move through an apartment very much in the same manner as currents tend to move through the waters of a lake or an ocean, and there is the same tendency to produce eddies and backward currents along the sides of the main current. Where the ventilation is in the same direction with the natural currents this tendency for irregular ventilation is exaggerated, since the natural currents tend to move in paths of least resistance and do not affect to any great extent the air in an apartment which is to one side of the currents of moving air. The brick industry with which the writer was at one time very familiar affords an excellent illustration of the point in question. Bricks were at one time burned almost exclusively in an open kiln, the fire being maintained at the bottom of the kiln, the discharged heat passing off at the top in such a manner that the currents for the distribution of heat moved in an upward direction or, as one might say, in a natural way. With this method of burning it was absolutely impossible to secure a uniform distribution of heat and the bricks in certain portions of the kiln would be burned much better than those in other portions. In the last ten years closed kilns which admit the heat at the top and draw it out at the bottom have been used to a considerable extent, and with these kilns it has been found quite possible to secure a perfectly uniform distribution of heat and consequently a uniformity of product not possible with the old system, that is, a system similar to that of downward ventilation and which may in some respects be considered as unnatural, is accompanied with a perfectly uniform distribution of the air, and this was impossible to obtain by the other method. The principal difficulty with downward ventilation may be found in starting the ventilation system provided it is obtained by natural means and without the aid of a heated chimney or an exhaust fan. Until the chimney is warmed by the actual flow of air from the ventilation system it would require considerable force to start the air in motion in the proper direction, although, if once started, it would continue its motion with considerable force. For these reasons the construction described, in which the ventilation may be started in an upward direction and then later converted into a downward direction by proper means and drafts may need to be employed, unless the ventilation chimney is especially heated or unless an exhaust fan is used.

There is probably no point regarding which there has been so much difference of opinion held by ventilating engineers as that relating to the direction of motion which the air should have in passing through a room. In many instances the discussion in relation to this point has been exceedingly bitter and, unfortunately, in practice there have been so many cases where both systems have failed to give satisfaction that the question is still far from being practically decided. A résumé of the arguments which are usually advanced to substantiate either position may be briefly summarized as follows; in favor of upward ventilation it is usually stated that, first, the natural course of the ventilation currents are the same as the heat currents in the room and hence the system is more natural. Second, the products of respiration, are lighter than the surrounding air and hence with an upward current are immediately carried away. Third, the system can usually be installed more easily and can be operated with less force than a system of downward ventilation.

The arguments induced in favor of downward ventilation are as follows: first, the ventilation is opposed to the natural currents in the room and hence can be more uniformly distributed horizontally than when moving with the natural currents. Second, the products of respiration consist of gases having about the same density as the air and also of vapor of water. These products, although lighter than the air of the room when first discharged, are not essentially lighter when cooled to the temperature of the room, and as this soon occurs the effect of the products of respiration on the ventilation is immaterial. Third, the principal source of disease is now well established to be due to the breathing of microbes with which the air is loaded and these microbes are usually carried by dust and are found associated with dust. Thus, for instance, the microbe of consumption is only virulent after the discharge from the consumptive person has been thoroughly dried. An upward current of air tends to carry the dust particles from the floor or furniture where they are most plenty into a position where they will be respired. In the case of downward ventilation the dust particles are carried naturally into a position where they cannot propagate disease. Fourth, the system of downward ventilation can be readily and satisfactorily installed when fans are used and is at present employed more extensively in American school house ventilation than any other system.

The arguments, as above stated, all have a certain amount of weight and the reader must judge of the relative importance of those presented.

The number of failures which have been experienced in mechanical ventilation are generally to be charged to using improper proportions of ventilating flues or machinery, or of introducing the air in such a manner that it could not be uniformly distributed. The ventilation by means of heated chimneys, as shown in the preceding article, is more expensive than the methods of ventilating with fans, but in cases where the amount of air to be moved is small, as in residence heating, it is perhaps the only system available, and in such a case the principles which have been described in the preceding articles can be applied with satisfaction.

Heating and Ventilating Large Office Buildings.

Thos Barwick

THE tall building of to-day presents to the heating and ventilating engineer a study of greater importance than any other style of building. In this class of building space has to be utilized with the greatest economy, and it is not an easy task to properly heat and ventilate the building in an economical manner without a great deal of reflection.

The heating of buildings of this kind may be accomplished by direct radiation, but this does not provide for the proper supply of air to the various apartments to take the place of the vitiated air. In some tall buildings attempts at ventilation have been made by placing transoms over the doors of the various apartments and allowing the vitiated air to pass through them into the corridors and halls and then up through the elevator shafts, exhausting through fans on the roof, the supply of fresh air being taken in through registers placed in the window sash over at back of the direct radiators. In many places this method has been inoperative, because of the drafts of air that would be carried across the rooms, and therefore the openings have been kept closed. In other buildings only the direct system of radiation has been placed and air has to be supplied by the crevices in the window sash. This is also a bad system, because when the wind is high the draft is far too great for the heat given off by the radiator to warm.

