "A" might be enough alone to cause the difference, but there might also be some other contributing cause, such as that mentioned by Harlow, which would account for the trouble in the one case and the freedom from trouble in the other. Harlow stated from his experience that even in two stations with exactly the same fuel, a heavy deposit might be found in one while in the other there would be no deposit at all. The reason he suggested, was that in one case the high temperature of the superheater elements caused the iron oxide on the outside of these elements to act as a catalyst in oxidising the $SO_2$ to $SO_3$.

The author's remarks about the Boiler Availability Committee's work in his reply to Mr. Harford also applied to Mr. Le Pla's questions.

Mr. Spanner was to be congratulated on compiling in such detail the interesting information regarding the effectiveness of the special tubes designed by him in increasing the rate of heat transfer. The author agreed that "coring" of the gases in the tubes should be avoided and appreciated that the "Swirlyflo" design, as demonstrated by the figures submitted, seemed to do this and to increase the effectiveness of the surface to a marked extent. He did not take such a pessimistic view as that held by Mr. Spanner about the effect of retarders because it was obvious that they, too, prevented "coring", and published figures showed that they increased the heat transfer rate of the tube surface to a considerable extent by increasing the velocity of the gas flow at the inside tube surface. In this respect, incidentally, as Mr. Spanner implied, the term "retarder" was a misnomer. The author remembered seeing in the early 'twenties heat-exchanger tubes which had been passed through rolls with undulated surfaces. These rolls made four rows of fairly closely pitched indentations along the length of the tube, each row being at 90° round the tube surface from the adjoining row, the undulations in opposite rows being out of pitch with those in the other rows. Such a tube presumably created turbulence inside and had an increased rate of heat transfer, but it probably presented greater cleaning difficulties than the plain tube. The "Swirlyflo" design would not appear to fail in this respect but Mr. Spanner unfortunately gave no information on the point.

The author regretted that he found the argument in Mr. Parry's contribution rather difficult to follow, and he was surprised that. if in his paper in 1936 Mr. Parry offered a complete solution to the problem of maintaining water-tube boiler surfaces clean, trouble sometimes still occurred in this respect. The author saw no reason after a further ten years' experience to modify in any respect the contribution he made to the discussion on that paper. He would only remark that in addition to the soot blower blowing with the gases, a counter-draught blower or, according to circumstances, a blower on the air side (such as that illustrated in Fig. 29) was supplied on the rotary preheater. In this respect, one of the largest boilermakers in the country, for whom some 50 rotary preheaters were now on order, always preferred the counter-draught type. The boilers made by that boilermaker functioned in a most satisfactory way, notwithstanding Mr. Parry's condemnation of the counter-draught blowers used on the air preheaters. It might be, therefore, that other people had some knowledge of the intricacies of soot blowing, and that such knowledge was not entirely the prerogative of Mr. Parry.

In conclusion, the author wished to express appreciation to the Council for the facilities accorded him in the presentation of his paper, to the Chairman for his courteous introductory remarks, and to Mr. Timpson for his kind comments in moving the vote of thanks. He would also like to thank all those who had contributed to the discussion.

## International Congress of the Sea, Ostend, July 18th-22nd, 1946.

The last international assembly of marine engineers and naval architects prior to the outbreak of war took place in Belgium, when the International Congress of Naval Architects and Marine Engineers was held at Liége in August, 1939. It is therefore fitting that our energetic and resilient Belgian friends should have promoted the first post-war gathering of this kind. The occasion was the International Congress of the Sea, held at Ostend from 18th to 22nd July, 1946 to commemorate the centenary of the Dover-Ostend mail service.

The Institute was officially represented at the Congress by Mr. A. C. Hardy, B.Sc. (Associate Member of Council), other British delegates being a representative of the Foreign Shipping Relations Branch of the Ministry of Transport and Mr. Lascelles of Lloyd's Register of Shipping.

The Congress was divided into eight sections, the third dealing with "arts mécaniques et industries maritimes" being of special interest to the Institute. In this section papers were read on the subjects of "A 100 Years' Review of the Dover-Ostend Cross-Channel Ships", "Electricity for Fishing Vessels", "Recent Developments in Dredger Machinery", "Future Ship Developments". "Developments in Cross-Channel Cargo Liners", and "Fishing Vessels of the Future".

The highly-excellent organisation, the sufficiency of foreign delegates and the arrangements to cope with them, which were marked features of the Liége Congress, could not be expected in present circumstances. Nevertheless, the hotel services in Ostend were in marked contrast to the present austerity of the catering services in Great Britain and as a contribution to international good will the Congress was an unqualified success.

## Visit to the National Physical Laboratory, Teddington

On Saturday afternoon, 31st August, 1946, by kind permission of the Director, a party of 14 members participated in a visit to the National Physical Laboratory at Teddington.

It was not possible to include the whole of the establishment in the conducted tour made by the party, but a highly-instructive afternoon was provided by visits to the materials testing laboratory, and the departments concerned with models of river estuaries, the wind tunnel, creep testing, electric high tension and—of special interest to the visitors—the experimental tank where the construction and testing of models was explained.

