STUDIES ON FUELS FOR TEA DRIERS—V.*

STOVES AND FURNACES FOR TEA DRIERS WITH SPECIAL REFERENCE TO OIL-BURNING INSTALLATIONS

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The scope of this paper is limited to a discussion of some of the problems involved in the supply to the drier of the necessary volume of air at the required temperature. The question of the most advantageous use of this air in the drier will not form part of the paper.

The function of an air-heating furnace is to raise the temperature of a large volume of air through a comparatively small range, approximately 120°F, by means of the heat generated by the combustion of a small quantity of air with the fuel used. The efficiency of the stove is the ratio of the heat energy absorbed by the drier air passing through the stove to the heat energy supplied by the combustion of the fuel. This efficiency is affected by the design and workmanship of the stove and by the efficiency of the combustion of the fuel.

Types of Air Heaters.—Air heaters fall naturally into two main types "Indirect" and "Direct". At the present time practically every air heater in Ceylon is of the indirect type.

Indirect Heaters.—These heaters are employed when it is desired to obtain hot air uncontaminated by the presence of the products of combustion. It is, therefore, necessary to ensure that the hot air is kept entirely separate from the combustion gases and this is effected by causing the air to pass through ducts which are heated on the other side by the gases.

* The Institute does not necessarily endorse the views expressed in papers contributed by persons not members of the Staff.

"Indirect" heaters are of various types:—

Tubular (a).—Tubular heaters may either have air passing through the tubes and the hot products of combustion passing outside the tubes (air tubes) or

(b)—the products of combustion passing through the tube which is surrounded on the outside by the air which is to be heated (fire tube).

Sectional.—In this class, special cast-iron sections are employed to separate the products of combustion from the air to be heated. Any number of these sections may be connected together to make up a number of air paths in parallel. One advantage of the sectional type of heater is that, provided space exists for the purpose and combustion can be efficiently carried out, it may be extended in order to provide additional heating capacity as required.

There is another type of "Indirect" heater which is not much used. In this the fuel is used in a boiler to produce steam which is then led to a radiator through which the air to be heated is drawn.

Direct Heaters.—This item serves to describe those air heaters in which it is permissible to mix the products of combustion with the air which is to be used for tea drying.

In this type of heater the oil fuel is first burned in a separate combustion chamber, and the resulting combustion products which leave this chamber are immediately mixed with the amount of diluted air necessary to reduce the temperature of the mixture to that which is required on entry to the drier.

It is a much more efficient machine than the indirect heater because there is no loss due to the escape of hot gases up the chimney, the full heat generated by the combustion of fuel being available down to the exhaust of the drier. The cost of installing a stove of this type should be much less than the indirect heater; as it is merely a furnace constructed of refractory materials.

Direct heaters can usually only be used with liquid or gaseous fuel, because these fuels are practically free from impurities, and can be burnt steadily at constant efficiency. Solid fuels cannot ordinarily be used in direct heaters owing to the comparatively large percentage of objectionable impurities which they contain, and because perfect combustion cannot be maintained throughout the whole period the stove is in use.*

The air to the drier is drawn into the stove round the outside of the refractory material, keeping it at a reasonable temperature before being mixed with the products of combustion at the back of the stove. The insulating surfaces exposed to the atmosphere are those swept over by the air going to the drier and as these surfaces are at a relatively low temperature there are no problems involved with the insulation.

The usual procedure with these stoves is to allow the products of combustion to pass up a chimney until the furnace has warmed through and combustion is satisfactory. This usually takes about 15 minutes, as the amount of brickwork to be heated up in the furnace is small.

The chimney damper is then closed and the drier damper which is coupled to it opened, and the drier is ready for use. It is essential, however, that the liquid-fuel burner installed should give perfect combustion at all times, otherwise there is the possibility of the tea being tainted. There are several such burners on the Ceylon market.

The great advantage of this type of heater is that practically the whole of the heat units contained in the fuel are available for heating the drying air, and not for raising and maintaining at the correct temperature comparatively large amounts of steelwork. Consequently the fuel consumption of this type of stove is much lower than that of the "Indirect" type.

A number of stoves of this type have been in use for a number of years, and have been described by Mr. James Forbes (Jnr.) and Dr. Norris, in their "Report on a Visit to Java" issued by the Tea Research Institute.

