No. 132

THE INSTITUTION OF
POST OFFICE ELECTRICAL ENGINEERS

The Heating and Ventilating of Post Offices and Telephone Exchanges.

BY

W. T. GEMMELL, B.Sc. (Hons.), A.M.I.E.E.

A PAPER

Read before the Northern Centre of the Institution on the 19th March, 1930.

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Introduction.

The adequate heating and ventilating of Post Office buildings and those under Post Office control is the concern of the whole of the Engineering Department, inasmuch as we all have to spend at least some part of our working day in rooms in those buildings. In these circumstances each one constitutes himself a judge as to the efficiency or otherwise of the heating and ventilating arrangements made for his personal comfort, and it is on this judgment that any system is appraised or condemned. If all men were made to the same pattern, with the same susceptibilities to changes of temperature and changes in the constitution of the air of a room, it would be possible to design the heating and ventilating of an office to please everyone. There is, however, even among experts, great difference of opinion in regard to what is the ideal to be aimed at in providing these services.

Investigations have been made by various people at different times with a view to determining what might be called the limiting quantities of impurities permissible in the air of a room which is occupied by human beings, *i.e.*, the percentage impurities above which air could be definitely labelled as impure. So far as the author is aware, however, there has been no complete agreement on this point. Even if precise information were available, it is quite conceivable that, in some particular case, scientifically pure air might be very uncomfortable to breathe and might on this account prove detrimental to general health. As an example, one might refer to the prejudicial results to health produced by breathing air, a large proportion of which has already been breathed once, even when this has been expired by perfectly healthy persons. The investigations previously referred to have shown fairly conclusively that variation in carbon dioxide percentage within very wide limits has no ill effects, while the percentage of oxygen in air can be reduced considerably without any noticeable adverse effect on the bodily functions, so that the unhealthiness of expired air is not, apparently, due to the increase in the percentage of carbon dioxide or to the decrease in percentage of oxygen as is generally supposed. The particular feature of vitiated air which renders it unhealthy is not, therefore, revealed by a test of the gaseous composition of the air.

As a general rule, the merits of the ventilation of any room are assessed not by an analysis of the air, but by the feeling of comfort produced and with most people comfort in ventilation is analogous to the absence of draughts.

As there is uncertainty regarding the ideal to be aimed at in ventilating, so in heating there is a wide diversity of opinion regarding the most suitable room temperature to suit a particular class of work. A room which is cold to one man will be warm to another, and it is clear that no uniformity of result can be obtained when measured by the gauge of individual feeling. The trouble that the ventilating and heating engineer experiences in designing installations is in reconciling two opposite views and striking the happy medium to satisfy the majority. Unfortunately it is the dissatisfied minority from whom complaints are received, and speaking from my own experience, the writer knows of only one heating installation which has not at some time or other given rise to complaint from at least one member of the staff.

The foregoing remarks, of course, apply more particularly to offices where the comfort of the staff is the major consideration. In telephone exchange apparatus rooms, more particularly in automatic exchanges, apart from the comfort of the staff employed, the criterion of the efficiency of the heating and ventilating is the number of faults in apparatus directly attributable to the inadequacy of these services.

A full discussion of the theory of the transference of heat and flow of fluids is outside the scope of such a paper as this, which is only intended to give some idea of the various systems in use in Post Office buildings, together with the general principles involved and the practical method of applying these principles.

Principles of Heating and Ventilating.

Various systems of heating and ventilating are in use, each having its own particular application according to the size of the building, the purpose for which that building is to be used and the facilities available. In every case, however, the result aimed at is the same, *i.e.*, that the room temperature can be maintained at a uniform desired level, whatever the outside conditions and that the air of the room shall always be fresh. Room temperatures can, of course, be measured easily and quickly by thermometers placed in suitable positions in the room and the heating installation can be claimed to be satisfactory if it is capable of maintaining the room temperature specified under all conditions.

It will be clear, however, from the introductory remarks that the word " fresh " as applied to the air of a room has no scientific meaning and that there is no simple measuring instrument which can be used to determine definitely whether the ventilation is adequate or not. A ventilating system is, therefore, designed to do two things—(1) supply or extract a predetermined quantity of air from the room without causing excessive draughts; (2) ensure that no obnoxious smells are caused by the ventilation system.

A room at a higher temperature than the outside air is continuously losing heat by conduction through the boundary walls and ceiling and by heat taken away by the air used for ventilation, this air being at room temperature when it leaves the room. The amount of heat lost by conduction through the walls and ceiling depends on the difference of temperature between the inside and outside air and on the material of which the building is constructed.

The conductivity of the structure may be regarded as constant and therefore if there is a constant flow of heat into a room, the temperature of that room will rise until the heat lost equals the heat received. In its simplest form this may be expressed as follows:—

$$Q = KA\,(T - t) + CV\,(T - t)$$

Q = heat received by the room in unit time.

T = room temperature.

t = outside temperature = temperature of incoming ventilating air.

K = heat conducted through structure per degree difference between outside and inside temperature per unit area in unit time.

A = area of walls, ceiling and floor.

V = volume of ventilating air per unit time.

C = heat required to raise unit volume of air 1° in temperature.

It will be obvious that if no heat is supplied to a room then heat will be lost until $T = t$. The formula, in the form given, is applicable only to the case of a room surrounded by air of the same temperature. In practice, a room is usually adjacent to other rooms having various temperatures, the material of the inner walls is different from that of the outer walls, ceiling and floor and so on, and it is necessary to determine the heat loss for each particular portion. It will be appreciated that if the temperature of an adjacent room, such as a boiler room, is higher than room temperature, there will be a gain, and not loss of heat.

The following table gives some values of K for various windows, walls, etc., found in buildings, K being defined as the co-efficient, which when multiplied by the difference of temperatures between the inside and outside air, will give the average number of B.T.U. per hour which will pass through each square foot of the surface :—

Nature of Structure	Thickness in inches.	Value of K British Thermal Units.
Single window; ordinary glass	—	1.08
Double Window	—	·45
Single Skylight	—	1.04
Brickwork	4½″	·49
	9″	·37
	14″	.281
	18″	·235
Brickwork with 1″ plaster	4½″	·44
	9″	·306
	14″	.238
	18″	.206
Brickwork with air space	9″	.295
	18″	.198
	21″	.180
Concrete	4″	·55
	6″	·47
	8″	·41

The theoretical calculation of heat loss is made by measuring the areas of glass, walls, ceiling and floor of the particular room and multiplying each by the appropriate value of K and the difference of temperature which is assumed to exist on the two sides of the heat-losing surface.

To this heat loss must be added the heat required to raise the temperature of the ventilating air from the external temperature to the room temperature. The specific heat of air is .2379 B.T.U. per lb., *i.e.*, .2379 B.T.U. is required to raise the temperature of 1 lb. air by 1°F. At 32°F. and 14.7 lb. sq. in. 1 lb. of air occupies approximately 12.5 cu. ft. so that .019 B.T.U. is required to raise the temperature of 1 cu. ft. of air from 32°F. to 33°F. As ventilating calculations are always based on volume and not weight of air, this latter figure is the more useful in determining the quantity of heat carried away by the air passing through the room.

In central heating systems the summation of the heat lost by each room in a building gives the heat to be supplied by the heating installation.

In addition to the heat supplied by the installation there is also the heat given off by the occupants of an office. The average amount of heat given off by an adult human being, awake, active, and in good health, is about 400 B.T.U. per hour, made up roughly by 120 B.T.U. given off by contact with the air, 172 B.T.U. by radiation, and the balance, 108 B.T.U., in the breath and otherwise. Practically, however, this factor is too uncertain to take into account in determining the amount of heat to be supplied.

The quantity of air required for ventilating is dependent upon the average number of occupants of the room and/or any special work carried out in the room. Except in the case of automatic telephone exchanges, where the air is filtered before being passed into the apparatus room, no special steps are taken to condition the air for ventilating Post Office buildings, and once the quantity of air is determined, the design of a suitable system to deliver or extract the air as required is a comparatively simple matter. Generally speaking, it is found in practice that, if sufficient air is entering a room to ensure two or three changes per hour, the ventilation is satisfactory, provided the velocity of the air is not excessive and there are no draughts.

1. DIRECT HEATING.

The direct method of heating is by far the simplest, but it is very inefficient and consequently, in all except very small buildings, some form of central heating is usually installed. An open fire produces a heating effect entirely different from that given by radiators and pipes of a central heating installation and it is difficult to obtain any reliable data from which the exact quantity of heat given to a room by the fire may be determined. The greater portion of the heat is given off as direct radiation from the glowing coals, the heat waves being of short wave length compared with the relatively long wave lengths of the radiated heat from hot water or steam radiators. These high frequency waves impinge on the walls and contents of a room where they are partly absorbed and partly reflected, the walls being warmed in the process. The air of the room is heated mainly by conduction from the chimney breast and walls surrounding the flue which becomes warm by contact with the hot flue gases. In some cases effort is made to extract more heat from the flue gases by arranging a ventilator for incoming air in such a way that the air passes round the outside of the flue before delivery to the room.

From such experimental results as are available it would appear that the efficiency of an open coal fire is not more than 15%. It is thus very extravagant in fuel and, in addition, there is considerable labour involved in carrying fuel, cleaning and removing ashes.

With all these disadvantages and in spite of the existence of Smoke Abatement Societies, the coal fire still retains its popularity, and it is no uncommon thing to find that in old buildings, where a central heating system has been installed, the open fires are still retained.