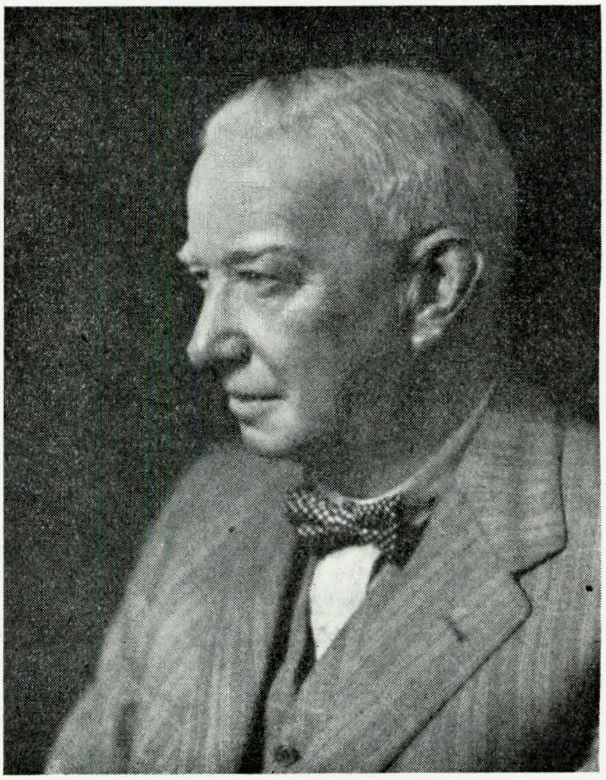
At the end of the very interesting and instructive tour the visitors' thanks were expressed to the able guide who had conducted them by Captain P. Watkinson (Member).

## OBITUARY.

### Mr. William Hamilton.

It is with deep regret that we record the death of Mr. William Hamilton (Vice-President and Member 3954), which occurred at his home at Monkseaton, Northumberland, on Thursday, 28th August, 1946.

Mr. Hamilton, who was seventy years of age, was a native of Campbeltown and received his early engineering training with Messrs.



Lobnitz & Co., Ltd. of Renfrew. He joined Messrs. G. & J. Weir, Ltd., in 1901 and after experience in various departments of the works and outside staff, went to Newcastle in 1904 to assist Messrs. Weir's representative on trials, etc. He remained on the North East Coast and in 1912 was appointed to take full charge of the Newcastle office where, as the firm's representative, he was widely known and consulted for his experience and ability as an engineer. He remained in this post until the time of his death.

Mr. Hamilton joined the Institute in 1920 and in 1937 was elected Vice-President for the Newcastle area, an office which he continued to fill until his decease. He was also a member of the North East Coast Institution of Engineers and Shipbuilders and of the Institution of Engineers and Shipbuilders in Scotland, and an associate member of the Institution of Naval Architects.

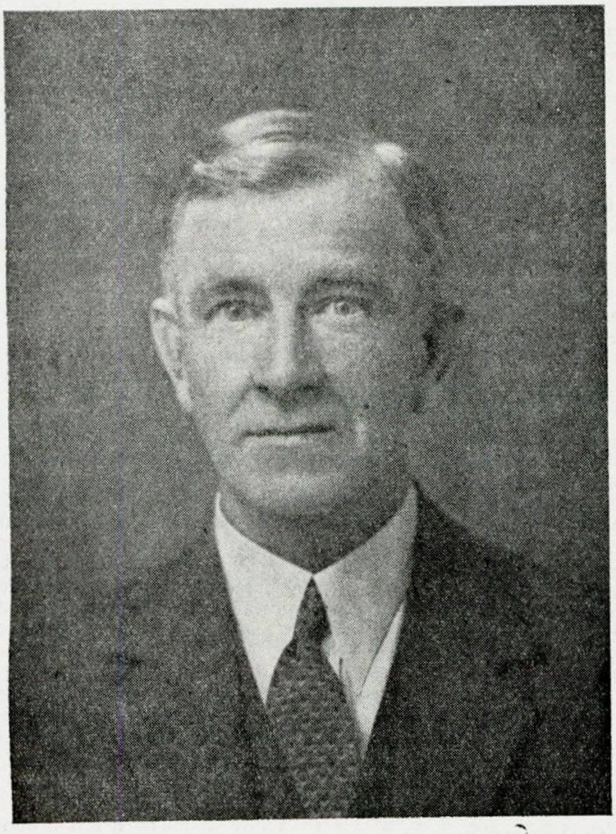
Mr. Hamilton, whose death will be keenly regretted by a wide circle of friends in the marine engineering world, is survived by his wife and one son.

### Mr. Alexander James McCowan.

The death of Mr. Alexander James McCowan (Vice-President and Member 7924), which occurred at Sydney, N.S.W., on Sunday, 1st September, 1946, has been recorded with deep regret.

