CHAPTER VI.

HEATING OF PUBLIC BUILDINGS, CHURCHES AND STORES.

IN GENERAL.

Several features commend the furnace system of heating and ventilation when properly applied in public buildings and churches. The apparatus is the simplest of all and is comparatively inexpensive. Heat may be generated quickly and when no longer needed the fires may be allowed to go out without danger of damage to any part of the system from freezing. When properly proportioned an air supply sufficient for ordinary requirements may be secured. Without further description a good idea of such a system can be gained from the plans given of a town hall, Fig. 36 showing the basement and Figs. 37 and 38 the first and second floors, while Figs. 39 and 40 are details and sections.

In buildings similar to those illustrated in this chapter, in which all the rooms are rarely used at the same time and are practically never fully occupied simultaneously, it is common practice to install an apparatus with switch dampers to direct the hot air into either of the principal rooms or to divide it between them.

It is not necessary that an apparatus so arranged should be large enough to heat the entire building to 70 degrees with a frequent change of air. (Table XVII shows that the grate surface necessary to heat 150,000 cubic feet of space with a 15-minute air change will heat 250,000 cubic feet with a 30-minute change.)

If the building is thoroughly warmed before occupancy, either by rotation or by a slow movement of air, the chapel or Sunday school in the case of a church may be shut off until near the close of the service in the auditorium, when a portion of the warm air may be diverted to it. When the service ends the switch damper is thrown over and all the air is discharged to the Sunday school. The mixing damper will prevent overheating.

SIZE OF FURNACE.

To determine the size of the furnace first reduce the entire exposed wall to equivalent glass surface (E. G. S.) by adding to the actual amount of glass one-fourth the area of solid walls. With a non-heated attic reduce the ceiling to equivalent glass surface by dividing its area by 20.

When there is no attic space and the room to be heated extends to the roof divide the roof area by 10, instead of 20, to obtain its equivalent glass surface. Fig. 36 shows basement plan of a town hall, while the first and second floor plans are shown in Figs. 37 and 38. Details and sections are shown in Figs. 39 and 40.

The basement is generally so warm that the loss of heat

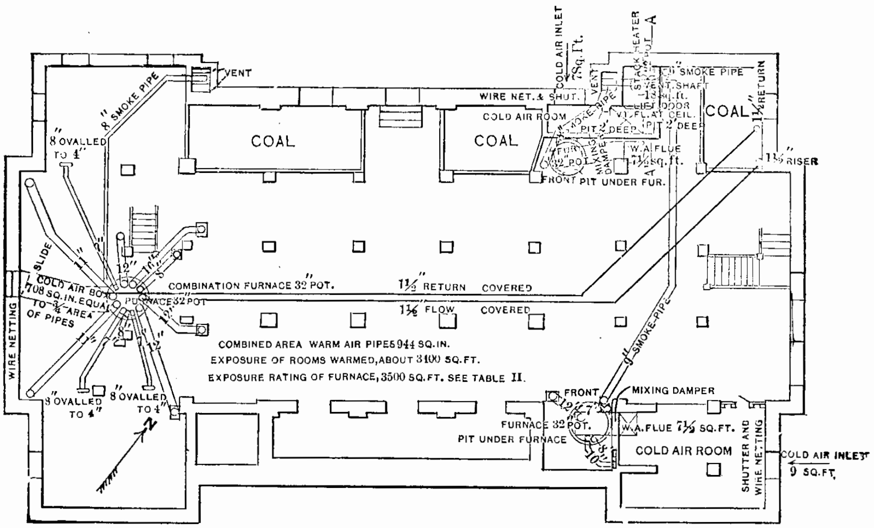

Fig. 36.—Furnace System of Heating and Ventilating a Town Hall.—Basement Plan.

through the first floor may be neglected; otherwise, divide its area by 20 or 25, according to its construction, to reduce to equivalent glass surface.

Having determined the equivalent glass surface multiply it by 85 (the loss in heat units per hour per square foot of glass with 70 degrees inside, 0 degrees outside). The product is the total number of heat units lost per hour by transmission. Add 5 to 10 per cent. when the building is severely exposed.

To this must be added the loss of heat per hour by the escape of air. Basing the air supply on the common allowance of 1000 cubic feet per hour per occupant, as stated in Chapter IV, we have: Number of occupants multiplied by 1000 equals volume of air required per hour.