It has been clearly demonstrated in actual service over a number of years that so far as the use of oil fuel is concerned, direct mixing has no harmful effects as regards flavour, etc. on the tea.

* Note by Ed.—The "Java" heater can be used with charcoal.

Indirect Stoves—for tea drying, until quite recently, have been designed for the use of solid fuel and the oil-firing furnace designer has been compelled to effect a compromise between expediency and desirability, but even so the application of oil firing has met with remarkable success. There is now much closer co-operation between the tea-drier manufacturer and the liquid-fuel furnace designer which is tending to much more satisfactory results. The temperatures produced by the combustion of liquid fuel are much higher than those produced by solid fuel. This is a considerable advantage because the quantity of heat lost in the flue gases is less, as there is a smaller volume passing, and the rate of heat transfer to the drier air is considerably accelerated in the region of the furnace. As stated above, the majority of indirect stoves were designed for solid fuel, and for the reason just given it is necessary adequately to protect them from damage due to excessive heat. This can be done by the use of satisfactory refractory and insulating material in certain parts of the stove, and by the dilution of the products of combustion in other parts of the stove by the admission of extra air. We cannot lay down fixed rules for the insulation of furnaces, or the amount of dilution required, but each stove must be considered individually.

With regard to the actual combustion of the liquid fuel it is essential that the amount of air admitted to the furnace should be capable of being regulated accurately. Air admitted at the burner should be the correct quantity for the proper combustion of the oil fuel. Dilution air which may be regulated to reduce the temperature of the products of combustion should not be admitted through the burner or through the air regulator, as this excess air interferes with the efficient combustion of the fuel. Any excess air required should be led through the ducts to the rear end of the combustion chamber and mixed with the products of combustion after combustion has been completed. The temperatures attained by the correct combustion of liquid fuel are very high and the rate of transmission of heat by radiation at this temperature is considerable. These temperatures, in fact, are too high for direct transmission to metal surfaces with the existing designs of furnaces because the flow of the drier air on the outer side of the furnace is not sufficiently great to absorb the heat transmitted by radiation. It is, therefore, usually necessary to provide a certain amount of insulation to the furnaces. An oil burner should be capable of maintaining satisfactory combustion without the assistance of incandescent brickwork. Nevertheless, in a suitably proportioned combustion chamber refractory materials can perform several valuable functions in respect to:—

(1). Accelerating combustion
(2). Promoting good mixing
(3). Ensuring clear and smokeless combustion.

An average criterion for combustion chamber volume in the majority of oil-fired furnaces for tea drying is to allow 3 lbs. of oil per hour per cubic foot, or 3 cubic feet per gallon per hour.

The protection of stoves from excessive temperatures is carried out in two ways: refractory materials and insulating materials are both required, due to the fact that it is difficult to obtain a material which combines the good features of both. Refractory materials are required because they are capable of withstanding very high temperatures and are mechanically strong, but these conduct a considerable amount of heat and are therefore poor insulators. Insulating materials are in almost all cases of a soft and friable nature and must be protected against possible pressure or abrasion. In addition they are not capable of withstanding the same high temperatures to which refractory materials can be subjected.

Refractory Materials.—The first essential in a refractory material is that it should have a high melting point. It is also important that it should have a high softening point under load. The reason for this is that as a rule there is no sharply defined melting point, most refractories beginning to soften at temperatures well below the melting point. It is also advantageous that refractories employed in furnaces intermittently operated, such as the furnaces of tea driers, should have a smooth expansion curve and that this coefficient of expansion be as small as possible. The most suitable quality of refractory for use in the furnaces of oil-fired tea driers is one composed of 43 per cent alumina and 50 per cent silica, the remaining 7 per cent being made up of small proportions of various impurities.

A typical brick answering to this rough specification has a melting point of 1750°C. (Cone 34) and will support a load of 50 lbs. per square inch up to a temperature of 1610°C. (Cone 27). The coefficient of linear expansion of this brick was found to be 0.00000575 per °C. over the range up to 1400°C.

The cheaper type of firebrick sold in Ceylon does not meet this specification and we recommend the use of special grade firebricks which are obtainable in Ceylon for use in oil-fired furnaces. The slight additional cost is more than outweighed by the increased life of the lining.

Insulating Materials—suitable for use in oil-fired furnaces consist of types manufactured from diatomaceous earth or asbestos. Diatomaceous earth is more expensive than asbestos, but allows less heat to be passed through it and will stand up to higher temperatures.

