CHAPTER V.

THE HEATING AND VENTILATION OF SCHOOL BUILDINGS.

GENERAL DISCUSSION.

For school buildings of suitable size the furnace system is simple, convenient and generally effective. Its use is confined as a rule to buildings having not more than eight rooms. For large ones it must generally give way to some form of indirect steam apparatus with one or two boilers, which occupy less space and are more easily cared for than a number of furnaces scattered about. Like all systems that depend on natural circulation unaided by fans the supply and removal of air is considerably affected by changes in the outside temperature and by winds.

RELATIVE FUEL CONSUMPTION.

In small school buildings heated by furnaces the fuel consumption per room is greater as a rule than in larger ones warmed by other methods. This is not attributable, however, to a low furnace efficiency so much as to other causes—viz.: The air supply is affected by winds to a greater extent than in large buildings in which the supply is governed by the speed of a fan. It thus frequently happens that a greater quantity is driven through the furnaces than is necessary for the proper ventilation of the building. This involves a waste of heat. Small buildings have a greater exposure in proportion to their cubic contents than larger ones, hence their loss of heat by transmission is correspondingly greater. The janitor service in such buildings is less efficient and less skillful firing the rule.

THE FURNACE.

The furnaces used are generally built of cast iron, this material being durable and easily made to present large and effective heating surfaces. Several forms of furnaces have been designed especially for this service. They are made up of vertical sections placed side by side, as in ordinary sectional boilers and heaters. The makers claim from 50 to about 100 square feet of heating surface per square foot of grate, which are much greater ratios than in furnaces of ordinary types. Much of the surface in these furnaces is of the extended form.

AIR PASSAGE IN FURNACE.

To adapt the larger sizes of house heating furnaces to schools a much larger space must be provided between the body and the casing to permit a sufficient volume of air to pass to the rooms. The free area of the air passage should be sufficient to allow the air to pass through with a velocity not greater than 400 feet per minute.

PORTABLE OR BRICK SETTING.

A galvanized iron casing is generally used in connection with galvanized flues in buildings having wooden partitions. In brick buildings the furnace setting and the flues are generally built of that material.

SIZE OF FURNACE.

The size of the furnace is based on the loss of heat through the walls plus that carried away by the air passing up the ventilating flues or leaking out through other openings.

Assuming that a single furnace heats two rooms, which is common practice, we should proceed to calculate the loss of heat by transmission as follows: Suppose the school rooms to be of average size, 28 x 32 x 12 feet, and to have 140 square feet of glass, this amount being the average of a number of measurements taken by the writer. Reduce the wood and plaster or bricks walls to equivalent glass surface by dividing their area by 4. Reduce the floor or ceiling to equivalent glass surface by dividing the area by 20 or 25, according to the conditions. Add these equivalents to the area of glass in the windows. The equivalent glass surface of the walls is equal to $\frac{(28 + 32) \times 12 - 140 \text{ square feet}}{4} = 145$ square feet. The equivalent glass surface of the floor or ceiling equals $\frac{28 \times 32}{20} = 44.8$ square feet. Adding to these items the actual glass surface in windows gives a total of 145 + 44.8 + 140 = 330 square feet approximately. Multiply this sum by 85 (the number of heat units transmitted per hour per square foot of glass with temperature of 70 degrees inside and 0 degree outside). The product is the total loss of heat per hour by transmission. In this case 330 × 85 = 28,050 heat units, or for two rooms 56,100 heat units.

To this must be added the heat carried up the ventilating flues or lost by leakage. Assuming each of the two rooms to contain 50 occupants who are each supplied with 30 cubic feet of air per minute, we have for the volume of air passing through the two rooms per hour 2 (50 × 30 × 60) = 180,000.

Each cubic foot of air escaping at 70 degrees temperature with the outside air at 0 degree carries away 1¼ heat units, hence the loss by ventilation is equal to 180,000 × 1¼ = 225,000 heat units per hour. Adding to this the loss of heat by transmission gives 281,100 as the total loss of heat per hour from the two rooms. The furnace must be capable of imparting to the air passing through it an equal amount.

With the more regular and skillful attendance it is safe to assume a higher rate of combustion in school house heaters than in those used in residences. Assume therefore a maximum rate of 6 pounds of coal burned per square foot of grate surface per hour. The air passing over the heating surface is much greater in volume and lower in temperature than in house furnaces, therefore we should expect even with the more rapid rate of combustion, to obtain about the same efficiency as in the latter.