In case the seating capacity is unknown a change of air every 15 or 20 minutes may be assumed, or even a 30-minute change when the space per occupant is unusually large or the requirements not at all exacting. Since 1¼ heat units are removed by each cubic foot of air escaping at 70 degrees temperature in zero weather, to ascertain the total loss of heat by ventilation multiply

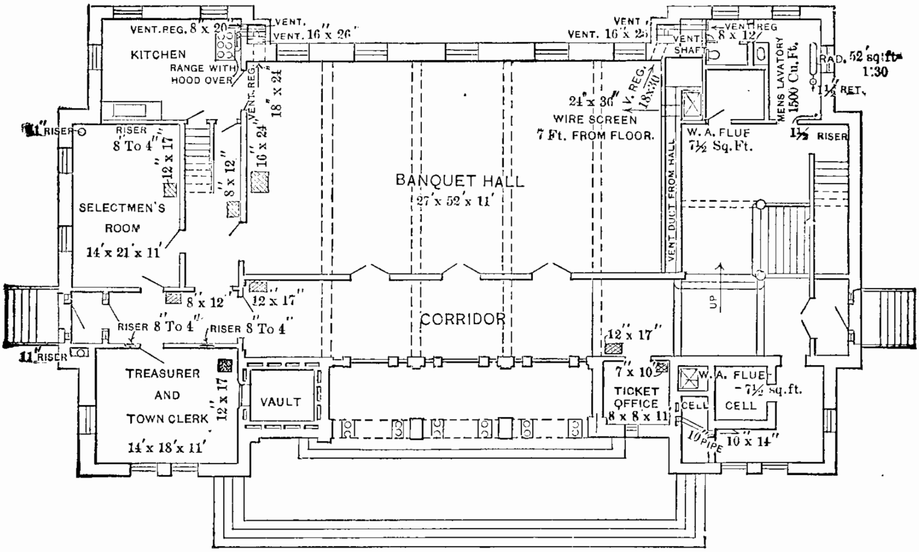

Fig. 37.—First-Floor Plan.

the volume of air removed per hour by 1¼; add this to the loss by transmission and the sum gives the total loss per hour, or $T + V = Q$. When the heating is intermittent, unless provision is made for returning the air to the furnace, add 10 to 15 per cent.

To determine the size of the furnace simply divide the total loss of heat per hour from the building by the heat given to the air passing through the furnace per square foot of grate. Assuming a rate of combustion of 5 pounds of coal per square foot per hour and 8000 heat units utilized per pound of coal burned, we have

$5 \times 8000 = 40{,}000$ heat units per square foot of grate per hour.

Hence $\frac{Q}{40{,}000} = G\ S =$ average area of fire pot in square feet.

ANOTHER METHOD TO DETERMINE SIZE OF FURNACE.

When the walls are of greater thickness than 12 to 16 inches, or where greater accuracy is desired than is obtained by using the above approximate method, the values prescribed by A. R. Wolff may be employed.

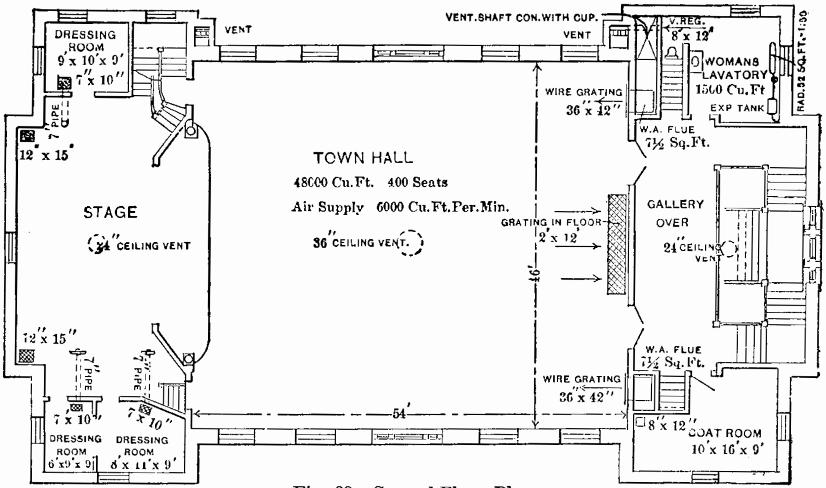

Fig. 28.—Second-Floor Plan.

Table XVI—The Loss of Heat By Transmission with a Difference of 70 Degrees Between the Indoor Temperature and that Outside.

The loss in heat units per square foot per hour by transmission for—

(A)	(B)
8-inch brick wall	= 32
12-inch brick wall	22
16-inch brick wall	18
20-inch brick wall	16
24-inch brick wall	14
Single window	85
Ceiling (unheated attic)	5
Floor (unheated basement)	4

For other differences than 70 degrees between the inside and outside temperatures the loss of heat is increased or decreased proportionally. In using the above table simply multiply the wall area of a given thickness by the corresponding figures in column B. Add to this the loss of heat through the windows and that through the floor or ceiling, then add about 10 per cent. to allow for winds. The sum is the total heat transmitted per hour, to which must be added the loss by ventilation, calculated as just explained.