One great advantage of an open fire is the good ventilation provided by the flue. The hot products of combustion create a good draught to the flue causing a constant circulation and change of air in the room, and it is unusual to receive any complaint of stuffiness from the occupants of a room where an open fire is burning.

The efficiency of a fire can be considerably increased by enclosing it in a stove which is placed some distance from the wall and connected by a separate pipe to the brick flue of the building. In such a position the stove radiates heat to practically all parts of the room instead of to only half the room as is the case with an open fire set back in an ordinary fireplace. A stove also heats the air of a room by conduction and convection, much in the same way as the radiator of an indirect system. The amount of heat given off by a stove depends on the rate of combustion of the fuel, the surface area and the materials of which the stove is made. The surface temperature in well made stoves in good condition is usually 300-400°F. and the heat emitted about 800 B.T.U. per sq. ft. of surface per hour. The overall efficiency varies considerably with the make of stove and although 40% efficiency has been attained in particularly favourable circumstances, it may be taken that the average is somewhere between 25% and 30%. Owing to the high temperature of the radiating surface and the oppressive nature of the heat produced, these stoves are not suitable for the general heating of buildings and their only application is in the heating of temporary accommodation for stores and workmen where first cost has to be cut down to a minimum.

Gas fires are installed in the comparatively few cases where circumstances are such that an open or closed fire, burning coal or coke, is not practicable because (1) the room is not in constant use or (2) labour for cleaning and attending a fire is not available. Mention has already been made of the high frequency heat waves radiated by glowing coals, and the same remarks apply to an even greater extent in the case of the heat radiated from the high temperature gas fire elements. The heat from a gas fire appears to scorch the skin without appreciably warming the body or the surrounding air. Gas concerns have recently contested this and it is understood have conducted a series of experiments to determine whether and how far the heat from a gas fire penetrates the human body, but the author has not seen any published results of these experiments, and cannot say whether they have been successful or not. Apart from the question of the relative value of the heating effect of a gas fire, the use of this form of heating can always be detected by obnoxious fumes, which find their way into the room after the fire has been in use for a short time, and this in spite of the efficient flues which must be provided whenever a gas fire is installed.

The great advantage of a gas fire is the absence of dust, ashes, and cinders, and the saving of labour required for cleaning and carrying fuel for an open coal fire. There is also the convenience of being able to obtain a supply of heat at very short notice. As the flue area of the gas fire is much smaller than the throat area of an open coal fire, the ventilating effect of the former is correspondingly smaller.

Electric fires, either of the resistance or luminous type, are preferable to gas fires, but the present price of electrical energy in many areas prohibits the general introduction of this form of heating for small isolated rooms where it would be most suitable. The heating element of the electric fire is at a very much lower temperature than the gas fire and consequently there is a greater feeling of warmth produced for the same amount of heat given off. There are, of course, no fumes with an electric fire, but the absence of a flue means that, although the air is circulating, the ventilation of the room is not improved as in the case of an open coal fire. It may be of interest to state that, as the result of a recent inspection of a certain small office by the Medical Officer, a recommendation has been made to replace gas by an electric fire, even though the annual cost will be greater, and this is, I think, only a particular example of what will be the general tendency within the next few years.

As distinct from gas fires, gas radiators are also used for heating small buildings. In appearance these are similar to the familiar hot water radiator, the gas being burnt at several jets situated in the bottom chamber. In most types the air necessary for the combustion of the gas is drawn from the room through openings in the bottom, the usual arrangement being for the radiator to stand on legs leaving a small space between the bottom, which is open, and the floor. With this type it is possible for the gas flames to be blown out by a sudden draught along the floor, and usually the first notification of this mishap is the strong smell of gas. Such a radiator is dangerous to use and cannot be left for any length of time without attention. So far as the Post Office is concerned, flueless type gas radiators were made obsolete some years ago, and for the gas-heating of unattended automatic telephone exchanges, where some form of heating is essential for the efficient maintenance of the apparatus, the Davis Balance gas radiator is now standard.

This balance radiator is made in two sizes, the single column and the three column. The principle is the same in each case, and will be understood from the following brief description of the larger type, as used by the Post Office.

Fig. 1 shews the general appearance of the radiator, and the constructional details are clearly shewn in Figs. 2 and 3.

FIG. 1.—GENERAL VIEW OF DAVIS BALANCE GAS RADIATOR.

The base, carrying three columns, has two burners, one under each of the outer columns, and two pilot flames. The pilot flames burn continuously, being originally lighted through plugs which have glass panels that enable the flames to be observed. The pilot jets and burners are accessible for inspection or cleaning, while the radiator is in position, through handholes; these are tightly closed by covers secured to the base by screws and washers. All joints are gas tight so that there can be no escape of gas or fumes into the room.

Each column has an internal steel tube, which ensures even distribution of heat. The centre column, which is connected at the top to those on either side, is divided by a horizontal partition into an upper and a lower half. An opening at the back, immediately below the partition, forms the air inlet, and another just above it constitutes the flue outlet. The air inlet and flue outlet form a single unit, and they are connected to the outer air through the wall by the flue and air box. The heat from the flames ascend through

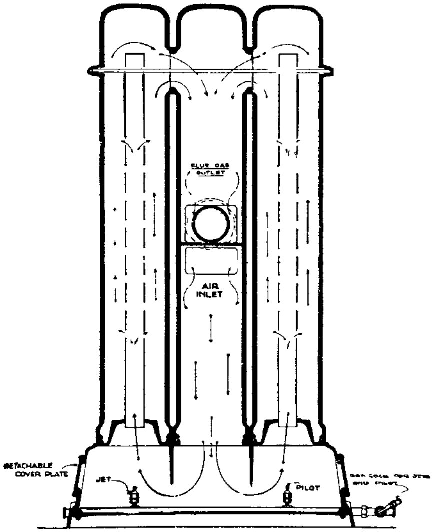
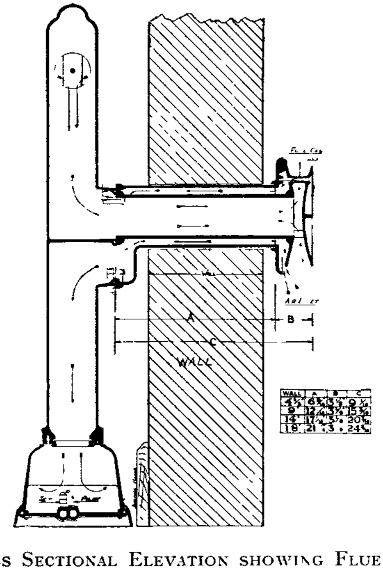


FIG. 2.—SECTIONAL VIEW SHOWING THE CONSTRUCTION OF THE DAVIS RADIATOR



WALL	A	B	C
4½"	6¾	3½	9 [illegible]
9"	12[illegible]	3½	15[illegible]
14"	17[illegible]	3½	20[illegible]
18"	21 [illegible]	3	24[illegible]

FIG. 3.—CROSS SECTIONAL ELEVATION SHOWING FLUE AND AIR BOX.

the two outer columns, drawing the air for combustion through the lower half of the centre column. The products of combustion pass from the top of the outer column into the upper portion of the centre column, and escape through the flue outlet. If the radiator is properly fixed, no down draught can take place to interfere with the flames or cause products of combustion to be blown back into the room, for the wind necessarily blows with the same strength into the air inlet as it does into the flue outlet and so balances in the burner base. The makers claim that tests with air currents of sixty miles an hour have failed to cause a flicker of the flames.

The only serious disadvantage seems to be the discolouration of the outside wall, caused by condensation of the steam contained in the flue gases which are discharged into cold air close to the wall.

The main dimensions and particulars taken from the maker's list are:—

Number of columns	3
Height overall	41″
Width, including tap	26½″
Depth overall	21¼″
Depth, excluding flue and air box...	9⅜″
Height from floor to bottom of flue and air box	18½″
Opening in wall for flue and air box	6″ wide × 8¾″ high
Hours service per therm	10 – 20 cu. ft. hr.
Heating capacity for offices ...	1440 cu. ft.

The particulars regarding heating capacity are of very little use without further particulars concerning temperatues attained, situation and structure of buildings, etc.; but, taking an average case with inside temperature 60°F. and outside temperatures 30°F., the efficiency of the radiator works out at about 50%.

2. INDIRECT OR CENTRAL HEATING.

Low Pressure Hot Water.

It is safe to say that 99% of the central heating installations in Post Office buildings are low pressure hot water systems, using coke-fired boilers of the cast iron sectional type. This system is described in some detail in a paper* read by Mr. T. J. Monaghan before the Irish Centre of this Institution in 1912, and it is not now proposed to go very fully into the theory and design, but the following brief description and details may be helpful in making for the completeness of this paper.

The low pressure hot water system consists essentially of a boiler, a system of pipes and radiators, a supply tank and an expansion tank, these tanks usually being combined into one.

Fig. 4 shows the essentials of this system, with a single pipe circulation.

The water in the tank has a free air surface and therefore the maximum pressure on any part of the system is that due to a head of water equal to the difference of level between the tank and the lowest part of the system, usually the boiler. In a very large building, say of eight floors, the head would be about 100 ft., equivalent to a pressure of 43.4 lbs. per sq. in., so that even in large installations the maximum pressure is comparatively small.

The heat flow in any system employing a direct fired boiler and a circulating fluid may be shown diagrammatically as in Fig. 5.

The low pressure hot water system is very flexible in its operation as, by regulating the stoking, the temperature of the circulating water can be maintained at any figure to suit the prevailing outside conditions and, by operating the valves in the circulations and radiators, the water may be made to give up its heat where most needed.