Mr. McCowan was born in 1886 and served his apprenticeship with Messrs. Robison & Co. of Melbourne from 1903-08. He then entered the service of Messrs. McIlwraith, McEachern & Co., as a seagoing engineer, and for part of the rather more than three years he was in this Company's employ he was posted to Messrs. Harland & Wolff's Belfast yard during the building of the t.s.s. "Karoola".

He then joined Messrs. Fyvie & Stewart, consulting engineers, of Melbourne, as a draughtsman and engineer, a post in which he remained for over four years until he joined the Royal Navy as an



engineer lieutenant. Two years later, in April, 1919, he was appointed a ship and engineer surveyor to Lloyd's Register of Shipping and was stationed at Liverpool. In May, 1920, he took up duty as the Society's exclusive ship and engineer surveyor at Melbourne, and in July, 1934, he was appointed principal surveyor for Australia and New Zealand and stationed at Sydney.

Mr. McCowan was appointed as the Institute's Vice-President for the Sydney area in 1942, an office which he still held at the time of his death. The death of Mr. McCowan at the comparatively early age of 60 years is keenly regretted in Australian and New Zealand shipping circles and by his many friends in this country. He leaves a widow.

## ADDITIONS TO THE LIBRARY.

### Presented by the Publishers.

**The British Corporation Register of Shipping and Aircraft**—"The War Years in Retrospect and a Brief Account of the Society's Origin and History".

**Transactions of the Institution of Engineers-in-Charge.** Session 1944-45. Vol. 50.

**Transactions of the Society of Naval Architects and Marine Engineers, New York.** Bound Volume 53. 1945.

**British Standards Institution.**
PD 541 Amendment No. 1 to B.S. 852: 1939—Toolmakers' Straightedges.

**B.S. 1306: Part 1: 1946—Non-ferrous Pipes and Piping Installations for and in Connection with Land Boilers.** British Standards Institution, 28, Victoria Street, London, S.W.1, Publications Department, price 2s. post free.

This new standard is similar and complementary to B.S. 806—Ferrous Pipes and Piping Installations for and in Connection with Land Boilers. Part 1 applies to the general and detailed construction of the copper pipework connecting a land steam boiler to engine, turbine or industrial plant, and to all auxiliary pipework in connection therewith, together with individual pipes and fittings forming parts of such installations. It lays down limits of pressure and temperature for the use of copper piping installations and bronze castings used in connection with such installations.

B.S. 1306 will be completed at an early date by the issue of Part 2—Seamless Copper Tubes with Plain and Screwed Ends for Steam Services.

**The Price of Admiralty.** By Paul McGuire, Lieutenant, R.A.N.V.R., and Frances Margaret McGuire. Oxford University Press, 1944, 308 pp., profusely illus., 15s.

This book not only describes the life of a distinguished naval officer, the late Commander J. H. Walker, M.V.O., D.S.C., R.A.N. and of his ship, H.M.A.S. "Parramatta", but also explains very clearly the meaning of sea power and the great value and use of our Navy.

The early chapters give details of the origination and development of the Australian Navy. Emphasis is given—and quite rightly—on the vastness of the Australian coastline and the area that must be covered to protect her trade routes.

The rest of the book is then devoted to the telling of the vivid story of H.M.A.S. "Parramatta" from her launching at Sydney to her loss in action off Tobruk. To those who served in the Red Sea and on the Tobruk ferry service in 1940-41, it will revive memories—the heat, the strain of long hours of watching, waiting and action, the monotonous diet, but with it, too, the comradeship and indomitable spirit of men who are banded together to perform a difficult task.

To those who served in other spheres the story will give the prominence, so well deserved, to the splendid part played by the small ships and their crews in this vital theatre of war.

The authors are to be complimented on their ability to put the reader aboard the ship and enable him to "live" the story through.

**Pressure Gauges** ("Mechanical World" Monograph No. 19). By J. R. Fawcett, B.Sc., A.M.I.Mech.E. Emmott & Co., Ltd., 1946, 26 pp., 15 Figs., 1s. net.

The engineer who is faced with the problem of measuring pressure will find little or nothing to help him in the usual engineering reference books.

This monograph sets out the points which should be watched when buying and installing pressure gauges and gives the procedure for maintenance and simple repairs.

Whilst of special interest to instrument managers and mechanics, it contains information which will be found very useful to works engineers, general engineering designers and erectors.

**Power Transformers.** No. 11 of "Electrical Engineer" Series. Third edition. By J. Rosslyn. George Newnes Ltd., London, 1946, 228 pp., 107 diagrams and photographs, 7s. 6d. net.

The installation, testing and maintenance of power transformers requires specialized knowledge. This book presents in a condensed form principles, connections, tap changing gear, protective gear, oil equipment and testing and descriptions of the various transformer faults and failures met in practice. The photographs are very useful and the diagrams well drawn.

The reviewer has experience of power transformers exceeding the largest capacities referred to in the book and would say it is well written and forms a convenient practical reference manual of value to electric power engineers engaged on power transformer work.