Granting, then, that 8000 heat units per pound of coal burned will be taken up by the air passing through the furnace we have 6 × 8000 = 48,000 heat units utilized per hour per square foot of grate surface. Hence to ascertain the requisite grate area simply divide 281,100, the total loss of heat per hour, by 48,000. The quotient is 5.86 square feet, equaling about a 32-inch fire pot.

In determining the size of furnace required to heat rooms on the north or west side of buildings unusually exposed add as a factor of safety at least 10 per cent. to the estimated loss of heat. It has been found in practice that furnaces with a 32-inch average diameter fire pot having ample heating surface will heat two ordinary 50-pupil rooms to 70 degrees in zero weather.

CORRIDOR HEATER.

Corridors may best be heated by a separate furnace. If it is attempted to warm them from a furnace connected with the schoolrooms the flow of air will be very uncertain, since it tends to pass directly up the large vertical flues. The size of the corridor furnace may be based on the exposure according to Table II. (See Chapter I.) A slight allowance should be added, however, to compensate for the cooling effect of outside doors at the beginning of sessions. Corridor registers should be set in the floor to serve as foot warmers.

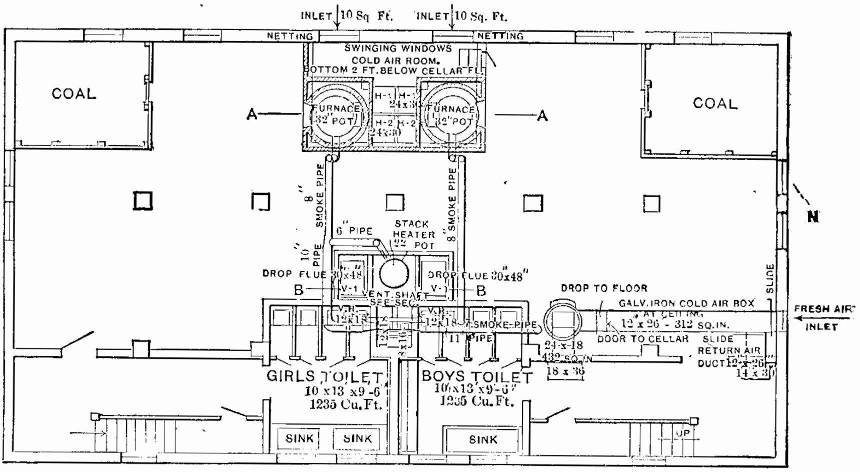

Fig. 28.—Basement Plan (9′ 6″) of School Building Heated by a Furnace System.

LOCATION OF FURNACE.

The furnaces, as in Fig. 28, should be located as nearly as possible under the flues with which they are connected to lessen the resistance and loss of heat and to facilitate the arrangement of mixing dampers. A pit at least 2 feet deep should be provided under each furnace to permit an even distribution of the air over the heating surface.

COLD AIR ROOM.

In school buildings a cold air room is far preferable to the ordinary box. The flow of air is more regular and the resistance to its passage to the furnace is reduced to a minimum. Less attention need be paid to the location of the cold air inlet with reference to the points of the compass than when an ordinary air box is used. With large inlet and flues rooms can be successfully heated when taking air from the lee side of the building. Portable furnaces are sometimes placed within cold air rooms. In such cases they must be double cased throughout and the flues leading from them be thoroughly protected to reduce the loss of heat.

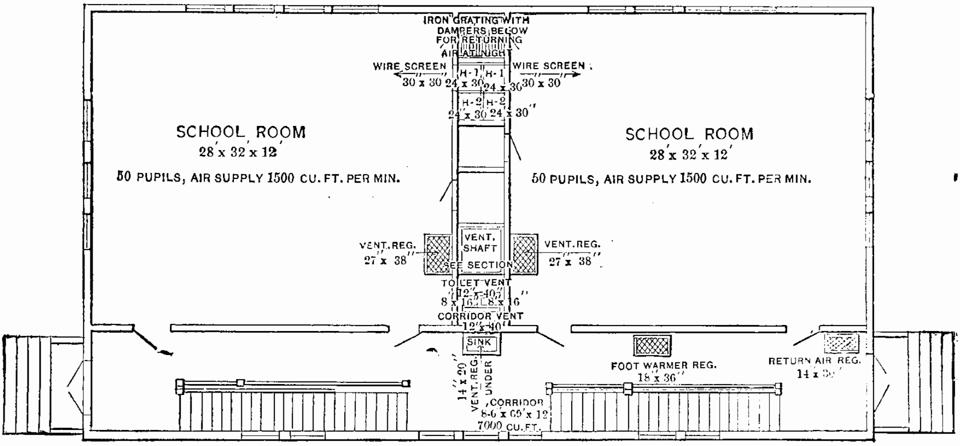

Fig. 29.—First-Floor Plan (12′ 0″) of School Building Heated by a Furnace System.