The efficiency of any system depends principally upon the boiler and the circulation of the water, the latter being determined by the design of the pipework.

Practically all boilers installed now are of the sectional cast iron type, of which there are numerous makes on the market, each designed to obtain the greatest possible heating surface for any given capacity. Compared with the old type wrought iron boiler they are easy to transport and erect, and experience has shown that, with reasonable care in operation,

* I.P.O.E.E. Professional Paper No. 50.

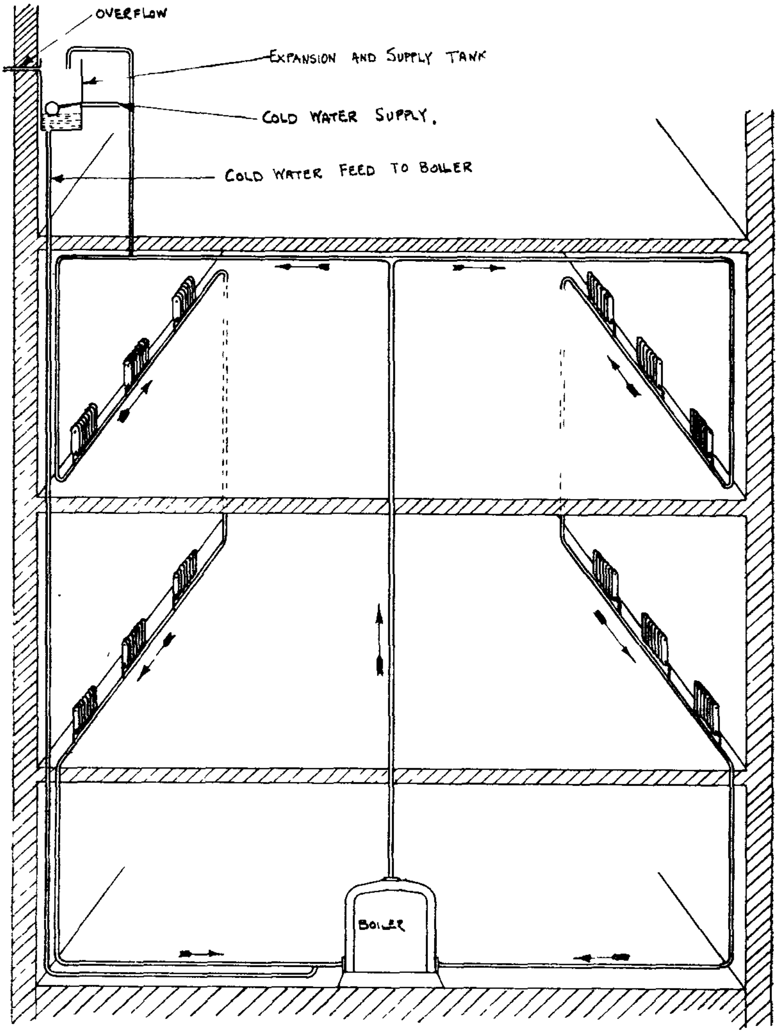


FIG. 4.

little is to be feared from fractured castings due to changes of temperature.

Heat transference depends upon the difference between the temperature of the fire and the temperature of the circulating water. The greater the difference in temperature the

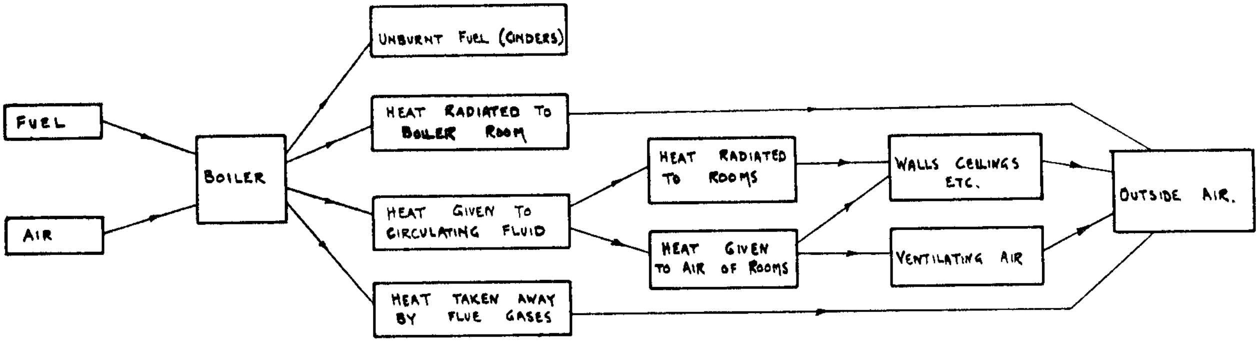

FUEL
AIR
BOILER
UNBURNT FUEL (CINDERS)
HEAT RADIATED TO BOILER ROOM
HEAT GIVEN TO CIRCULATING FLUID
HEAT TAKEN AWAY BY FLUE GASES
HEAT RADIATED TO ROOMS
HEAT GIVEN TO AIR OF ROOMS
WALLS CEILINGS ETC.
VENTILATING AIR
OUTSIDE AIR.

FIG. 5.

more efficient will the boiler be. The greatest economy is therefore obtained by working the boiler at the lowest possible temperature of the water consistent with maintaining the flow of heat from the pipes and radiators to the building.

Heat taken away by the flue gases is heat lost and the lower temperature of these gases before they escape to the chimney, the smaller the heat loss. Theoretically, maximum boiler efficiency would be obtained by cooling the products of combustion to the same temperature as the circulating water 160°F.—180°F., but as the majority of heating boilers are worked by natural draught the practical effect of such cooling would be to reduce the quantity of air to the boiler below that necessary for complete combustion of the fuel. The draught depends upon the temperature of the flue gases and the height of the flue so that, for any particular boiler and flue, there is a minimum temperature of flue gas which will be just sufficient to produce the draught required for the complete combustion of the fuel used. In a normal installation, working at maximum boiler economy, the temperature of the flue gases is about 350°—400°F. In some cases the temperature may even be reduced to about 300°F., but the danger in using such a low temperature is that the gases leaving the chimney may be so far cooled as not to be readily dissipated in the surrounding air and may even fall to the ground and cause a nuisance.

The circulation of hot water in a pipe system depends on the elementary fact that, when water is heated, it expands in volume and decreases in density, although the application of this fact to the complete theory of the circulation of water in a heating pipe is somewhat involved and complicated. The general principles will, however, be understood from consideration of the one-pipe circuit shown in Fig. 4. A riser or flow pipe is taken from the top of the boiler, rises as direct as possible to the highest point in the circulation and returns, through the rooms to be heated, to the bottom of the boiler.

A combined cold water feed and expansion tank is connected direct to the boiler. When the water in the boiler is heated the water in the riser is also heated by convection, and as it rises in temperature increases in volume and decreases in density. The excess volume of water is driven into the expansion tank, leaving a column of hot water in the riser and a column of cold water in the return pipe. The absolute pressure at the bottom of the riser and return is of course the same, but at the top the pressure in the riser is greater than that in the return by an amount proportional to the difference in weight of the hot and cold columns.

Water at 160°F. occupies approximately 1.0234 times its volume at 45°F. so that, neglecting any increase in the sectional area of the pipe, a column of water 100 ft. high will expand to 102.34 ft. and therefore the head producing circulation in a circuit having a riser 100 ft. high would, for the temperatures given, be 2.34 ft., this being equivalent to a pressure of 0.9 lb. per sq. in. Although not a very large pressure it is in the majority of cases found sufficient to produce the desired circulation, the pipework being proportioned to obtain the rate of flow required.

The heat is given up by the circulating water to the metal of the pipes and radiators by conduction and thence to the building partly by direct radiation and partly by convection. Radiators are devices used for obtaining a large heating surface in a small space and have now become practically standardised with one, two, three or four column cast iron sections screwed together to make up the heating surface required.

The heat given off by a radiator naturally varies with the design of the radiator and the difference between the temperature of the water and the temperature of the room and the air in contact with the radiator. For a difference of 100°F., a value of 140 B.T.U. per sq. ft. of heating surface may be taken as representing the average emission from a two-column cast iron radiator with bottom connections; the emission from the pipework is about 50% more than this.

While the surface area of heating pipes and radiators in any room cannot by itself be taken as an indication that the room temperature will be maintained at the desired level, it is found that the proportion $\frac{\text{heating surface}}{\text{cubic capacity of room}}$ is, within certain limits, sufficiently constant to provide a check on more detailed calculations. This proportion, known as the heating factor, is expressed as so many sq. ft. of heating surface per 1000 cu. ft., and for Post Office buildings the usual factors are as shown in the following table:—

Room.	*Heating Factor.*
Public Offices	15-16
Sorting Offices	12
Switch Rooms, Instrument Rooms, Retiring Rooms	18
Clerical Offices	16
Messengers	15
Stores, Passages	10

These are the factors necessary to maintain the temperatures given in the table on page 9 with an outside temperature of 30°F.

Boilers were formerly rated in terms of the sq. ft. of heating surface which they were capable of heating, but it is now more usual to rate them in B.T.U. per hour transmitted to the water. The exact rating of a boiler is not easy to determine experimentally, and it may be taken for granted that the rating given in a manufacturer's catalogue represents the maximum power of the boiler when worked under the most favourable conditions with skilled stoking and attendance. As most installations are stoked by unskilled men and attendance is only given at infrequent intervals, the practical rating of a boiler should be regarded as about 30% below the catalogue rating, which allows a small margin for extension of the installation if required.