To overcome the objections raised by the tenants the engineer having charge of the building increases the pressure of the steam in the heating mains and therefore, when single one-pipe connected radiators are used, multiplies the difficulties by holding the condensation in suspension in all the large radiators, especially so where the float air valves are used, or air vents without drip pipes carried to the cellar; the same may be said of double pipe connections to the sectional form of radiator, when the connections are made on one end, which is practically only a one-pipe supply to all of the radiators except the first section.

Objections to the apparatus in such a building can be overcome by increasing the surface and carrying the steam in the mains and radiators at atmospheric pressure; the ventilation being defective it would be costly to attempt to correct it, but to favor the comfortable occupation of the building I would recommend carrying the steam pressure in the heating apparatus at or as near to atmospheric pressure as possible.

In many places I know of steam is being circulated at atmospheric pressure where they formerly used 15 pounds pressure, and in each case where the reduction of pressure has been made a saving in fuel and attention has been quite marked and the trouble of noise and other difficulties overcome.

I find a number of large office buildings where they are using electric elevators and lights and taking their current to supply them from the street mains, paying the meter price for the electric current during the summer and winter months. In many of these buildings the caretaker has to be an experienced man, capable of taking care of and erecting electric apparatus, and therefore well paid. In winter months the building is heated by steam direct from the boilers in the building. In most cases the buildings are using sufficient current during the winter to make it profitable to the owner to put in a proper electric plant of ample size, using the exhaust steam from the engines to warm the buildings.

The using of exhaust steam, if brought down to atmospheric conditions, would cost practically nothing to heat the building providing sufficient exhaust from the machinery was available, and in most cases there is sufficient current used to make it pay.

The cost for current has been metered in some of these buildings during summer and winter and is known; the cost for fuel for warming is also known, and since for each kilo-watt of electric power used the coal usually used for heating 10,000 cubic feet of space would be ample to supply the engine to produce the above amount of electric energy, the exhaust steam, if used without back pressure, would heat practically the same amount of space during most of the winter months. Therefore, since you have to burn fuel to supply heat to the building in the winter months, why not use it to produce power for making the electric current and use the waste product after coming from the engine, when but slight amount of heat has departed from it in producing the light and power? Since the boiler has to be used to heat the building and the coal has to be supplied, also the man to run the boiler, why not employ competent men to look after the electric and heating plants and save money?

If the apparatus is put in properly and of the best material and workmanship, you will not have expensive repairs, and the cost of maintaining the plant can be figured in the cost for light and heating; the interest on the money spent for plant can also be charged to the same account.

Assume a building, say 75 by 90 feet and 12 stories in height, or about 165 feet, not an infrequent size at present, or 1,113,750 cubic feet of space, and let us assume you have store on first floor and lofts above. There would be required to heat such a building a boiler capacity of about 150 horse power.

Let us assume that the building is heated for the time between the first of October and the first of April, or say 180 days; now the average consumption of fuel for a heating boiler in a low pressure plant is four pounds of coal per horse power per hour; therefore, if steam was kept on from 6 A. M. to 8 P. M. it would require 14 times four pounds or 56 pounds per horse power.

Say such a building as we have described will require the equivalent of 100 horse power to heat the building, and there would be required 5600 pounds or 2.8 tons of coal consumed per day on an average.

The above building would have at least two freight and two passenger elevators, and one pump for supplying water to the roof tank, also an electric lighting system for which current is taken from street mains.

Assume that the four elevators are used nine hours per day and the running distance to be 170 feet of travel and at about 400 feet per minute, the weight to be carried being, say, 1000 pounds, and counter weighted to any excess; each would require 12 horse power, and in all probability they would be running at the same time. Add to the above the loss in transmission, friction, etc., we would have about 70 horse power for the elevator service, say five horse power for the pump, and about 25 horse power for the lights used in the day; these requirements are constant and figure up to 100 horse power. To maintain the above plant with fairly good engine about four pounds of coal per horse power per hour would be required, or 3600 pounds, or 1.8 tons for the nine hours, so that the cost of the coal at $3 per ton would be $5.40, and for the other five hours of heating 100 horse power at four pounds per horse power there would be required 2000 pounds or one ton, cost $3, which is practically the same as required to heat the building under the other method, and you get the light for the extra cost of maintaining additional help and interest on the plant.