**Essential Metallurgy for Engineers.** (Second Edition)). By Dr. A. C. Vivian. Sir Isaac Pitman & Sons, Ltd., 1945, 150 pp., 33 figs., 8s. 6d. net.

The time has passed when an engineer could successfully pursue his profession with a negligible knowledge of the properties of metallurgy or metallic materials. Modern developments in engineering have advanced so rapidly and the available alloys and compounds become so numerous that it has become essential for an engineer not only to understand how his raw materials are produced but also to be able to appreciate the effect of modern manipulative processes on the original properties. Further, many engineers have for long been baffled by the lack of correlation between the various mechanical tests so far standardized, and which have formed up to the present their sole guide in deciding the suitability of a particular material for a specific purpose.

Dr. Vivian's work in attempting to remove the above disabilities is well known, and the second edition of his book will be welcomed by all interested in this field of engineering practice. The first seven chapters deal in a simple but effective way with the modern concepts of physical metallurgy which practising engineers would have difficulty, even were time available, in unravelling from the more abstruse contributions of the pure metallurgists. Chapter 8 deals with the subject of mechanical properties from a somewhat novel but more rational standpoint than is usual. The following thirteen chapters cover concisely the more standard information included in publications on metallurgy for carbon steels, alloy steels and the normal non-ferrous alloys, whilst the concluding three chapters contain useful information regarding "Alloy Specifications and Markings", "Corrosion", and "Curative Measures in General".

The text is clearly printed, well illustrated, and the book should provide a useful introduction to the subject of metallurgy for engineers and students who have to obtain their knowledge in a limited time.

**The Modern Diesel.** Edited by G. Geoffrey Smith, M.B.E., and revised by Donald H. Smith, M.I.A.E., of "Motor Transport". Tenth edition 1946. Iliffe & Sons, Ltd., size 4¾in. by 7in. (F'cap 8vo.)—viii plus 254 pp.—nearly 200 illus., 6s. net.

When in 1930 the first edition of this handbook was in preparation, the compression-ignition heavy-oil engine was at an early stage of development and the present-day attainments were only envisaged.

The Diesel principle, however, has been so successfully employed for large stationary and marine engines, and held such promise of improved efficiency, that the production on a commercial basis of smaller sizes for transport of all kinds was regarded in this country as a matter of urgency.

During the intervening years the compression-ignition engine has made enormous headway, mainly due to active research and experiment by road transport manufacturers. To-day this type of power unit has attained an almost unassailable position for road and railcar transport, and for marine craft down to the smallest sizes.

This is the tenth edition of a handbook which has served its purpose in familiarizing many thousands with the characteristics of oil engines and the intricacies of fuel injection and equipment.

It is now possible to include references for those new British engines that are already available, as well as to concentrate on those technical characteristics and performance capabilities which were responsible for the wide and rapidly expanding adoption of the Diesel unit. The book is profusely illustrated, and covers the theory and practice of Diesel power for use on the road, on the sea and in the air.

Considerable space has again been devoted to fuel ignition equipment and to combustion-chamber design—with particular emphasis on the swing towards direct-injection systems, especially those of the toroidal-cavity piston type.

Chapter contents include: The Term "Diesel"—A General Survey—The Compression Ignition Cycle—Fuel Injection Systems—Cylinder Head Design—Heavy-oil Fuel—Road Transport—Transport Diesels in Service—Diesels and Railway Service—Aircraft Engines—Marine Service—Marine Engines.

**Earth, Moon and Planets.** By Fred. L. Whipple. Published by J. & A. Churchill Ltd., London, 1946, 276 pp., 140 figs., of which more than half are actual photographs, 18s. net.

This book is one of a series of eight written by the various members of the staff of the Harvard University Observatory and consequently merits careful attention. As the title implies, the author confines himself to the planets, and he gives a delightful account of each one. Between Mercury and Pluto, a distance of 39.5 A.U. (3,671,000,000 miles), one finds such a variety of planets of such different sizes and conditions that one wonders why the Earth was the only one chosen as the abode of life as we know it. In very simple language the author deals with all their puzzling movements, their masses, atmosphere, and satellites.

The author deals more fully with the planet Earth, giving a mass of detail of the atmospheric and geological conditions, as well as the tides, time, and seasons. He mentions the various theories of the origin of the Earth and the Earth-Moon system. He might have spared us the suggestion on page 245 that when the Moon left the Earth, it left a huge gap where is now the Pacific Ocean. If this theory is correct, surely both Moon and Earth would have been in a very plastic condition during this happening, and the surfaces of both bodies would soon have become comparatively smooth again. Depths and heights would not have appeared until the Earth became solid, many millions of years later.

The author's descriptions of Mars and Jupiter are particularly interesting reading. The numerous maps and photographs are excellent and quite up to date. Chapters 4, 5 and 6 especially contain a wealth of knowledge, and the appendices are valuable additions.