The following information extracted from the heating plans of installations recently brought into service in the Northern District will give some idea of the main particulars of heating systems:—

Building.	Total cube c. ft.	Cube Heated c. ft.	Boiler Power BTU p.hr.	Heating surface sq. ft.	
				Pipes.	Radiators.
Small garage	15,000	15,000	88,000*	140	120
P.O. & T.E.	32,000	22,000	117,000	139	261
do.	100,000	88,000	410,000	751	879
do.	132,354	104,155	453,000	729	1083
Auto. T.E.	910,000	735,000	2,500,000	4350	6500
Garage	200,000	198,000	360,000	1182	238

* Classic boiler.

A general view of a sectional cast iron boiler is shown in Fig. 6. The particular pattern is made in sizes varying from 40,000 to 1,200,000 B.T.U. per hour rated capacity. The usual fittings provided on a low pressure hot water boiler

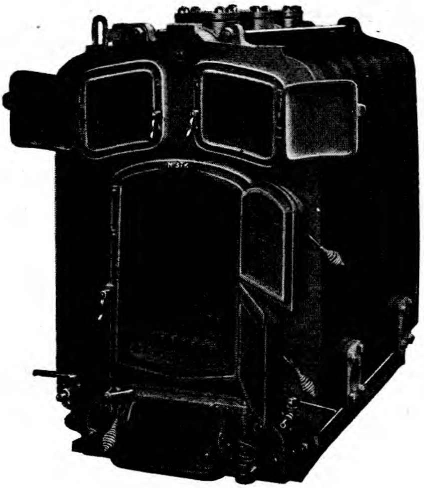


FIG. 6.—SECTIONAL C.I. BOILER.

are:—thermometer, safety valve (either dead weight or spring loaded, altitude gauge, the scale of which is calibrated in lbs./sq. in. and also in feet head of water, the normal working head being indicated, drain cock and drain pipe for emptying the boiler and a damper for regulating the draught. Flanges are provided at the centre of the top of the sections to take the risers and at the bottom on either side to take the return pipes. The flanges required are specified when ordering. A sectional elevation of the boiler is shown in Fig. 7 and this indicates the path of the flue gases from the furnace to the flue.

Another type of low pressure hot water installation is that in which the boiler is itself made to supply heat direct to one of the rooms in the building. As the quantity of heat radiated by an unlagged boiler is very large, this type of installation is only applicable to small buildings. The boiler is similar in appearance to the ordinary domestic hot water boiler, and is usually placed in the largest room in the build-

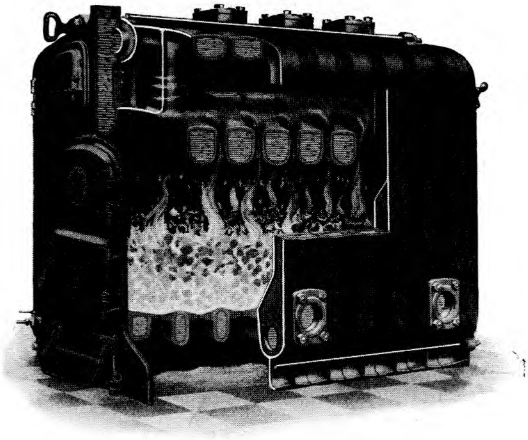


FIG. 7.—CROSS SECTION OF C.I. BOILER SHOWING FLUES.

ing, such as a Sorting Office. The heat given off direct from the boiler varies from about 15% of the total heating power of the boiler in the smaller sizes to 9% in the larger sizes. The operation is the same as an installation in which the boiler is placed in a separate chamber ,but particular care has to be taken in the design of the flue and in the stoking to ensure that fumes are not blown back into the room.

A boiler of this type is shown in Figs. 8 and 9. The same fittings are provided as on an ordinary low pressure boiler, but as a general rule provision can only be made for one flow and one return.

Instructions for the working of low pressure hot water heating apparatus are given in a leaflet (Form T.E.479) issued to all officers responsible for these installations, and if these instructions are followed a well-designed system should function satisfactorily, even with unskilled stoking. Reference has already been made to the flexibility obtained with this type of heating by regulating the boiler temperature to suit outside conditions. Investigations into many complaints of inadequate heating, show, however, that the boiler temperature is affected by two factors in no way connected with the outside temperature—(1) economy in fuel stimulated by the Fuel Rationing Forms now in use; (2) reduction of the time spent on stoking to a minimum, consistent with

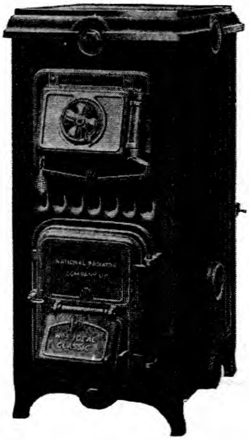


FIG. 8.—GENERAL VIEW OF CLASSIC BOILER.

keeping the fire alight; and cases can be quoted where a room temperature of 60° has been expected at 5 o'clock in the morning after the boiler fire has been banked all night, the boiler temperature falling to about 80°F. The efficiency of a low pressure hot water installation is 65%—75% and may even, with skilled stoking and regular attention, attain 80%,

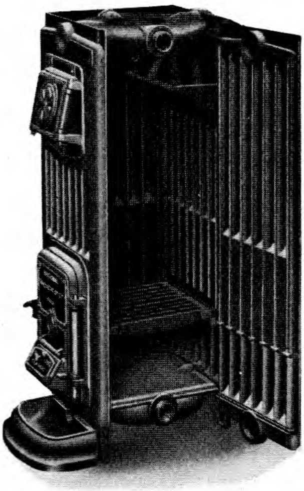


FIG. 9.—SECTIONAL ELEVATION OF CLASSIC BOILER.

but obviously under no circumstances will more heat be given out than is put in, and this fact cannot be too strongly impressed on those responsible for the heating of buildings.

The Low Pressure Steam System is similar in appearance to the hot water system, consisting, as it does, of pipe circuits, with radiators where increased heating surface is required; but the circulating fluid is low pressure steam and the radiating surfaces are at a much higher temperature than in a hot water system. The circulation of the steam is produced by condensation of the steam in the radiators and pipes, the water of condensation flowing back to the boiler through a pipe which enters the boiler below water level.

The chief disadvantages of the system are:—

(1) Frequent and careful stoking is necessary to maintain the correct boiler pressure, which is usually a few lbs. per sq. in. above atmosphere. This, of course, only applies to installations where a separate steam boiler is installed for heating.

(2) Lack of flexibility owing to the large rise in pressure of steam for comparatively small increases in temperature and to the fact that a steam radiator can only be controlled by shutting it off altogether.

(3) The high temperature of the radiating surfaces produces discomfort in the immediate neighbourhood of these surfaces.

For these reasons low pressure steam heating is only used in P.O. buildings when a cheap steam supply is available from boilers which have been installed for some other purpose, as in the P.O. generating stations now shut down. Even in these cases it is now the practice, when an extension of the building is made, to instal a low pressure hot water system, the water being heated by the steam in a calorifier.

The Medium and High Pressure Hot Water Systems need only be briefly referred to here. In the high pressure system the water is contained in a hermetically sealed pipe which forms a continuous circuit, provision for the expansion of the water being made by leaving an air space in a tube fixed to the highest point in the circuit; in the medium pressure system this expansion tube is replaced by a combined pressure and vacuum valve, which relieves excess pressure on the system. As in the low pressure system, the circulating power is produced by the difference in temperature of the hot and cold columns, but as the temperatures are much higher, the circulation is much more vigorous. The heating surface consists of a single hydraulic pipe about $1\frac{5}{8}''$ external dia., one portion of the pipe being formed into a coil placed in the furnace to form the boiler. The proportion of the pipework in the furnace is calculated from the estimated furnace temperature likely to be maintained, the proportion between the boiler and the heating pipes varying from one-sixth to one-tenth according to the temperature maintained. Calculations with this system are very simple where only one or two rooms are heated, but become somewhat complicated when one coil is used to supply heat to a number of rooms, owing to the considerable variation in temperature throughout the pipe. It is therefore preferable in such cases to arrange for a separate installation for each room, each circulation having its own boiler coil in the furnace.

The total water content of the system is small and consequently any stoppage in the pipework is likely to lead to dangerously high temperatures and pressures; valves are therefore not placed in the circuit and the only heating control obtainable is by regulation of the furnace temperature.

The system is fairly simple in operation but requires careful maintenance, owing to the high pressures used. It has one big advantage in that heat can be got up very quickly, but suffers from the lack of flexibility and the disadvantage of high temperature radiating surfaces.

The Plenum System of heating is a system in which the circulating fluid is air taken from the outside and forced over a heating surface into the room or rooms to be heated, where the heat is dissipated to the structure, etc., and thence to the outside air. The essentials of a Plenum system are a fan room, a fan, a suitable heating surface for warming the air to the desired temperature and a duct system to distribute the warmed air to the rooms as required. Filters for cleaning the air are added in many installations.

The Plenum system of warming buildings is very costly in upkeep due to the large quantity of air which is heated and to the power used in driving the fan, and unless elaborate apparatus is installed to condition the air as regards humidity, the delivery of large quantities of heated air into a room produces a feeling of intense dryness which is far from comfortable. This system is not used in Post Office buildings as a primary means of heating, but is installed in automatic telephone exchanges to supplement other methods of central heating in the event of excessive humidity of the air of the apparatus rooms. As the major problem in these rooms is to obtain adequate ventilation with the exclusion of dust, the Plenum system used by the Department is discussed in greater detail later under ventilating systems.

Heating of Unattended Automatic Telephone Exchanges.