Recent research by certain manufacturers of refractory and insulating materials has resulted in the development of a "high temperature insulating brick". This gives a compromise between insulating property and capability to stand high temperatures. This high temperature brick has not yet reached that stage of perfection at which it may be used without the protection of a refractory lining in the combustion chambers of oil-fired furnaces. We undernote typical thermal conductivities which indicate the relative quantity of heat which would pass through the same thickness of materials. These figures are expressed in B.T.U's./sq. ft./inch thickness/°F/Hour:—

Aluminous firebricks ...	9
Silica brick ...	11
Diatomaceous earth ...	0·7 to 1
Asbestos	1·6
High temperature insulating brick from	2·0 to 3

In order of suitability for high temperatures the materials are placed as follows:—

(1) Silica brick
(2) Aluminous firebrick
(3) High temperature insulating brick
(4) Diatomaceous earth
(5) Asbestos

It may be mentioned that for intermittent work pure silica brick is not satisfactory, and a combination of silica and alumina, such as we have given, makes one of the most useful refactory bricks for tea firing stoves. Stoves are sometimes insulated from the external atmosphere by a considerable thickness of firebrick backed up, where the temperature permits, by common brick. It is obvious from the figures we have given that these two materials have quite high thermal conductivities and in order to reduce the heat losses to reasonable proportions it is necessary to employ walls which are disproportionately massive. Another disadvantage of these walls is that they retain a considerable amount of heat and they take a very long time to heat up to a steady working temperature, absorbing in this process very large quantities of heat which are accordingly not available for useful work in the heater. In a fuel-oil furnace it is generally sufficient to protect metal surfaces with refractory materials when there is a flow of air to be heated on the other side of the metal surface. Where there is no flow on the other side of the metal surface, or where there is a large area of brickwork used in the construction of these stoves, it is advisable to protect the metal with an insulating medium and to insert an insulating medium in front of the brickwork to prevent heat being absorbed by it.

Fuel Economy.—We pointed out in the paper in *The Tea Quarterly* [1] how to obtain the best results in burning oil fuel. It is essential that the flow of air to the furnace tubes and chimney stack is capable of proper control. Only that air required for the combustion of the fuel should be admitted at the burner nozzle or through the air director. Any air required for dilution of the products of combustion must be mixed with the products of combustion after they have passed through the furnace. Separate ducts and a regulator should be used for this purpose.

The practice of spraying liquid fuel over a surface of broken firebricks should be avoided as there is no control over the air supply and it is admitted in a very haphazard way.

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(1). *The Tea Quarterly* 1936, Part III, page 111.

There should be no leakage between the fireside of the stove and the drier air side of the stove and there should be no possibility of air leaking into the flue gases through openings or badly fitted joints in the stove. Any air admitted through the leakages interferes with the draught and reduces the efficiency of the stove by being heated to chimney temperature without doing useful work on the drying air.

Draught.—In order to attain the desired output it must be possible to burn the required amount of fuel in the combustion chamber, and also to draw in such quantity of air as may be required to dilute the products of combustion down to a safe working temperature. Many air-heating furnaces rely for the production of draught on a chimney, and much trouble may be caused by failure to consider in advance all the factors affecting draught. The designer having arrived at a calculated maximum oil consumption rate must work out the friction which it will be necessary to overcome in:—

(a). Drawing the necessary air for combustion through the air director.

(b). Drawing in the necessary air for cooling.

(c). Passing the diluted products of combustion through the heater itself.

(d). Evacuating these products through the chimney to the outer atmosphere.

It is also necessary to calculate the temperature at which the gases will leave the air heater and that at which they will leave the chimney in order to arrive at a satisfactory height for the chimney.