The book is well worthy of study, especially by amateur astronomers and students.

**Fire Protection Year Book 1946-7.** Edited by V. J. Wilmoth. Published by Lomax, Erskine & Co. Ltd., Aldwych House, London, W.C.2, Crown 8vo. 210 plus xxviii pp., red cloth cover, gilt lettering, 7s. 6d. post free.

One more welcome sign of the return of peaceful conditions is the alteration of the title of the newest edition of the annual reference book of the Fire Service, and of all connected with fire fighting and fire prevention, from "Fire Protection & A.R.P. Year Book" to "The Fire Protection Year Book, 1946-7". This new edition has been completely revised and brought up-to-date in the light of the very great changes which have occurred since the end of the war. Much information has been added, and several sections which dealt with A.R.P. have been deleted.

In the preface, the editor points out that although the return of the Fire Service to Local Authority control has been promised, restoration cannot but take a considerable time yet, and the present uncertain conditions make an authoritative reference book even more essential.

As in past years, the contents are divided into sections for easy reference by means of stiff tabbed cards. These sections comprise: details of the N.F.S. by regions and fire forces; fire brigades overseas; alphabetical list of N.F.S. officers with their postings; a list of Government departments, institutions and associations; legislation relating to fire fighting and fire protection; water data; miscellaneous data all of which has been carefully checked, re-arranged and brought up-to-date; commercial and trade section, including a comprehensive list of proprietary names, a classified directory or buyer's guide, and an alphabetical list of the more important manufacturers of fire equipment. The final section, which is a great improvement on previous editions, comprises an entirely new and re-arranged index, allowing any item to be found with the minimum of difficulty.

This is a reference book which should be on the shelf of everyone connected with fire fighting, fire prevention, and fire insurance and in the reference section of every public library.

**Creeks & Harbours of the Solent.** (Third edition, revised). By K. Adlard Coles. Published by Edward Arnold & Co., 1946, 117 pp., profusely illus., 15s. net.

This book is well worth reading by anyone contemplating visiting the Solent, and the author is to be congratulated on the completeness of his work. The approaches, navigation instructions, beauties, places of historical interest, anchorages and facilities are so well described that there is nothing better a yachtsman intending to visit these creeks and harbours would require, and anyone contemplating doing so would be well advised to take a copy of this book with him, which would be most useful as well as interesting.

Those who read "Creeks & Harbours of the Solent", so aptly described by Mr. K. Adlard Coles, will be anxious to see for themselves all the beauties mentioned, and many who have already visited these creeks before reading this book will have the desire to make a return visit with a copy of "Creeks & Harbours of the Solent" before them.

Referring to page 24, paragraph 3, the shallowest part of the Brambles is S.E., not S.W. of North Thorn and Thorn Knoll buoys. The author might have added that High Water remains stationary in the Hamble River for about 3¾ hours, and in consequence there is a very strong ebb, so that sailing yachts without auxiliary power in light winds should endeavour to enter the river on the flood.

**To Be An Engineer.** By Lt.-Col. J. R. W. Murland, B.Sc.(Eng.), A.C.G.I., A.M.Inst.C.E., A.M.I.E.E., A.M.I.I.A. Methuen & Co., Ltd., London, 1946, 180 pp., 7s. 6d. net.

Early in this book there is acknowledgement that modern engineering covers a vast field and that its many ramifications can only be known to the specialists. The intention of the author is to concentrate on the principal points which are considered to be common to the training of all engineers.

The first chapter is an explanation of what is meant by "engineering" and for the purpose of the book a "professional engineer" is defined as "one who has been elected a corporate member of one of the three major engineering institutions—that is to say, one who is a member or associate member of any one of the Institutions of Civil, Mechanical or Electrical Engineers". There will be many readers—certainly the 5,000 members of this Institute—to whom this definition will be unacceptable and the title of the book unreasonable, as it is really a description of the training and qualifications necessary to become an associate member of one of the above-mentioned institutions. Some By-laws are reproduced in full and twenty-eight pages of the book are devoted to details of the A.M.Inst.C.E. examination.

There are altogether twelve appendices, including lists of engineering and scientific societies, universities which award engineering degrees, technical colleges, schools and institutions as well as regulations for the B.Sc.(Eng.) examination, the National Certificate course, and a form of apprenticeship indenture.

To those who are thinking of becoming civil, mechanical or electrical engineers this book contains much of interest and value. It is one of a series of which "To be a Surveyor" has been published, and "To be an Architect" is now in preparation. One is left wondering why the publishers sought to cover the whole field of engineering by Lt.-Col. Murland's book when it apparently seemed desirable to deal with surveying and architecture in separate volumes.

## Presented by the Author.

**"Il Calcolo Delle Vibrazioni Torsionali Nei Motori a Combustione Internal". (The Calculation of Torsional Vibration of Internal Combustion Engines, with Special Reference to Marine Engines).** By Dott. Ing. Giovanni Rossi (in Italian). Published by Collana Tecnica "Grandi Motori", 1944, 255 pp., profusely illus. (price unknown).