FRESH AIR SUPPLY.

The net area of the cold air inlet should be equal to the aggregate area of the flues leading from the furnace. An inlet of generous size is especially important during mild weather, when the air is heated and expanded but little and consequently has but slight force as compared with zero weather conditions. A swinging damper or slide should be used to regulate the flow of air during winds and to shut it off at night. To work properly and economically the furnace must have an adequate supply of air at all times. An oversupply during winds will be likely to occur unless the inlet damper is intelligently managed.

RETURN AIR OPENINGS.

A duct or opening for returning air from the rooms to the furnace, as shown in Fig. 29, should be provided for use while the building is unoccupied, when the air supply for the furnaces may be taken from indoors without harm and with economy in fuel.

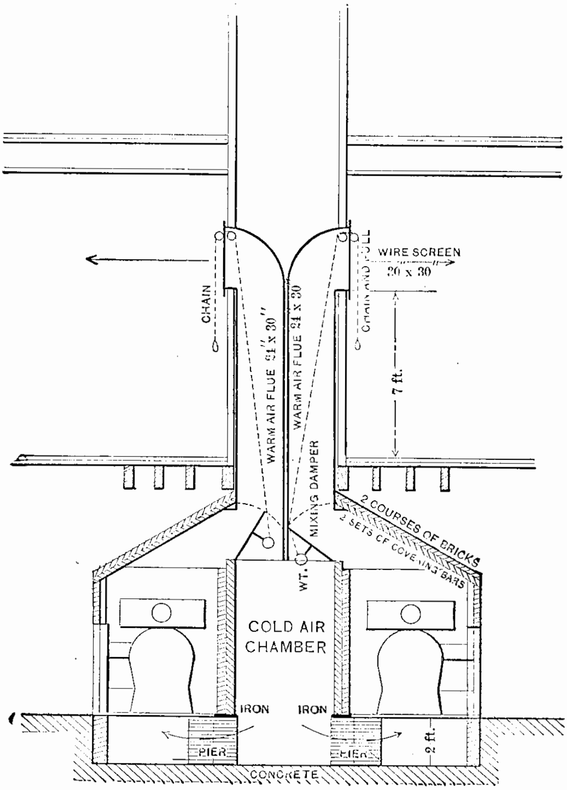

Fig. 30.—Sectional View of Furnaces on Line A A of Fig. 28.

When cold air boxes are used they should be built of galvanized iron or brick. The building laws in many places prohibit the use of wooden ones in public buildings.

MIXING DAMPERS.

At the base of each warm air flue is placed a mixing damper, operated by a chain from the schoolroom above, as shown in Fig. 30. By means of this damper the teacher may regulate the temperature of the room at will without seriously affecting the volume of air delivered, since the damper, in cutting off the supply of warm air, simultaneously opens an equal area for the inflow of cold air, and *vice versa*. The damper should be arranged so that the cold air will pass up at the rear of the flue and out at the top of the warm air opening in the room. If allowed to pass up the front of the flue the cold air is likely to descend on the heads of the pupils. Cold air should enter the flue from below the mixing damper. The weight of the damper will then keep it tightly shut. If closed by pulling up on the chain, unless the latter be drawn up perfectly taut, leakage of cold air will be likely to occur.

LOCATION OF FLUES.

The proper location of fresh air and ventilating openings to secure the most thorough distribution throughout the room is a matter that should be most carefully studied in laying out the system. The locations which have been found to give good results in practice, with rooms having exposures as indicated, are shown in Figs. 31, 32 and 33.

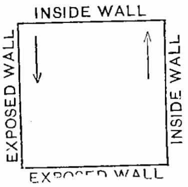

Fig. 31.

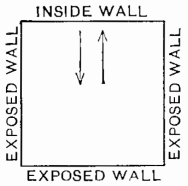

Fig. 32.

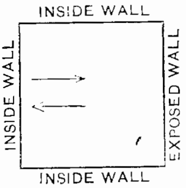

Fig. 33.