UNSUITABLE OIL-FIRING EQUIPMENT

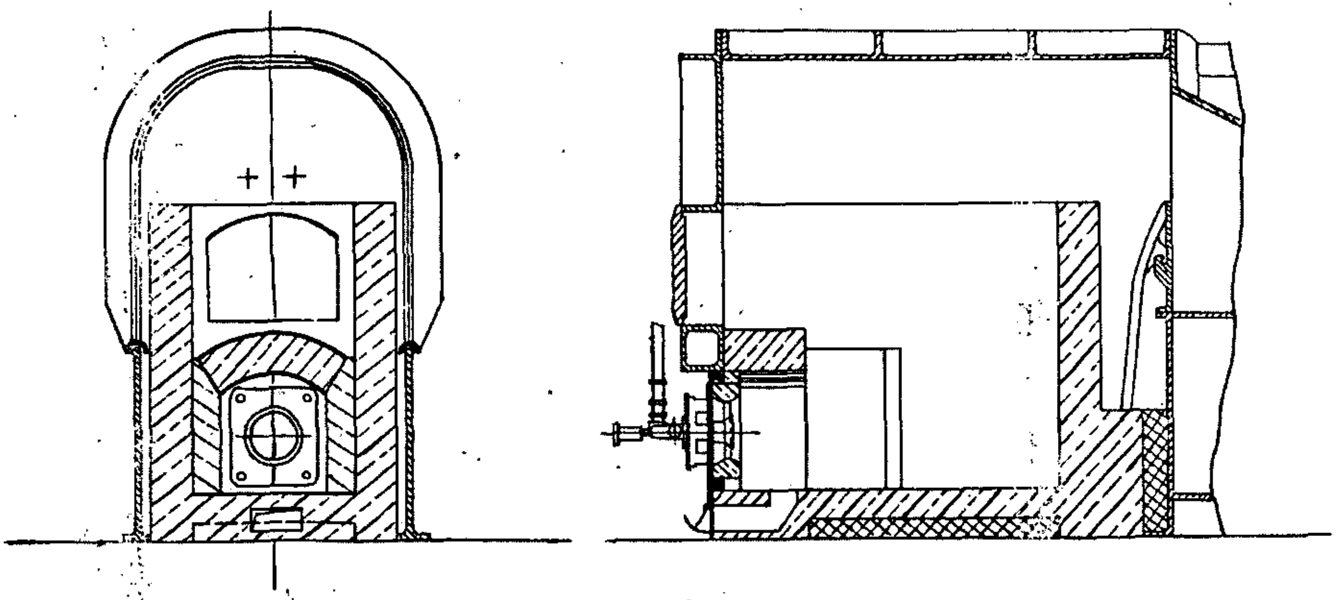
(1). The choice of oil-firing equipment was in many cases influenced almost entirely by the cost of the equipment rather than by its suitability for the purpose in view. Many of the burners employed are of a distinctly primitive type, necessitating the use of incandescent brickwork pillars or masses of broken brickwork to effect the atomization which should have been done by the burner itself. Such considerations very often jeopardised the success of the conversion.

(2). Many conversions were carried out in a manner not entirely in accordance with the correct principles. This was probably due to a lack of technical knowledge and emphasised the need for co-operation between the consumer and/or the air-heater manufacturer and the oil-firing expert. There is now no excuse for this lack of co-operation as many burner manufacturers, and at least one of the oil groups, maintain staffs fully conversant with the principles involved.

On most estates at the present time the only instruments used are thermometers and temperature recorders. These instruments merely record temperature fluctuations and do not regulate the temperature. They are of great value but it is essential that the calibrations should be checked regularly, and we consider that it is a very good plan to mark circles on these charts giving the firing and exhaust temperatures to which the estate is working and instructing the teamaker that the temperatures must be kept within these limits.

Descriptions and illustrations which follow show the application of oil firing to various types of heaters which have been enumerated above, giving practical examples of the principles involved in oil firing.

Drawing No. F.O.T. 3723 (Fig. I)—illustrates an air-heater of the fire tube type. This represents a conversion to oil firing of an air-heater which had been designed for solid fuel. It will be noted that the combustion chamber is entirely within the heater itself, and that therefore it was only necessary to provide refractory protection for the metallic parts of the heater. The burner is of the low air-pressure type and is fitted with an air director. The burner itself passed 25 per cent of the total air required for combustion, the remainder being induced through the air director. The floor of the combustion chamber will be seen to be lightly insulated. At first sight it might appear that the floor should be much more heavily constructed in order to avoid heat loss. This, however, was unnecessary as the diluting air required to cool down the combustion products to a safe temperature was brought in through the port placed underneath the burner and consequently swept the floor, thus keeping it comparatively cool. It will be noted that practically no