To do the above economically you would require to expand the steam into the heating apparatus at or as near atmospheric pressure as possible, so that the cost of running the engines would be no more in winter than in summer for the same amount of light, etc.

This it is not possible to do under the present method of piping, owing to the great expense of putting in large pipes to overcome the friction in such a plant, and also because the air at 60 degrees or less is of greater specific gravity than the steam, which will require sufficient back pressure in many systems as erected under present methods of from six to 20 pounds in order to get rid of the air before circulation can be maintained in the system.

By exhausting the air from the heating system the heating surfaces are put in the best possible condition to receive the steam, and since the air is partially exhausted there is no resistance to be overcome by the steam, and it will travel through every part of the heating apparatus, even to the furthest or topmost radiators, which will have, in all probability, the quickest circulation.

This, of course, can only be accomplished by mechanical means, but the saving that can be made in fuel and in the worry and trouble of faulty circulation is of such material amount that the cost of changes in old systems have been promptly met by praise and prompt acceptance by those benefited.

I prefer to provide ventilation with the heating of large office buildings, and while the cost of maintaining ventilation will be additional to the cost of heating, the additional cost will not be so great where exhaust steam can be used at atmospheric pressure.

Since there is usually ample exhaust steam in large office buildings where fast running elevators and electric light machines are used, it is profitable in the long run, because the additional power required to run fans is but slight when the exhaust steam can be used without back pressure. Assume a large office building with steel columns; it is quite possible to arrange vent shafts upon the interior of the walls surrounding the columns, with their outlet at the roof story. The fresh air supply is as easily provided for, so that each portion of the building can be well supplied. This ventilation and heating must be provided for at the outset and should be arranged in consultation with the architect, so that all of the architectural features may be easily followed out.

In many cases the hallways are useful for both heating and ventilating ducts, and with careful adjustment a suitable amount of air can be supplied to each apartment. I prefer to supply fresh air to the offices in proportion to the cubic space, as the number of occupants is an unknown quantity. Therefore I would use as near to five changes per hour as possible as the minimum amount. Toilet rooms should have a change of air at least once in five or six minutes, which should keep them sweet and clean. No closet or toilet room in any building should be without proper ventilator; the best ventilated will be those where the marble slabs at the back of closets and urinals are left open at least a foot from the floor, with a space left between the slab and the wall of suitable size, the vent flue being connected with these spaces. Toilet flues should always be independent of any other flues, and a fan of suitable form should be in operation to induce a positive draft under all conditions of weather.

The air supply to all such buildings should be at a temperature of 65 degrees F. and never above or below this point; in fact, automatic regulation of the heat of the air should be under the control of an automatic thermostatic controlling device, so arranged that as the temperature of the outside air is lowered, as it will be at times during the day and night, the heating surface may be increased sufficiently to supply the demand to maintain the required temperature, and to close off the heating surfaces as the air rises in temperature.

This brings the steam heating down to the most rigid economy, as, by the above means, nothing but what is necessary will be used, and where live steam is used to warm the air it should be adapted in combination with expanding the steam to atmospheric pressure, so that the surfaces may be made to give off the greatest amount of heat units with the least consumption of fuel.

Where additional temperature is required in apartments it can be controlled by having direct radiators placed in the rooms, or by surfaces at the outlet of the fresh air flues, which should also be controlled by automatic thermostatic regulators. By these means a deal of inconvenience of the patrons and attendants is overcome.

The first cost of thermostatic regulation amounts to but little when the building is being constructed and is economical in running expense. The saving must be considered in the pleasure one enjoys in having a satisfied tenant.

If care and judgment are used in the management of office buildings, especially in the heating and ventilating, and in using of the exhaust or waste steam in doing the heating without back pressure, there will be less trouble from leaks and breakdowns, less trouble for expensive repairs, and an absence of the smell of vapors and gases of impure water distributed in the rooms; an equal saving in attendance and an abundant saving in the cost of running expenses that will warrant the owner in employing such a system, delivering the condensation from the heating apparatus without loss of heat beyond that which has been distributed in the various heating surfaces of the building.

To accomplish this an engineer must give proper study and thought to the detail of all the different points where economy can be effected and design an apparatus that will be economical in first cost within reasonable bounds, constant and practically economical in the consumption of fuel and the use of steam.

Pupils are always healthier in body and mind in snapping cold weather, if they can be kept comfortably warm indoors, hence a cold winter is the time of their greatest improvement if the school rooms are made comfortable and are properly ventilated. Our defenseless little ones ought never to suffer with cold nor be deprived of any of their privileges during these best days for study. Laws compelling the proper ventilation of school buildings will be a blessing.