Both warm air and ventilating flues are located along inside walls. The entering air is discharged through an opening 3 or 4 feet below the ceiling, toward or along the cold outside walls. The chilling effect of the latter causes the air to descend, to be drawn across the seating space, to the ventilating opening in or near the floor.

When it is impossible to arrange flues in the desired positions the air from the inlet may be directed to any part of the room by deflectors or diffusers placed in front of the openings.

MATERIAL OF FLUES.

The flues are generally built of galvanized iron, No. 24 gauge being commonly used, or of brick, with the inner surface smoothly plastered. In some respects galvanized iron is superior, being smoother and absorbing less heat while the building is being warmed. On the other hand, brick ventilating flues absorb rain that may be driven in, and can therefore be left open at the top. Those of galvanized iron require a hood for protection during storms.

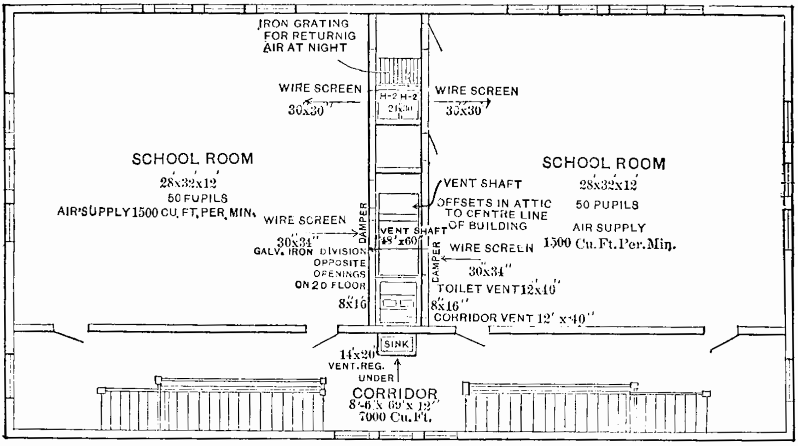

Fig. 34.—Second-Floor Plan (12′ 0″) of a School Building Heated by a Furnace System.

HOOD ABOVE FLUES.

The hood must extend far enough beyond the flue on all sides to prevent rain beating in even when descending at an angle of 45 degrees. Louvers or slats are often used for further protection.

The area of the flue, divided by the combined length of two sides, gives the proper clear hight between the top of the flue and the under side of the hood.

AREA OF FLUES.

The warm air flues rise from the furnace to a hight of 9 or 10 feet above the floor of the schoolrooms, discharging through a wire screen or register face. The area of the flues is generally based on a velocity of about 300 feet per minute in those leading to the first or second floors.

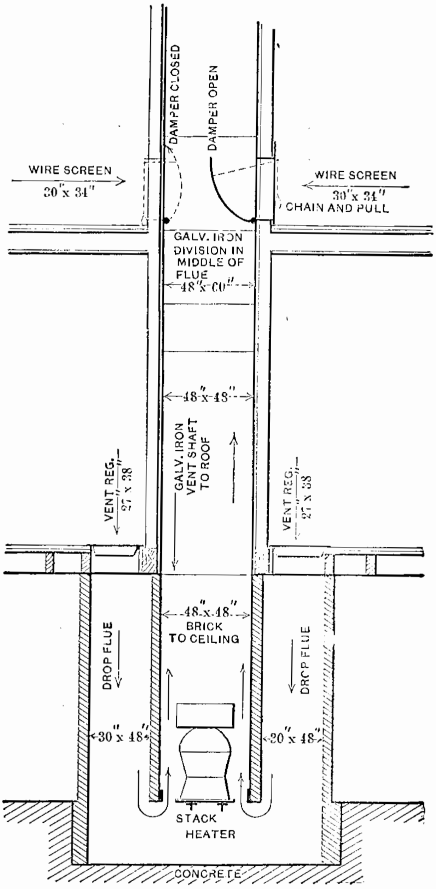

Fig. 35.—Section through Ventilating Shaft on Line B B of Fig. 28, Showing Stack Heater

In determining the size of flues from Table XIV, Chapter IV, it is well to reckon on a difference in temperature between the air in the flue and that out of doors not greater than 40 degrees. A flue based on the maximum difference in temperature existing in zero weather will be altogether too small to provide the requisite volume of air in mild weather. Theoretically, the greater the hight of the flue the smaller the area required. Practically it is often convenient to make the flues to both the first and second floors the same size, generally about 24 x 30 inches for 50-pupil rooms requiring 1500 cubic feet of air per minute.