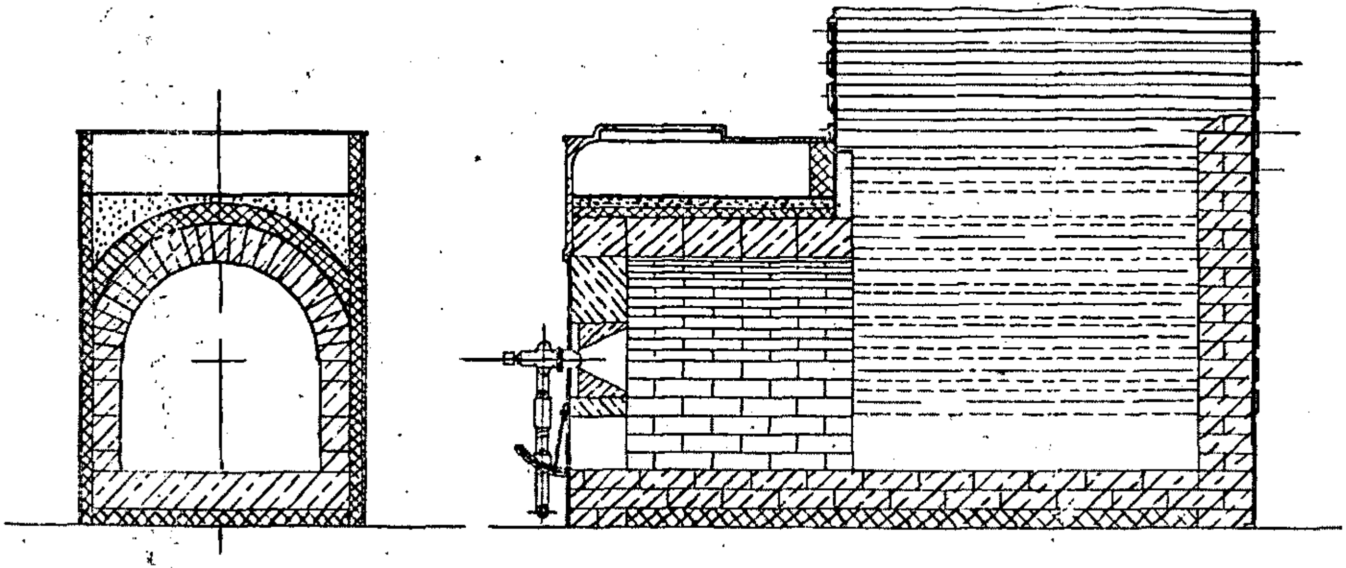
F.O.T. 3723

Fig. I

arch is given to the combustion chamber save the short one necessary to protect the metal work on the underside of the existing solid fuel firing door. The upper portion of the air-heater is so far removed from the level of the burner that it was considered unnecessary to continue this arch to afford protection, although provision was made to admit further cooling air if required above the combustion chamber arch.

Drawing No. F.O.T. 4005 (Fig. II)—shows an heater of air tube type. It will be noticed that in this case the combustion chamber is of the Dutch oven type, and that in consequence any heat passing through the combustion chamber walls will be transmitted to the atmosphere and therefore lost to the heater. In order to reduce this loss to reasonable proportions the combustion chamber, in addition to its refractory lining, has an outer lining of insulating material which will be seen to be protected by a casing composed of steel plates. The floor of the combustion chamber and of its continuation lying inside the heater is also well insulated as any heat travelling downwards through the floor will be lost. The oil burners are of the low air-pressure type in which 25 per cent of the air for combustion is taken through the burners. This type of burner was not supplied with an air director by the manufacturers and it was consequently necessary to arrange for the introduction of the remainder of the air for combustion through the ports which are shown underneath the burners. These ports are much larger than would be required for this purpose alone, the intention being that excess air should be induced through these ports in order to cool down the products of combustion to a safe temperature before they reached the tubes.