The introduction of automatic telephone systems has brought under the care of the Engineering Department a large number of small, unattended, satellite exchanges, and before passing on to ventilating systems it will be of interest to consider briefly the method of heating adopted in these cases. Heating in these exchanges is provided primarily for the efficient maintenance of the apparatus, and not for the comfort of staff. There are two main factors in the problem which presents itself, first, the determination of the minimum temperature necessary to ensure that condensation does not take place; second, the fact that the building is unattended, and the method of heating must be such that the system can be left for long periods without attention and without risk of fire.

The minimum safe temperature of automatic apparatus rooms depends on the hygrometric state of the air which is, of course, not constant for any appreciable time. Acting, apparently, on the principle that it is better to err on the side of safety, it has hitherto been the practice to maintain approximately the same temperature as in offices, *i.e.*, 60°F., but this practice has been modified somewhat, and the temperature to be maintained is now settled by the maintenance staff in accordance with the weather conditions.

As previously stated in this paper, the use of the Davis Balance gas radiator is now the standard method of heating employed in unattended automatic telephone exchanges. Thermostat switches were formerly fitted on these radiators, but have now been abandoned owing to their high cost, and unreliability. One or more radiators are fitted according to the size and situation of the room, and these are regulated by hand by the maintenance man during his routine visits to the exchange, the regulation being determined by the condition of the air and the evidence or otherwise of condensation on the equipment. Hand control of the heating should be satisfactory if visits to the exchange are fairly frequent, and no sudden change of temperatupre takes place, but both these factors are uncertain quantities, and if special visits have to be made to attend to the heating, the maintenance costs are likely to be excessive.

Owing to its comparatively high cost, electric heating has not yet been adopted to any great extent in the Department. In many cases, however, supply authorities are now offering very favourable terms for off peak loads with a high load factor, and I think that where such terms can be obtained the electric heating of unattended exchanges should prove an economic proposition. Electric heaters of the tubular type can be installed at very low cost, and reliable thermostats for controlling these heaters are available. The maintenance costs of such an installation would be negligible, and the only factor to be determined would be the temperature to be maintained.

Where, for one reason or another, electric heating cannot be provided, I would suggest that telephone equipment of more robust construction be installed, *i.e.*, more on the lines of the rural automatic exchanges, where heating is not provided.

*VENTILATING SYSTEMS.

All methods of ventilating buildings may be classified under one or other of the following :—

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* Since the paper was written the Committee appointed to investigate the problem of ventilating automatic apparatus rooms, has issued its report and the recommendations made by this Committee are being adopted in all future automatic telephone exchanges as standard practice. Where existing ventilating systems are unsatisfactory they will be modified accordingly.

It has been decided that in this country there is no need for elaborate methods of humidity control, and electrical heaters with thermostat control of fan and heater have been abandoned. The fan motor is now hand controlled by a starter situated near the motor. Extractor fans have been abandoned and the Plenum system is installed in all attended automatic exchanges irrespective of size. In the smaller exchanges a Plenum unit comprising a dry pad filter and fan is installed in the apparatus room near an outside wall. Air is drawn from the outside through a short duct and is filtered and delivered to the room by means of surface ducts through punkah louvres, either fixed or rotating. The number of Plenum units and louvres is determined by the size of the room. In large exchanges the fan is in a separate chamber and Visco filters are used. Where only simplex filters are installed initially, sufficient reserve of motor power is provided to permit of duplex filters being added should they be found necessary. Sheet iron surface ducts are provided terminating in 8″ by 4″ branches to take the punkah louvre.

(1) Natural ventilation, including systems in which air currents are induced by heat from radiators, etc.

(2) Mechanical ventilation, where flow of air is produced by some mechanical means, *e.g.*, a fan.

The provision of inlets and outlets for the natural ventilation of a building is usually settled by the architect, and the problem does not primarily concern us as an Engineering Department. It will be as well, however, to make brief reference to this method here, as the heating of a room has an important bearing on the ventilation.

There is very little doubt that an open window or windows is the cheapest and most efficient way of introducing fresh air into a building. The wind, blowing as it does in practically all directions, ensures that fresh air finds its way into every corner of the room. There is no stagnation, and the air currents carry out dust particles, both organic and inorganic, which are present in every occupied room. There is, of course, the objection that where the building is situated in a town open windows introduce a large amount of dirt in the form of soot, and added to this is the fact that very few people are inured to working with open windows. It is, therefore, the exception, rather than the rule, for windows to be opened, except on hot, sultry days.

Reference has already been made to the beneficial ventilating effects produced by an open fire, and where this method of heating is employed nothing further is required, but where central heating by radiators is installed air inlets and outlets must be provided for all large rooms; (small rooms usually receive sufficient change of air from the opening and closing of the door, cracks round the windows, etc., as no room of normal construction is airtight). Fresh air inlets are usually placed behind the hot water radiators, which are fitted with baffle plates to prevent the air entering the room without being warmed. The inlets are controlled by " hit and miss " regulators, operated by a slide rod from the side. The action of a ventilating radiator, as it is called, is to heat the air in its immediate vicinity, which, being less dense than cold air, rises, its place being taken by cold air drawn through the inlet, which in turn is heated. A current of warm air thus rises up the wall from the radiator; as the wall is a few degrees colder than the air of the room, a current of cold air descends, and at some point, depending upon the relative temperatures, the two currents mix, and are turned at right angles to the wall into the room. The air currents so set up should reach every part of the room. With high temperature radiators it is found that the hot air rises practically to the ceiling, causing a cold down draught in the centre of the room, or if there are deep ceiling beams the air current may be so deflected that the air in the centre of the room is not disturbed. The air thus introduced into the room finds its way out again through the door, cracks in the window fittings, and outlets near ceiling level which are fitted in many large rooms. Fig. 10 shows the circulation of air in a room under varying conditions. In automatic apparatus rooms the fresh air inlets behind the radiators are fitted with gauze screens to exclude dust as much as possible without restricting the air flow.

With the exception of large sorting offices, rooms in basements where fresh air inlets are not practicable, and automatic apparatus rooms, where special precautions are taken to exclude dust, it is found that natural ventilation meets requirements in the majority of rooms in buildings of moderate dimensions, such as Post Offices, and Telephone Exchanges.

Mechanical Ventilation.

When it is impracticable or undesirable to provide natural ventilation for a room, the circulation of air must be carried out by mechanical means and two methods are in general use:—

(1) Air extracted by a fan, either with or without duct work.

(2) Air forced into the room, usually called the Plenum system, whether the air is heated or not.

Extractor Fans.

Air may be extracted from a room by fitting an extractor fan in the wall, preferably an outside wall so that the air is discharged direct to the outside air. Provided that the outside wind velocity is not high, there is very little difference of pressure between the inside and outside, and it is usual to instal a propeller type fan, the efficiency of which is greater the smaller the difference of pressure against which it has to work. The principle of the propeller fan is similar to that

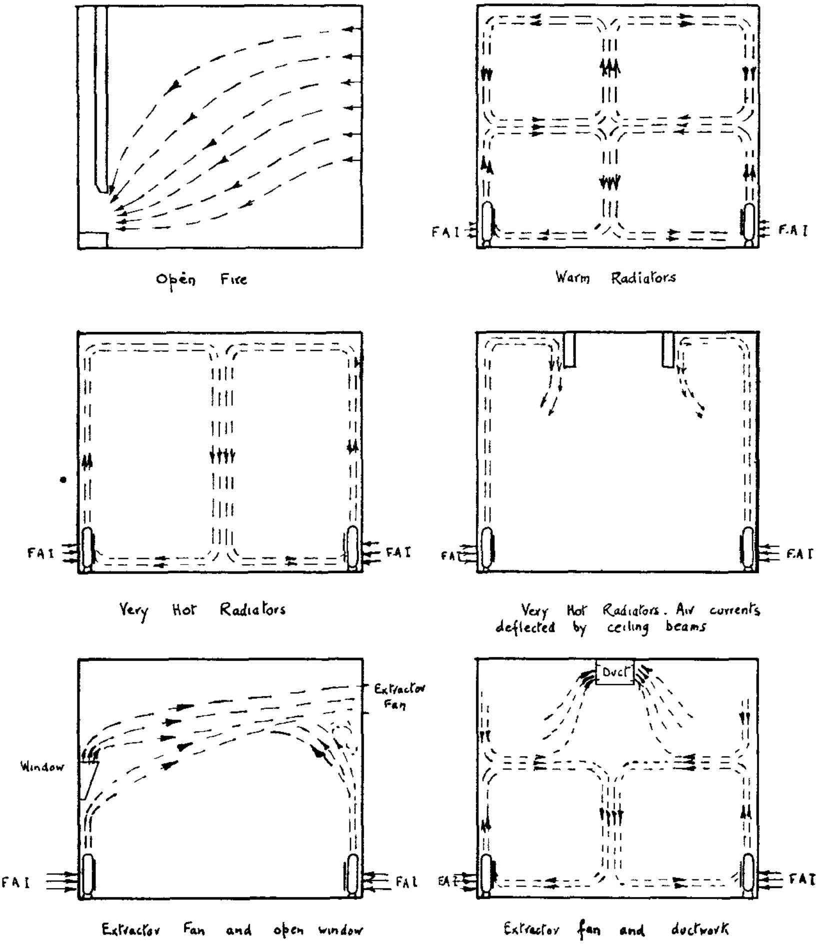


FIG. 10.

of the multiple thread screw, but, as the performance of a fan depends upon the shape of the blades, size of blades, diameter of fan, and speed of rotation, it is impossible to give results which can be applied generally. The following table, giving the rating of fans of different sizes, of one particular make, will, however, serve as an indication of the performance to be expected :—

No. of Blades.	Dia. of wheel, Ins.	Resis. in ins. water gauge.	Volume of air moved in cu. ft. per minute.	Revs. per minute.	Power H.P.
4	9	Free air	400	1300	.04
6	12	,,	1000	1300	.045
6	15	,,	1500	1100	.067
6	18	,,	2200	900	.08

The performance of a propeller fan is greatly influenced by difference of pressure between the two sides, for example, if the 12″ fan referred to in the above table were set to work against a resistance of 0.25″ w.g. the volume of air moved per minute would be reduced to 425 cu. ft., a reduction of over 50%. The choice of position for a propeller extractor fan is therefore a matter for careful consideration, as it will be appreciated that if the fan is placed in a position affected by wind, conditions may easily arise which render the fan inoperative even when running.