This volume is published by the Fiat engine company, and is the first of a series of books which they hope to issue each dealing with some aspect of research or some special problem in the design of heavy-oil engines. Judging by the present volume these are to be serious technical works, and are not intended as an advertisement; in fact except for the name of the company in small, scarcely readable lettering on the cover, the Fiat engine is hardly mentioned.

The author tackles his subject in a very practical manner, not suitable for the engineering student, but very useful to the trained engineer who understands the basic principles of vibration but wishes to study the methods of calculation suitable for use by the designer. There is a danger in this treatment, as with the help of this book anyone with a moderate knowledge of mathematics could make torsional calculations and might try to apply them without proper understanding of the meaning of the results obtained. This danger is only partly eliminated by a chapter on "Interpretation of the Results".

The first three chapters deal briefly and clearly with the most normal method of calculating the natural frequency of an elastic torsional system and of the forced vibration amplitudes in a heavy-oil engine, neglecting damping. The next long chapter deals with damping; it is right that this should be so amply treated, as it is the least understood and to most people the most difficult part of vibration calculations.

In the next section of the book dampers are dealt with at considerable length. Under this heading are included both true dampers and so-called "dynamic dampers" which are really methods of altering frequency either with speed or amplitude. Devices for splitting the system into two separate vibrating systems, such as electro-magnetic couplings, are also included as dampers. It is rather surprising to find that while many almost unknown devices are included in this chapter, certain others in common use are omitted.

The short chapter on "Interpretation of Results" is very valuable, its only fault being that it is much too short and could well have been extended to three or four times the length. In the brief space of fifteen pages the author deals with accuracy of the calculations, fatigue stresses, effect of machinery finishes, and type of material on fatigue, and the effect of the shape of the shaft, *i.e.* oil holes, discontinuities, etc.

The final and longest section of the book gives examples of the application of the methods of calculation to practical problems. This section is of real practical value and is probably more extensive and comprehensive than will be found elsewhere.

One serious fault in this book is that it has no index, no cross-indexing, no list of symbols used, and totally inadequate reference to other authorities that are quoted by the author. The difficulties of producing such a work at the time it was published (1944) is evidenced by an extensive list of corrections of errors. In spite of these faults, however, and of the fact that the book includes some opinions that might be subject to argument, it may be said that it is one of the most valuable books on this subject for the practical engineering designer that has yet been published, and it is to be hoped that it may be translated into English.

## Purchased.

**Turbine Engine Activity at Ernst Heinkel Aktiengesellschaft.** Combined Intelligence Objectives Sub-Committee. Item No. 5. File No. XXIII-14. H.M.S.O., 1945, 69 pp., 26 illus., 6s. net.

**German Air Foam Fire Fighting Equipment.** British Intelligence Objectives Sub-Committee. J.I.O.A. Final Report No. 28. H.M.S.O., 1945, 244 pp., profusely illus., £1 1s. net.

**Metallgesellschaft A.C., Frankfurt. Chemicals for Phosphating Iron and Steel.** B.I.O.S. Final Report No. 257. Item Nos. 21 and 22. H.M.S.O., 1945, 5 pp., 1s. net.

**Hansa Type Ships.** British Intelligence Objectives Sub-Committee. —F.I.A.T. Final Report No. 563. H.M.S.O., 1945, 2 pp., 6d. net.

**Heinkel-Hirth TL Gas Turbine Engine.** Combined Intelligence Objectives Sub-Committee. Item No. 5. File No. XXI-5. H.M.S.O., 1945, 8 pp., 16 illus., 2s. net.

**Report on High Voltage Switch Gear.** British Intelligence Objectives Sub-Committee. F.I.A.T. Final Report No. 514. H.M.S.O., 1945, 36 pp., 28 illus., 3s. 6d. net.

**Industrial Electronic Measuring Equipment.** British Intelligence Objectives Sub-Committee. B.I.O.S. Final Report No. 564. Items Nos. 1, 9 and 29. H.M.S.O., 1946, 20 pp., 3 illus., 2s. net.

**The "Coanda Effect".** Combined Intelligence Objectives Sub-Committee. Item No. 5. File No. IX-1, X-2, XII-1. H.M.S.O., 1944, 28 pp., illus., 2s. 6d. net.

**The Manufacture and Application of Lubricants in Germany.** Combined Intelligence Objectives Sub-Committee. Item No. 30. File No. XXXII-68. H.M.S.O., 1945, 46 pp., 4s. 6d. net.

**German Naval Distilling Equipment.** British Intelligence Objectives Sub-Committee. B.I.O.S. Final Report No. 555. Item No. 29. H.M.S.O., 1945, 271 pp., profusely illus., £1 7s. 6d. net.

**German Gear Cutting Plant, Gear Manufacturing Technique and Design Development.** British Intelligence Objectives Sub-Committee. Final Report No. 225. Item No. 29. H.M.S.O., 1945, 17 pp., 15 illus., 3s. net.