Experiments on New Method of Heating and Ventilating.*

THE principle of the method of heating and ventilation discussed in this paper is the utilization of the fact that air rarefied by heating will cause a circulation in the rooms of a building. This principle is applied practically by cooling the air near the ceiling of a room, by heating the air near the floor, or by both means. It has been the belief of the writer for some time past that the mechanical condition for such a sys-

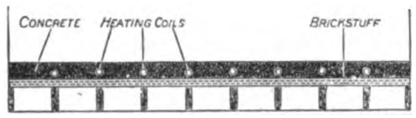

FIG. 1.

tem of heating might be furnished by the use of "earthenware-house" construction in the floors and ceilings, and to test the validity of this belief he carried out the two sets of experiments described hereafter.

The first set of experiments was carried out in the kitchen of the writer's village homestead, which was then vacated for repairs. It has a water-backed cook stove piped for domestic uses, to waste in the bathroom on the floor above, and is supplied by a tank in the attic. The stove was taken out and set in the cellar below and the flooring and ceiling coverings were ripped out. Porous brickstuff planks, $1\frac{1}{2}$ inch thick, were then fitted and spiked on the exposed faces of the floor joists, in order to furnish an air-tight and fireproof foundation. This floor measured 12 by 16 feet and served as a support for a heating coil composed of lengths of $1\frac{1}{2}$-inch iron pipe laid 12 inches apart and suitably connected with the waterback of the stove on the floor below. This coil was tested for leakage and provided with a petcock to enable air to escape, and the whole floor was then covered with a 4-inch layer of concrete made

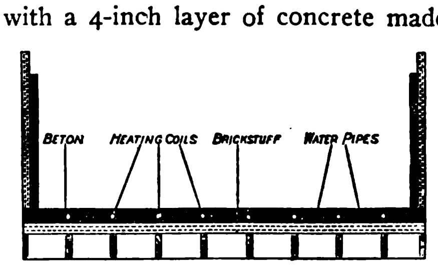

FIG. 2.

of equal volumes of native hydraulic lime, sand, and small gravel, as shown in Fig. 1.

For the purpose of experiment a temporary ventilating ceiling was made by sheathing the under surfaces of the rafters with $\frac{3}{4}$-inch matched pine boards. This ceiling was perforated with 144 auger holes from four to six inches apart. One-third of these were one inch in diameter and the remainder $\frac{5}{8}$-inch. Five of the 1-inch holes were provided with tin tubes opening in the floor of the bathroom, and the remainder opened into the wall void, 10 inches in depth, having direct communication with the outside air.

About three months later the floor had hardened and the experiment was begun. A platform was put up near the ceiling, the auger holes were corked from below and blankets were hung over the inside of the doors as an additional precaution against the entrance of the air. A thermometer was affixed to a partition wall at the floor level, another at an elevation of eight feet, and a third at the ceiling. A fire was then started in the stove and maintained for three hours, when the kitchen was entered. Each of the three thermometers indicated a temperature of 72 degrees, the water in the floor coil was at 135 degrees and the temperature outside the house was 40 degrees.

To rid the room of humidity the corks were drawn, which was followed at once by a drop of four degrees in the reading of the middle thermometer, the others remaining at their former reading. It was found that all the larger orifices, except the five opening into the bathroom, were discharging air downward, while no movement was discernible at the mouths of the smaller ones. The five tubes leading to the bathroom were discharging air upward under a pronounced pressure, although not of a volume equal to that dropped into the room through 45 holes of the same size. The only explanation of this state of affairs is that the outside air of 40 degrees entering through 45 1-inch holes was pushing up, because of its greater weight, the rarefied air at 72 degrees through 96 $\frac{5}{8}$-inch holes and the five 1-inch holes leading to the bathroom.

Subsequently the floor of the adjoining room, measuring 16 by 18 feet, was provided with a similar coil and the experiment repeated with the same results, except that six hours instead of three were required to bring the water to the same temperature.

These experiments show that under the given conditions there is an exchange of hot and cold air at the ceiling, which prevents drafts, and it is practicable to warm a small cottage with kitchen, living room, and two bedrooms, having about 500 square feet of floor area, by means of water from the stove.

The second series of experiments was carried out in a small greenhouse annexed to a steam heated dwelling. The greenhouse was a frame structure measuring 10 by 20 feet in the clear and 14 feet high above the floor. The walls were sheathed to a height of $4\frac{1}{2}$ feet with brickstuff, the remaining distance and the roof being of glass, single sashed but double glazed. The floor was prepared somewhat like that of the kitchen already described, and contained in addition to the heating coil several water pipes, as shown in Fig. 2. The floor was made by soak-

*A paper on a new method of heating and ventilation, read at the last semi-annual meeting of the American Society of Civil Engineers, by Charles Carroll Gilman, of Eldora, Ia.