The installation of extractor fans of this type, with dust-excluding shutters, is specified for all apparatus rooms of attended automatic telephone exchanges under 2000 lines, the fan having a capacity equal to one change of the air of the room per hour. Inlet ventilators, fitted with wire gauze dust screens are provided, and in favourable weather selected windows may be opened: these windows are fitted with removable cheese cloth screens, consisting of a framework carrying two sheets of cheese cloth with a space of about 1½″ between them.

Injudicious choice of the relative positions of the air inlets and the extractor fan or fans may prevent the main volume of air in the room from being disturbed, *i.e.*, fresh air is "short-circuited" between the inlet and outlet without ventilating the room.

The second system of air extraction, where a duct is employed, finds an application in the ventilation of Post Office basements, where bag rooms are usually situated, and in very large sorting offices. A fan of centrifugal type is employed, its inlet being connected to the duct and its outlet discharging to the outside atmosphere. The size and type of fan depends upon the length, size, shape and structure of the duct, and the quantity of air to be removed per hour. The duct is placed at the top of the room so that warm foul air is drawn off and cold fresh air finds its way into the room *via* the doors, etc. Where not built into the structure the duct is constructed of galvanised sheet iron with easy bends to offer little resistance to the passage of air.

The Plenum System.

This is the system which has been adopted for the ventilation of automatic apparatus rooms in automatic telephone exchanges, and has perhaps been the subject of more criticism than any other system. Before describing the system as used by the Post Office it will be as well to consider the general conditions obtaining in these rooms which give rise to the necessity for some special means of ventilating.

With the exception of Auto Unit No. 5 used in rural automatic telephone exchanges, which is self-contained in a specially constructed case and is kept dry by the heat generated by the apparatus, all automatic apparatus and wiring is exposed to the air of the room in which it is situated and is subjected to the same differences of temperature and humidity as the air. The apparatus also exposes a large surface on which dust from the air can settle, and this dust is a source of trouble should it get on the relay and switch contacts. Dust can, of course, be removed to some extent by a vacuum cleaner after it has settled, but, as this operation must be very carefully carried out to be effective, it would be a very laborious job and the cost would be a big item in the maintenance of a large exchange.

It is therefore better, if possible, to exclude dust from the apparatus room, so as to reduce the use of the vacuum cleaner to a minimum. In addition to the dust trouble, consideration must also be given to the question of humidity of the air of the apparatus room. As is well known, a damp atmosphere is prejudicial to the maintenance of the high standard of insulation so necessary for the efficient operation of automatic switching units, and it is therefore essential that the relative humidity of the air should never be so high as to cause condensation on either the walls or the apparatus. Until recently it has been the practice to incorporate an auxiliary electric heating unit in the Plenum system, so that in the event of the air of the apparatus room reaching saturation point, hot air could be introduced to raise the temperature and reduce the relative humidity. In practice, this heating is so rarely used that the instructions regarding the control of the heater have been suspended, and the heater is not being installed in future cases.

There has been great variety in the details of the Plenum systems installed so far, so that a detailed description of one installation would serve no useful purpose, and it will suffice to indicate the general design of a system incorporating the heating unit and automatic control.

A fan of the centrifugal type draws air from the fan room through filters, over a heating surface, and delivers the air to the apparatus room or rooms through louvres, which are controlled by the man in charge of the exchange. The fan room must be so arranged that there is an unobstructed air supply to the fan. If the room is on the roof, as is usual, louvres are made in the doors, and the windows are made to open. The openings into the fan room should be on the side remote from the chimney stack, but the building will not always permit of this, and it is not uncommon to find soot from the flue blown direct into the fan room, and so drawn into the filter.

A general view of the fan chamber of a small Plenum installation is shown in Fig. 11, the principal components being indicated. The controller, seen on the right hand side of the figure, permits the fan or fan and heater to be switched on or off by hand from the apparatus room, or by a thermostat, the thermostat being previously set by hand. The controller is so arranged that the heater cannot be switched on without the fan running.

Filters in use are of two types, the cloth filter and the viscous oil filter. In the former the air is drawn through a cloth screen, the material being woven close enough to extract dust from the air, but not so close as to cause high resistance to the passage of the air. In the viscous oil type the air is drawn over a surface covered with a viscous oil, a variety of methods being employed to present as large an oily surface as possible without high resistance.

Instructions for the cleaning of filters are supplied by the makers, but the frequency of cleaning is a matter for the maintenance staff, who should judge the necessity for cleaning by the increase in resistance as shown by the water gauge,

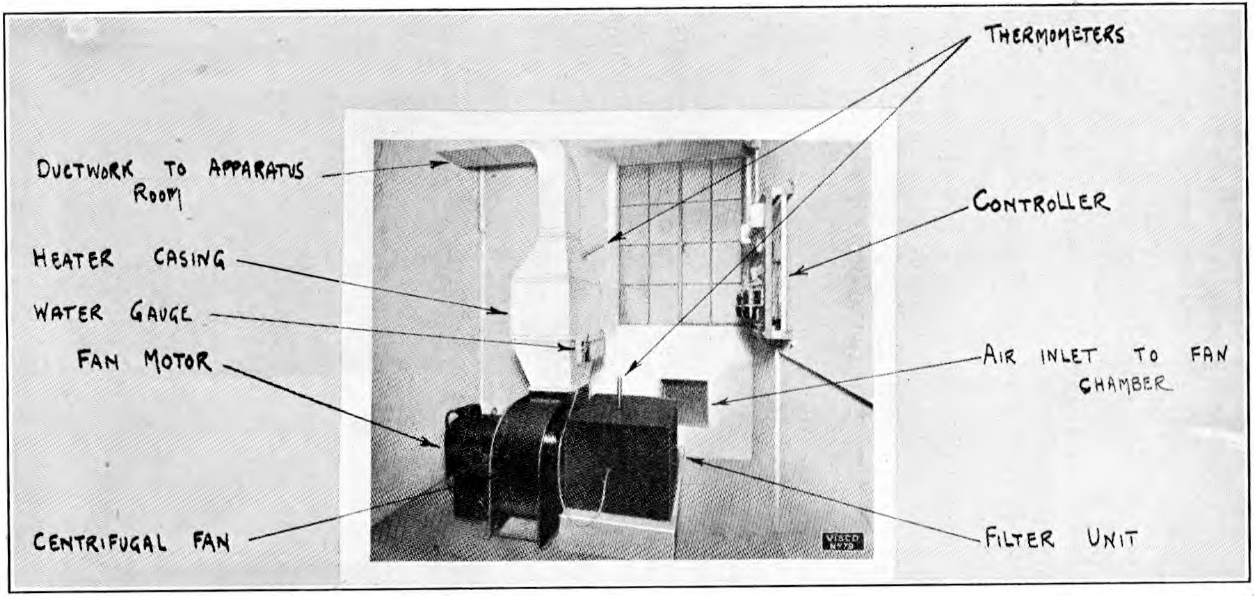


FIG. 11.—FAN ROOM OF AUTO. T.E.

and by an inspection of the filter. The inspection of the filter is probably a surer guide than the reading of the water gauge, owing to the small pressures involved. It is generally found that cloth filters are not cleaned sufficiently while oil filters are cleaned and re-oiled much too frequently. Average figures are not of much value in view of the different types of filters and different conditions of the air which they clean, but it may serve as a guide to state that the most efficient cloth filter requires cleaning about three times as frequently as an oil filter dealing with the same quantity and condition of air.

Experience with the different types of filters in use shows that the oil filter is much more satisfactory in operation and less costly in maintenance than the cloth filter. There are many devices employed in the design of oil filters to ensure that the air passes over a large surface of the viscous oil, and it may be of interest to describe in some detail the construction of the "Visco" filter which is probably one of the most efficient.

This filter is built up of units consisting of an iron framework with front and back of expanded metal, the openwork box so formed being filled with short ferrules of thin brass or coppered steel covered with a thin film of oil. The units are secured in a frame, forming the intake to the fan, by means of spring clips so that they are readily removable for cleaning.

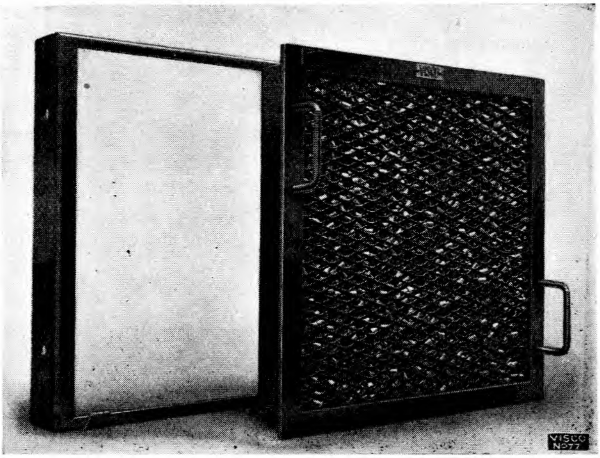


FIG. 12.—FILTER UNIT WITH FRAME.