**German Air-conditioning and Refrigeration Industry.** British Intelligence Objectives Sub-Committee. F.I.A.T. Final Report No. 573. H.M.S.O., London, 1945, 37 pp., 3s. 6d. net.

**Designs of Turbines for Auxiliary Pumping Machinery for the German Navy.** Combined Intelligence Objectives Sub-Committee. Item No. 29. File No. XXXIII-33. H.M.S.O., London, 1945, 126 pp., profusely illus., 15s. 6d. net.

**Description of Junkers .004 (203) Jet Propulsion Engines.** Combined Intelligence Objectives Sub-Committee. Item No. 5, 26. File No. XI-6, XII-9, and XIV-4. H.M.S.O., London, 1945, 33 pp., illus., 3s. net.

**The Ljungstrom Turbines in Germany.** British Intelligence Objectives Sub-Committee. B.I.O.S. Final Report No. 500. Item No. 31. H.M.S.O., London, 1945, 68 pp., illus., 9s. net.

Recent publications of The Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1.

**Classified Catalogue of the Library.** Second edition, revised and enlarged. Compiled by C. Brayden, Librarian, 180 pp., paper cover, 3s. 6d. post free.

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(iv) Some aspects of production where arc welded fabricated steel has been introduced into marine engineering. By J. R. Ferguson.

(v) Copper welding as applied to the repair of locomotive fireboxes. By G. Foster, B.Sc.

**Interrogations Regarding Use of Coal for Firing Gas Turbines.** British Intelligence Objectives Sub-Committee. F.I.A.T. Final Report No. 508. H.M.S.O., London, 1945, 12 pp., 1s. 6d. net.

**Survey of Electrical Control Devices in Germany.** British Intelligence Objectives Sub-Committee. F.I.A.T. Final Report No. 224. H.M.S.O., 1945, 25 pp., illus., 2s. 6d. net.

**Survey of a New Storage Battery.** British Intelligence Objectives Sub-Committee. F.I.A.T. Final Report No. 670. H.M.S.O., 1946, 3 pp., 2 illus., 6d. net.

## MEMBERSHIP ELECTIONS.

### Date of Election, 3rd September, 1946.

**Members.**

John Armer.
Ronald Caplen Beavis.
Arthur Edward Brown.
Wilfred Clarke, Lieut.(E.), R.N.R.
Donald Crawford Fletcher.
Benjamin Henzell.
Jan Karol Herman.
John Nelson Keith.
Ivor McIvor, Eng. Com'r., R.N.(ret.).
Frank Moss.
John Matthias Baden Parry.
Donald Pearson Rennie.
Gordon Seales.
Alexander Stuart.
Joseph Westoll Taylor.
Robert Blackie Thompson.
Walfred Thomas Warren.

**Associates.**

Henry Alcorn.
Alfred Annovazzi.
George Blakely.
David Brown.
Edward Arthur Cameron.
Stanley Desmond Clarke, B.Sc.
James Crawford.
Roy Bruce Finnis.
George Tanton Firth, M.B.E.
John Garden, Temp. Lieut.(E.), R.N.R.
Oliver Addison Glass.
Frank Jennings.
Harry Jervis.
William Gordon Lumsden.
Surendra Ratra.
Forbes Reid, Lieut.(E.), R.N.V.R.
Frederick John Rogers.
Andrew Cochrane Smith.
James Thompson.
Mannathazath Gopala Menon.

**Graduates.**

Charles Cash.
Roy Henry Clifton.
Raymond Alfred Coldicott.
Reginald Eyles.
Ernest Noel Grantham.
Clifford Frederick Charles Cecil Hopkins.
Trevor Palmer Jones.
Douglas Cowie Smith.
John Arthur Sullivan.
Alan Arthur Topp.

**Transfer from Associate to Member.**

Harold William Alcock.
David William Blyth.
Charles Alfred Logan.
Albert John Thomas Shoring, Lt.-Com.(E.), R.N.

**Transfer from Associate to Associate Member.**

Roy Arthur Northcote Cooke.
Santhanam Kasthuri.

**Transfer from Graduate to Associate Member.**

Cumbakonam Swaminatha Sundaram.

**Transfer from Student to Associate.**

Ronald Douglas Hewitt.

**Transfer from Student to Graduate.**

Peter Robert Allan.
Edward Moldrum Dawes.
Eardley Erroll Rockwell Newman.
Robert Edgar Westwood.

## PERSONAL.

A. W. S. Aitken (Member) has entered the service of the Ministry of Works and has been posted to the London area.

L. C. H. Alford (Associate), manager of the sales technical division of Messrs. Ruston & Hornsby, Ltd., has been elected an Associate Member of the Institution of Mechanical Engineers.