A further point worthy of note is that in this particular design the waste products of combustion after passing through the air-heater are collected in ducts at each side of the combustion chamber. These communicate with a common header box placed above the combustion chamber roof which serves to feed the outgoing gases to the chimney. There was a danger here that the draught might pull gases direct from the combustion chamber to the chimney through the joints of the brickwork if they should at any time open up, and a



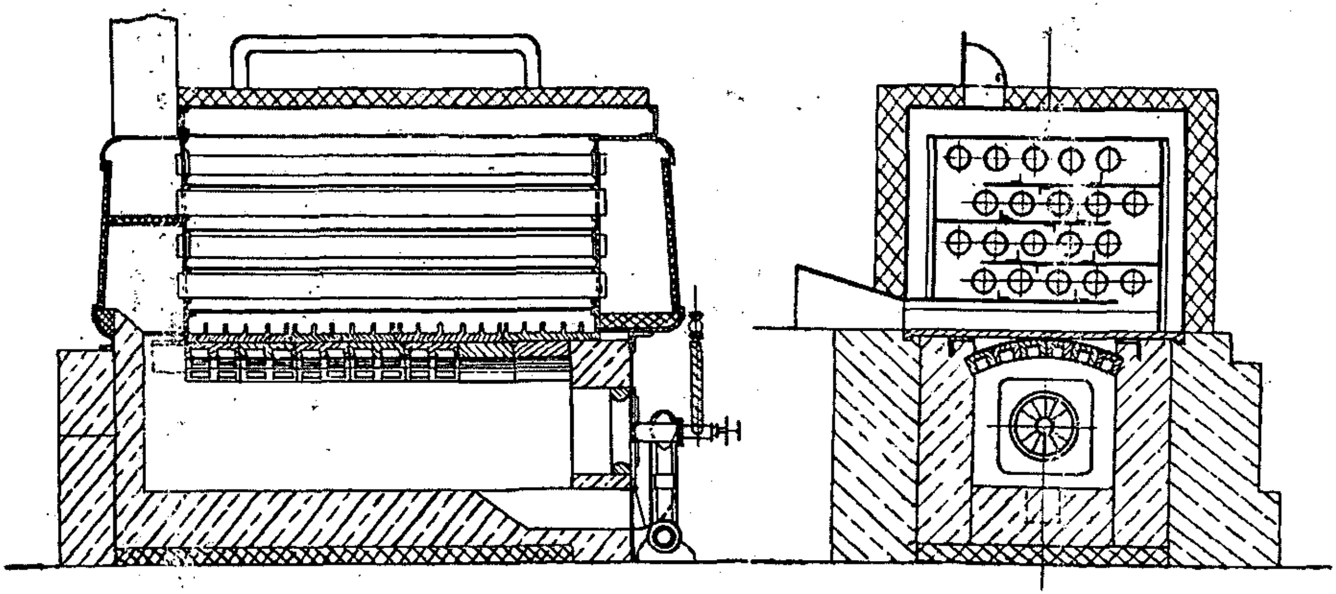
F.O.T. 4005

Fig. II

steel plate was accordingly fitted in order to seal off the header box from the combustion chamber. A further precaution against this was the interposition of sand between the brickwork and the steel plate.

As a matter of interest in may be pointed out that the designer when considering this particular conversion came to the conclusion that a better distribution of heat, and an improvement in heat transference, would be obtained by giving the hot gases a certain constraint which would force them first to travel through the middle portion of the heater and afterwards to divide into two portions which would travel along each side of the heater. This was effected by placing two baffles as indicated on the drawing. The effect of these baffles was to increase the velocity of the gases passing among the tubes and consequently slightly to increase the frictional resistance of the gas flow. This increase of friction had naturally to be taken into account when estimating the height of the chimney required. The designer naturally satisfied himself by calculation that these baffle plates would not suffer from overheating.

Drawing No. F.O.T. 3918 (Fig. III)—shows an interesting combination of the sectional and fire tube type of heater. The burner is of the low air-pressure type and is fitted with an air director. Such cooling air as is required is brought in through a port placed underneath the burner and serves to some extent to keep the floor of the combustion chamber cool. The heater itself is arranged so that, in addition to the fire tubes, the bottom of the casing is also intended to be heated and to transmit heat to air passing over it. In order to take advantage of this useful heating surface it will be noted that the combustion chamber arch is comparatively thin, and that the major portion is constructed of hollow box type bricks which permit a comparatively rapid heat-flow through the arch to the ribbed sectional underside of the heater. The combustion chamber floor is well-insulated and the side walls are made of thick brickwork of which the outer portion is common brick. The employment of thick brickwork for the side walls instead of, say, 9 in. firebrick plus insulation was decided upon in this case to afford adequate support to the air heater. It will be noted that the air-heater itself has not