A unit with its corresponding frame is shown in Fig. 12, the spring clip appearing at the top left hand side.

The ferrules shown in Fig. 13 are filled into the unit through a hole in the top, and if there is difficulty in cleaning the unit as a whole the ferrules can be emptied out and replaced by new ferrules. The dirty ferrules can then be cleaned as convenient.

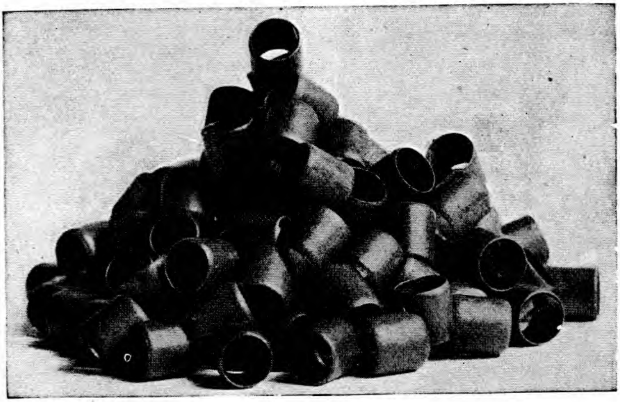
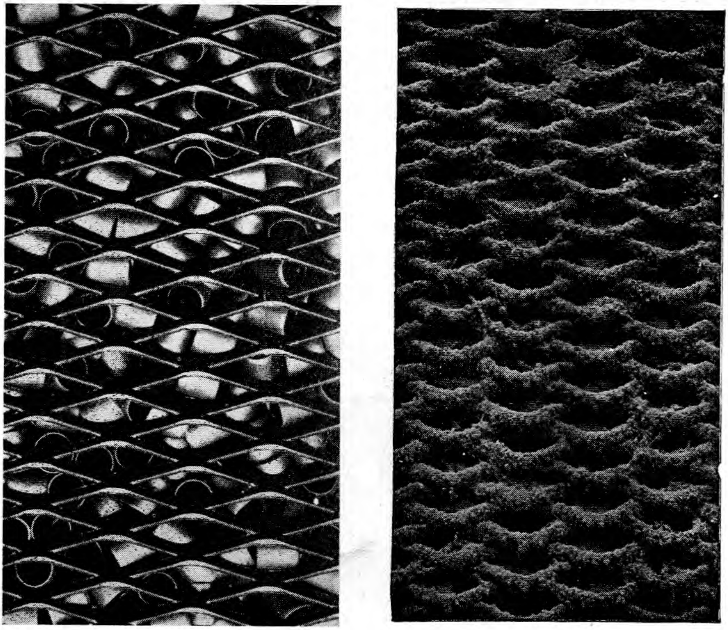


FIG. 13.—FERRULES USED FOR FILLING "VISCO" FILTER.

Each unit is 20″ square and has a normal rated capacity of 600 cu. ft. of free air per minute. Its resistance when clean is about 5 m.m. water gauge, rising to about 10 m.m. when dirty. The filter attains its maximum efficiency when fairly dirty and it is therefore not an advantage to clean frequently. About five to six weeks should suffice for all except abnormally dirty situations. Fig. 14 shows a photograph of the filter when dirty and when clean. It is claimed that the filter will remove 98% of the original dust content of the air passed through it, but the writer has no data to substantiate this claim. If cleaning with one filter is found to be insufficient, a secondary filter of similar construction may be fitted, the air passing first through the primary filter and then through the secondary filter. The double filter is shown in Fig. 15.

A filter of any desired capacity is made by building the units into a box framework to give the required area, the fan drawing the cleaned air from inside the box.

Between the filter and the intake of the fan is fitted an



CLEAN. DIRTY.

FIG. 14.—THE AIR INTAKE SIDE OF A FILTER.

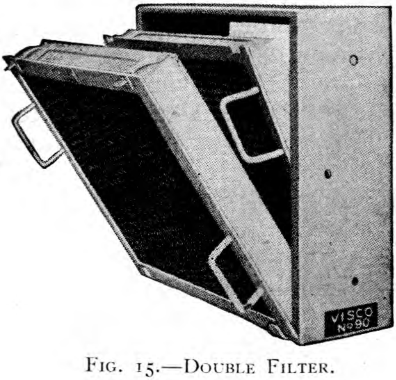


FIG. 15.—DOUBLE FILTER.

electric heater, capable of raising the temperature of the total volume of air by 8°F. The heater is usually of the ordinary resistance type, and the method of switching depends upon the requirements of the supply authority regarding the maximum load which may be switched on in one step.

This heater is used when the air of the apparatus room has, for some reason or other, a high relative humidity, the fan and heater circuits being interlocked so that the heater cannot operate when the fan is not running.

As previously stated, the heater is seldom used in practice, and in future installations will not be provided. The control gear will then be simply the fan motor starter.

The fan is of the centrifugal type with a direct coupled motor, and is indicated in Fig. 11. The impeller of the fan is shown in Fig. 16. The output of the fan is connected to the

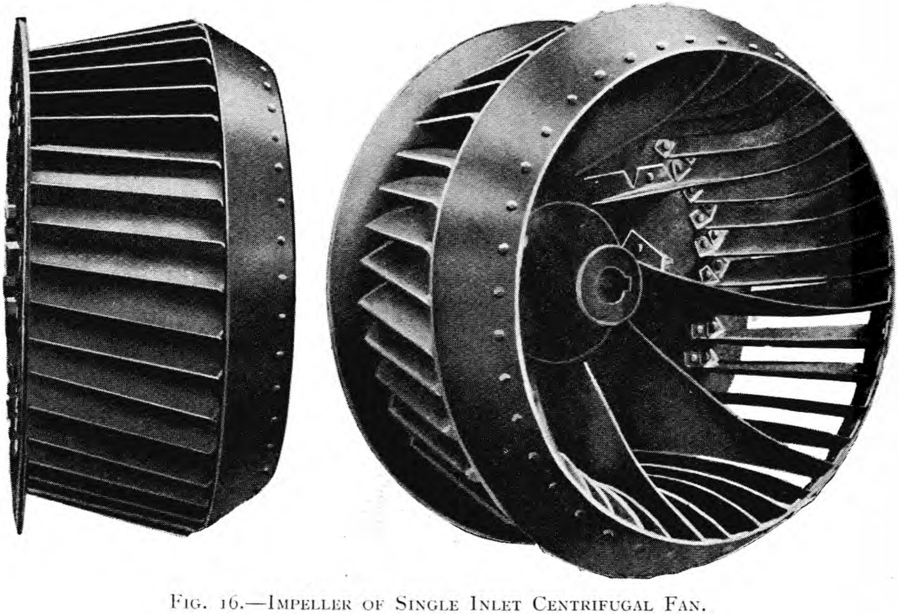


FIG. 16.—IMPELLER OF SINGLE INLET CENTRIFUGAL FAN.

ductwork leading to the apparatus room. In many cases the ductwork is built into the structure of the building. While this method has the great advantage that it keeps the ceiling of the apparatus room clear, it is very costly, and it is not always possible to reconcile building requirements with ventilating requirements. As a consequence the finished duct may easily offer considerably more resistance to the passage of air than is estimated. The tendency is now to provide surface ducts of galvanised iron, supported from the ceiling. With the exception that care should be taken to ensure that all bends are easy and therefore offer little resistance, the construction of this type of ductwork calls for little comment.

The construction of the outlets or louvres, through which the air is ultimately delivered to the room, has, however, been the subject of much thought and experiment, in order to determine the best arrangement to ensure that the air shall reach the various parts of the room in the correct proportion, more particularly between the apparatus racks, where there is a tendency for the air to become stagnant.

The simplest and most common type of louvre is a " hit or miss " regulator fitted on the side of the duct, a small diverting plate being fitted on the inside of the duct to deflect a proportion of the air stream through the regulator. This type is fitted in many exchanges, but is not satisfactory in operation, as the air cannot be distributed exactly as required.

The " Punkha " rotating type louvre, first introduced for ship ventilation, is now the standard, and is being fitted in all new installations. This louvre, shown in Fig. 17, is of the ball and socket type, and the air is delivered at a comparatively high velocity through a nozzle which is rotated by the action of the outflowing air. The angle of delivery and

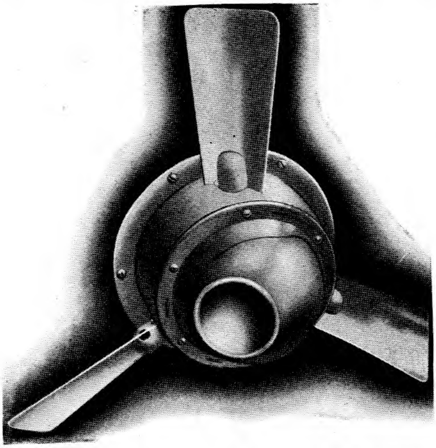


FIG. 17.—REVOLVING " PUNKHA " LOUVRE.

the quantity of air delivered can be adjusted as required by altering the position of the ball in its socket. The action is shown diagramatically in Fig. 18.