G. Altham (Associate) has been appointed an assistant engineer with Messrs. Braimbridge & Langford Jones of Liverpool.

R. H. W. Ambrose (Graduate) has joined the staff of the Anglo-Iranian Oil Co. for service in Iran.

F. Craig (Member) has been appointed senior marine engineer, Kenya & Uganda Railways and Harbours.

A. E. Crighton (Vice-President), who recently retired from the post of chief superintendent engineer of the Royal Mail Lines, has been appointed to the board of Messrs. Niven, Nelson & Matthews, Ltd., of Newcastle-on-Tyne, the patentees of the Nelvin range of thimble-tube boilers.

W. H. Currie (Member) has been demobilized from the R.N.V.R. with the rank of Lt.-Cdr.(E.), and has been appointed chief engineer of Industrial Exports, Ltd., of London.

T. Donaldson (Associate) has been appointed assistant works engineer with The North British Rayon, Ltd. of Jedburgh.

D. G. Dymott (Associate) has recently been appointed to the board of Messrs. H. S. Cattermole & Co., Ltd.

N. C. Fleming (Member) has been appointed engineer surveyor to the Royal Exchange Assurance Co., Ltd.

W. Gillies (Associate) has returned to shore employment as an engineering draughtsman with Messrs. Babcock & Wilcox, Ltd.

Com.(E.) J. G. C. Given, O.B.E., R.N. (Member), has been promoted to the rank of Capt.(E.), R.N. and has been awarded the C.B.E. for service with the Pacific Fleet in the Far East.

F. T. Green (Member) has taken over the management of The Hunter—St. Andrews Engineering Co., Hull.

Savell O. Hicks (Associate Member) was awarded the O.B.E. in the recent Birthday Honours in recognition of his meritorious services during the war as Regional Controller (Northern Ireland) for the Ministry of Supply, the Ministry of Aircraft Production and the Ministry of Production. He was twice seconded for special duties in Canada and the U.S.A. while serving in these capacities. Since being released at his own request, Mr. Hicks has been appointed to the board of Messrs. Davidson & Co., Ltd., engineers and ironfounders, Belfast.

Com.(E.) J. Hopwood, R.N.R. (Member), has been released from the Royal Navy and has been appointed to the staff of Messrs. Williams & Williams, Ltd., of Chester.

E. A. Jackson (Associate) has been appointed test engineer with The Hamworthy Engineering Co., Ltd., Poole.

J. F. Johnson (Member) has been released from the Royal Navy and has rejoined the outside department staff of The North Eastern Marine Engineering Co., Ltd., Sunderland.

D. S. Kennedy (Member) has been appointed engineering assistant to the construction manager of British Industrial Plastics, Ltd., of Oldbury.

J. B. Lockie (Member) has joined the staff of the Inspector of Machinery and Surveyor of Ships, New Zealand.

G. H. V. Lovatt (Associate) is now serving as R.N. Education and Resettlement Officer for the Port of Colombo.

R. W. Stuart Mitchell (Associate Member) has resigned as engineer-in-charge of development, engine division, The Brush Electrical Engineering Co., Ltd., to take up an appointment as lecturer in the department of civil and mechanical engineering and applied mechanics, Royal Technical College, Glasgow.

A. Muir (Associate Member) has been appointed an engineer assistant with the Ministry of Works at Leeds.

J. T. Parsons (Associate) has joined the staff of Messrs. Owen & Green, Ltd., of Liverpool.

B. Pugh (Associate Member) has been appointed Head of the Engineering Department at West Hartlepool Technical College.

Capt.(E.) Andrew W. Richardson, O.B.E., R.N. (Member) has returned to the Marine Department of Messrs. Babcock & Wilcox, Ltd., after having served in the Royal Navy throughout the war.

S. Rowland (Associate) has been appointed to the staff of Messrs. Bonar & Co. of Colombo.

Lt.-Com.(E.) C. A. Santwyk (Associate) has joined the staff of Vivien Diesels, Ltd., of Vancouver.

J. Small (Member) has been engaged by the Ministry of Works as a temporary engineering assistant at Liverpool.

C. H. Stanbridge (Member) has been released from the Army and has returned to his own business as consulting engineer at Port Elizabeth.

A. Taylor (Member) has been elected an Associate Member of the Institute of Fuel.

T. C. Towers (Associate) has been appointed maintenance engineer with The North of Scotland Hydro-Electric Board.

R. R. Waddington (Associate): We announced in our June issue that Mr. R. R. Waddington had taken up an appointment as the London representative of Messrs. Ruston & Hornsby, Ltd. (Marine Division). Mr. Waddington has now taken up his duties, but no change in the organization has taken place, Mr. J. M. Monro (Member) still being senior representative.

H. H. R. Walker (Member) has been appointed plant manager with Messrs. E. E. Kaye of Ponders End.

A. E. S. R. Wilson (Associate) has joined the staff of H. D. Williamson, consulting engineer, of London.

Lt.-Com.(E.) J. J. Wilson, M.B.E., R.N.R. (Associate Member), has been appointed an engineer surveyor to Lloyd's Register of Shipping.

R. Young (Associate Member) has been elected an Associate Member of the Institution of Production Engineers.