The tendency of the air to flow more readily to the upper rooms and overheat them is counteracted by the mixing damper, which cools the air in the flue and consequently diminishes the velocity with which it ascends. Adjustable dampers may be used in addition to advantage.

VENTILATING FLUE DAMPERS.

Dampers should be placed in ventilating flues to prevent the escape of warm air at night and to regulate the discharge in severe or windy weather, when over-ventilation is likely to occur. The latter is accompanied by excessive inward leakage of cold air around windows, causing chilly drafts.

REGISTERS AND SCREENS.

Wire screens of open pattern are preferable to registers for school house work on account of the greater freedom they afford to the passage of air. They are often made of ⅛-inch wire, 1¼ inch mesh, which gives a net opening equivalent to about 80 per cent. of the gross area.

To provide for the easy discharge of air the net area of wire screens or registers should be somewhat in excess of the area of the flue.

In ordinary 50-pupil rooms a wire screen of open mesh pattern at least 30 x 30 inches, or a register not smaller than 30 x 36 inches, should be used for the warm air inlet. The ventilating openings in or near the floor should, if possible, have an area slightly in excess of that of the fresh air inlet.

The draft is so strong at the ventilating openings on the first floor of a building having two or more stories that a register 27 x

38 inches is generally large enough for a 50-pupil room located on that floor.

STACK HEATERS.

It is customary to group the ventilating flues together in a main stack or shaft, at the bottom of which is placed a stack heater consisting of a small furnace or stove. The function of the latter is to maintain, during mild weather, a sufficient excess of temperature in the shaft to secure the requisite removal of air from the rooms. Cast iron stack heaters are the most serviceable and are most commonly used. The ordinary heating stove as applied to this service is accessible only through a large door placed in the side of the vent flue. This door often fits loosely, allowing an inward leakage of cold air, thereby diminishing the effect of the flue. Furthermore, the stove is so unhandy to care for that it is likely to be neglected by the janitor.

A small furnace is much better adapted in every way to this work.

SIZE OF STACK HEATER.

The size of the stack heater is governed by the hight and area of the ventilating shaft and the volume of air to be discharged in a given time.

The hight is generally but a few feet greater than the topmost point of the roof, the area but little in excess of the combined area of the 24 x 30 inch warm air flues, and the volume equivalent to about 1800 cubic feet of air per hour per occupant. With such conditions in the ordinary two-story building a difference of nearly 20 degrees between the temperature of the air in the flue and that out of doors will be required to produce the desired velocity and air removal. That is, whenever the outside temperature rises above 50 degrees, for example, a fire must be maintained in the stack heater, its intensity to be increased as the outside temperature rises, in order to maintain an excess of temperature of 20 degrees in the shaft.

It is assumed that whenever the outside air approaches the normal temperature of the room, windows will be thrown open and an abundant circulation secured in that manner, thus dispensing with the use of the stack heater. As a matter of fact, the small stoves usually employed for this service are utterly inadequate.

In ordinary two-story school buildings a stack heater having ½ to ¾ square foot of grate surface per standard 50-pupil room will maintain a nearly constant removal of air from the rooms until a point is reached when all fires may be dispensed with and windows opened without harm.

ARRANGEMENT OF STACK HEATER.

It is unquestionably best to bring the vitiated air into the ventilating shaft—see Figs. 28 and 35—below the stack heater. Owing to the lack of space and the increased cost of building drop flues this arrangement is seldom carried out in ventilating rooms above the first floor.

On the second floor and above the ventilating openings generally connect directly with the shaft. A curved damper hinged at the bottom (see Fig. 35) and adjusted by a chain is used at such openings. The ascending currents from below, passing rapidly by the edge of this damper, tend to create a suction through the ventilating openings. This, combined with the natural tendency of the air to flow into and up the flue, is sufficient, as a rule, to secure the desired removal of air from upper rooms.

BOILER WITH COILS IN VENTILATING FLUES.

To avoid the bother of maintaining a fire in several stack heaters a small steam boiler is sometimes used to supply coils placed in the ventilating flues just above the openings from the rooms.

About 20 square feet of heating surface is generally allowed for each ventilating flue from a 50-pupil room, but with this small amount the volume of air removed per minute will fall off rapidly as the outside temperature approaches 70 degrees.

Steam is condensed so much more rapidly in coils thus placed than in ordinary direct radiators that the actual heating surface in the ventilating flues should be nearly trebled to give the proper boiler rating expressed in square feet of ordinary cast iron direct radiation.