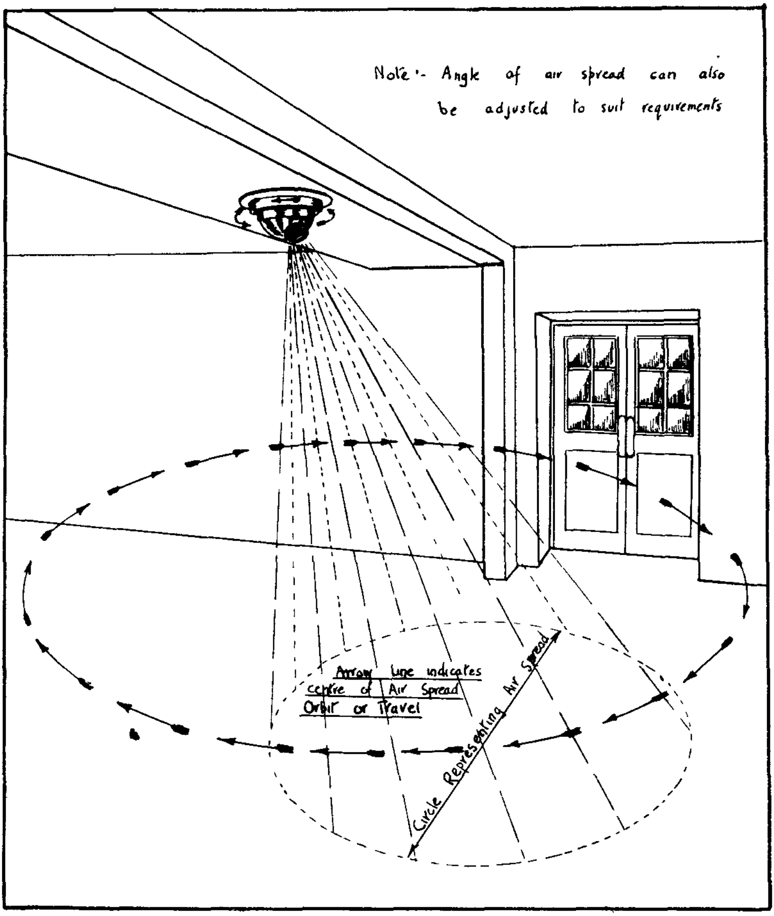


Fig. 18.—Operation of "Punkha" Revolving Louvre.

The louvre, as used by the Post Office, is constructed to fit on the end of an 8″ × 4″ branch duct, run on the underside of the ceiling. Each branch duct is fed from the main duct run on the soffits of the beams near one side of the room. The louvres deliver the air near the centre of the room. Fig. 19 shows a typical lay-out of ductwork and Fig. 20 a photograph of the actual installation. As already stated, the difficulty is to find room for surface ducts on a ceiling already overcrowded.

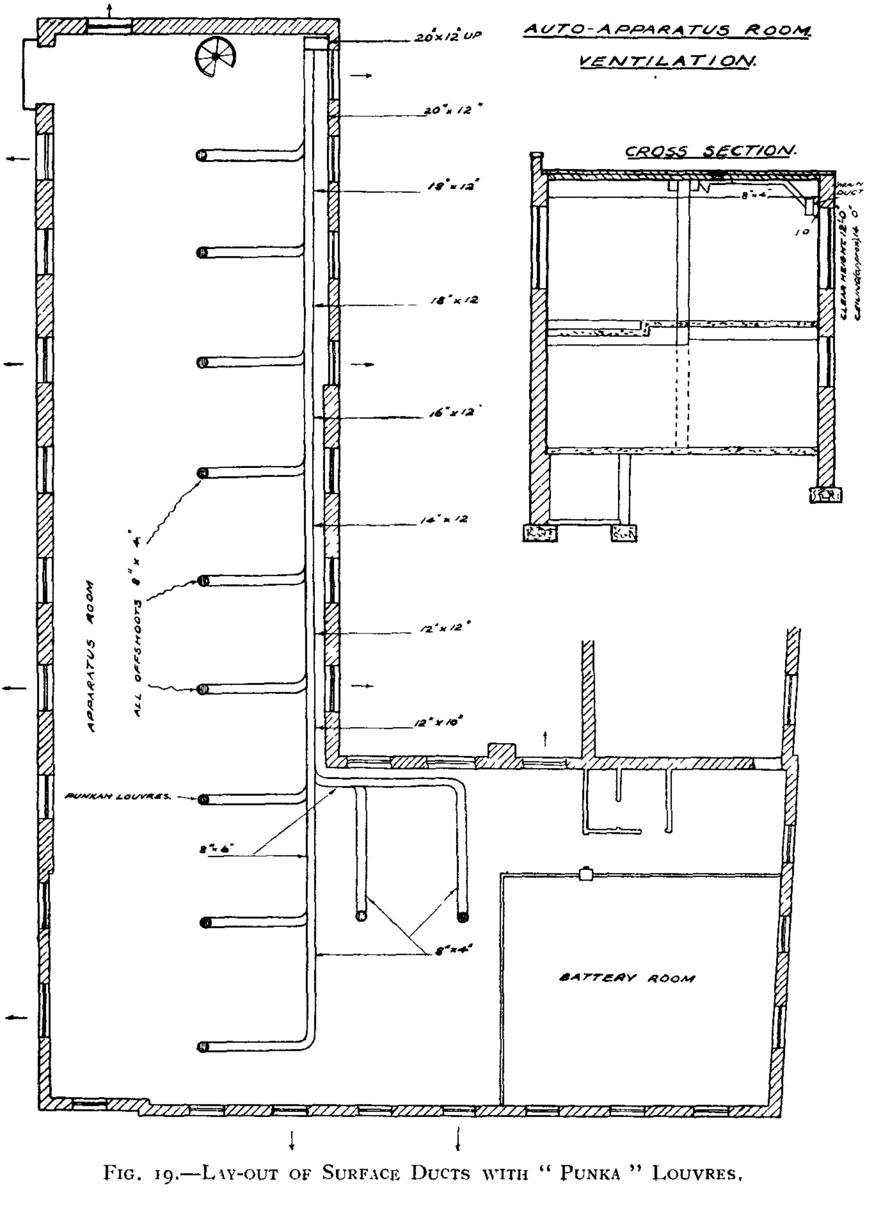


FIG. 19.—LAY-OUT OF SURFACE DUCTS WITH "PUNKA" LOUVRES.

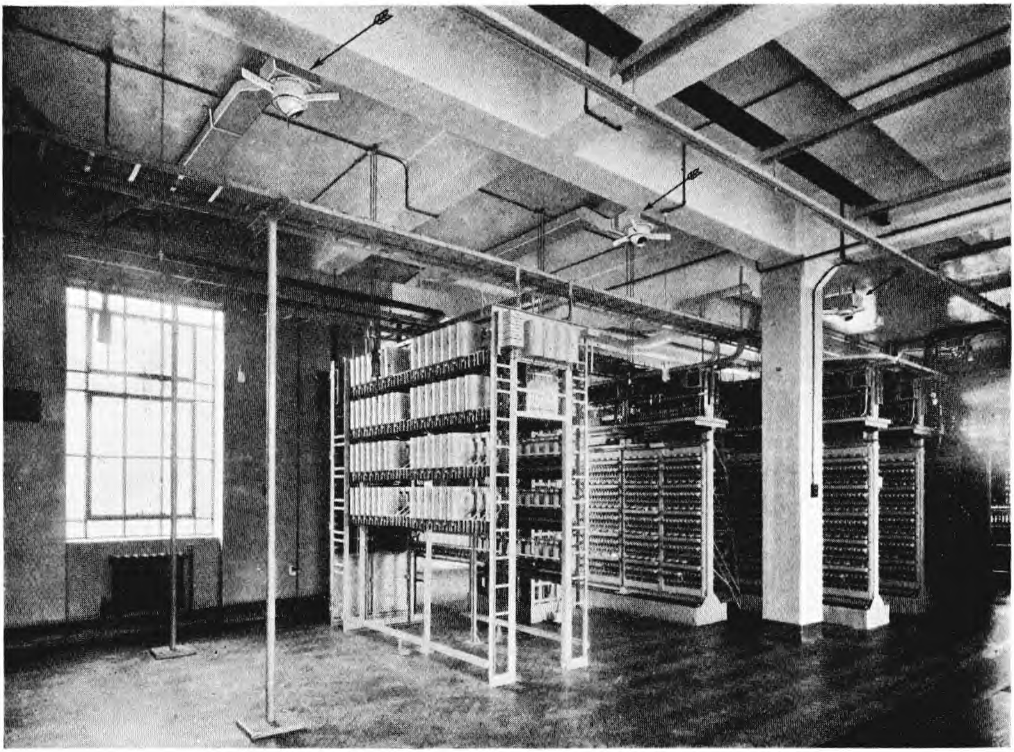


FIG. 20.—VENTILATING DUCTS AND LOUVRES IN AN AUTOMATIC APPARATUS ROOM.

The air finds its way out of the apparatus room *via* dust-excluding outlets, consisting of light mica or thin aluminium flaps, arranged to open outwards under slight pressure, and to close against any back draught from the outside. In calculations, the velocity of air through these outlets is taken as 10 ft. per second.

In a paper of this length, it is impossible to touch upon every aspect of the subject, and much that might have been included has had to be omitted, but it is hoped that such information as is contained herein will be of interest to those members who are usually concerned with the effects rather than the practice of heating and ventilating.

In conclusion, it is desired to acknowledge my indebtedness to The Davis Gas Stove Co., Ltd., Messrs. Thermotank, Ltd., The National Radiator Co., and The Visco Engineering Co., for the loan of blocks for the figures in this paper.

BIRCH AND WHITTINGTON, PRINTERS, STATION ROAD, EPSOM.