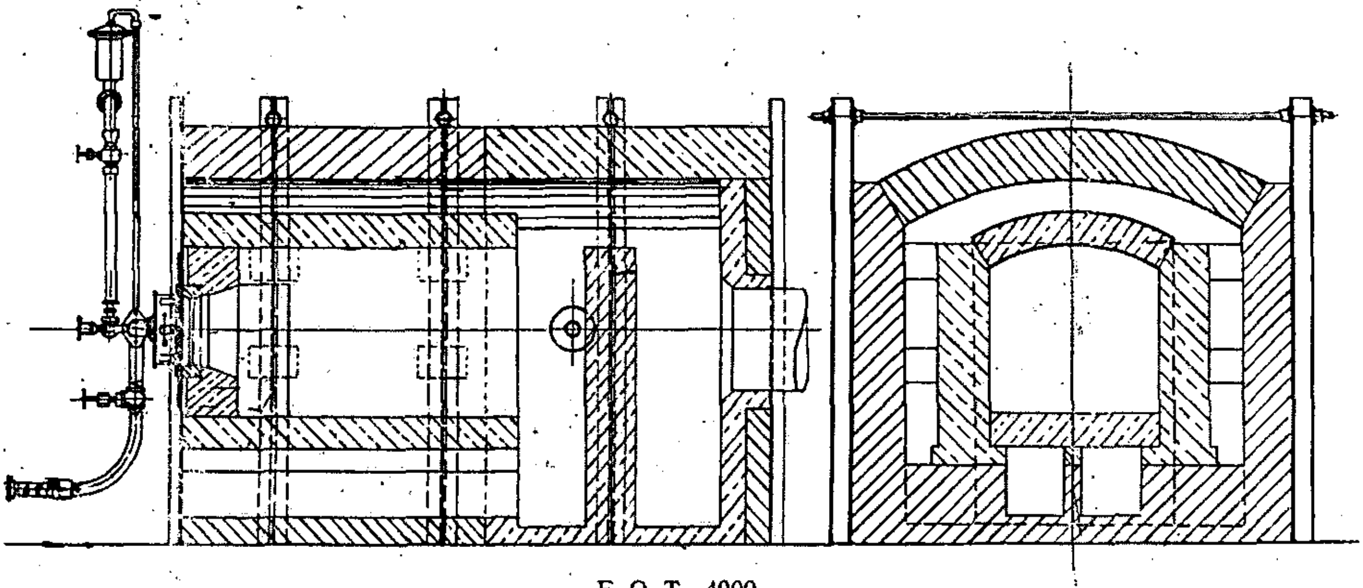


F.O.T.-39/6

Fig. III

been forgotten and that insulation has been provided where it was thought to be necessary.

Drawing No. F.O.T. 4000 (Fig. IV)—is typical of the direct mixing type of air-heater. The oil burner is of the low air-pressure type passing about 25 to 30 per cent. of the air through the burner itself. The remainder of the combustion air is induced through the natural draught air director. The combustion chamber is formed of thin brickwork as to the sides and arch which are completely enclosed in an outer brick chamber, the spaces between the combustion chamber and the outer chamber being utilised as ducts through which the cooling air is led. This construction ensures that the combustion chamber refractory will be kept at a satisfactorily low temperature and that no brickwork at a high temperature — with the unavoidable exception of the combustion chamber front — will be in communication with the atmosphere. The effect is that heat losses are kept down to an almost irreducible minimum. The baffle wall at the end of the combustion chamber forces the products of combustion into intimate mixture with the cooling air induced under the floor, around the sides and above the arch. The mixing having been completed, the air at the required temperature is led through ducting to points at which it is required. This drawing shows devices which afford protection in the event of failure either of the air supply from the fan to the burner or of the electricity supply. It will be noted that these devices consist of two valves in the oil line. One of these is connected by means of a pipe to the air supply pipe and the pressure of the air supply is thereby transmitted to a diaphragm which, while the pressure remains, holds the oil valve open. Should the air supply fail a spring would force the diaphragm in the opposite direction thus closing the oil valve. In the event of electrical failure a solenoid operated valve, which is connected to the main electricity supply and owing to magnetic action is normally held open, would be released and would shut off the oil. These two devices eliminate the possibility of oil dribbling into a hot combustion chamber and gasifying with possibly dangerous results, and are most useful adjuncts to plants which may be required to operate with the minimum of supervision or of skilled attendance.



F. O. T. 4000

Fig. IV