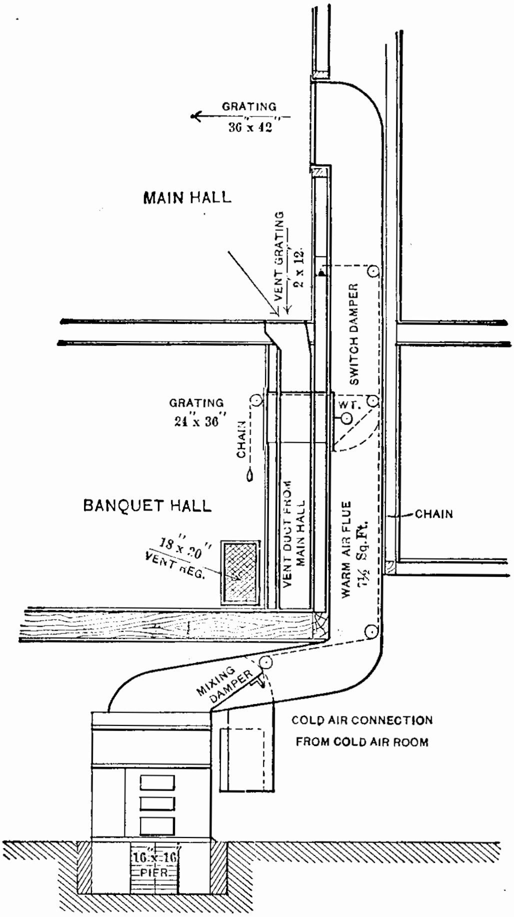

Fig. 39.—Sectional Elevation of North Furnace.

Dividing the combined losses by transmission and ventilation by 40,000 gives the grate surface in square feet, which is to be increased, as previously stated, when the apparatus is to be used intermittently.

AN APPROXIMATE METHOD TO DETERMINE SIZE OF FURNACE.

It frequently happens that sufficient data are lacking to pursue either of the methods of calculation just described. In such cases Table XVII will be found useful. This table is based on the loss of heat by transmission plus that by leakage or escape of air from buildings having an average glass surface. The combined loss of heat divided by 40,000 gives the grate surface or average fire pot area in square feet stated in the table.

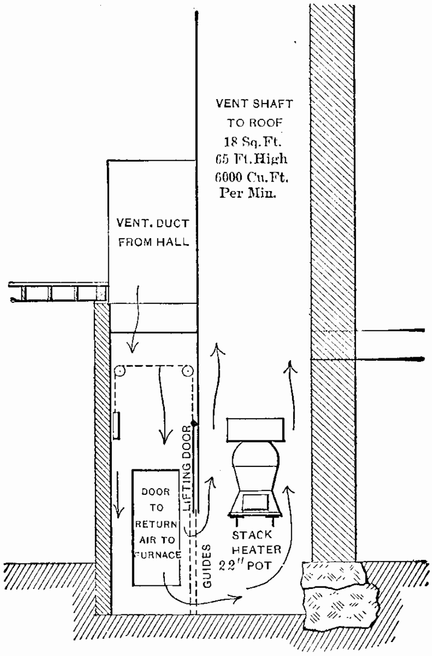

Fig. 40.—Section at A A, Showing Stack Heater and Ventilating Shaft.

Table XVII.—Showing the Grate Surface in Square Feet Required to Heat Buildings of Regular Form—i. e., Without Extended Ells—When the Air is Changed Once in 15, 20 or 30 Minutes.

Cubic contents.	Square feet grate surface required when air is changed every— 15 minutes. Square feet.	20 minutes. Square feet.	30 minutes. Square feet.
50,000	9.9	8.4	6.8
75,000	14	11.6	9.3
100,000	18	14.9	11.7
150,000	25.8	21.2	16.5
200,000	33.6	27.2	21
250,000	41.3	33.4	25.5
300,000	48.7	39.2	29.9

For severely exposed buildings add from 5 to 10 per cent. to the grate surface stated in table to allow for winds. Add 10 to 15 per cent. for intermittent use.

When several furnaces are to be used, proportion them according to the exposure appointed to each, the combined grate surface of all to equal the amount stated in the table.

Table XXI, Chapter X, will be of assistance in determining the diameter of fire pot in inches corresponding to a given grate surface in square feet.

An inspection of Table XVII will show that the larger buildings require less proportionate grate surface than smaller ones, since they have less exposure as compared with their cubic contents. The loss of heat by transmission is correspondingly less.

AREA OF COLD AIR BOX.

In churches and public buildings the area of the cold air box—see Fig. 41—should be 90 to 100 per cent. of the combined capacity of the furnace pipes. This is especially important for heating and ventilating in mild weather, when a small amount of heat but a large supply of air is desired. This can be secured only by using large flues and cold air box.

FRESH AIR INLET.

The best location for the cold air inlet is on that side of the building which faces the prevailing cold winds. It is often necessary, however, to place it elsewhere to avoid making the box of excessive length.

When the heating is intermittent, the use of a return duct—see Fig. 42—materially lessens the time and fuel consumed in warming the building. This return duct may be run independ-

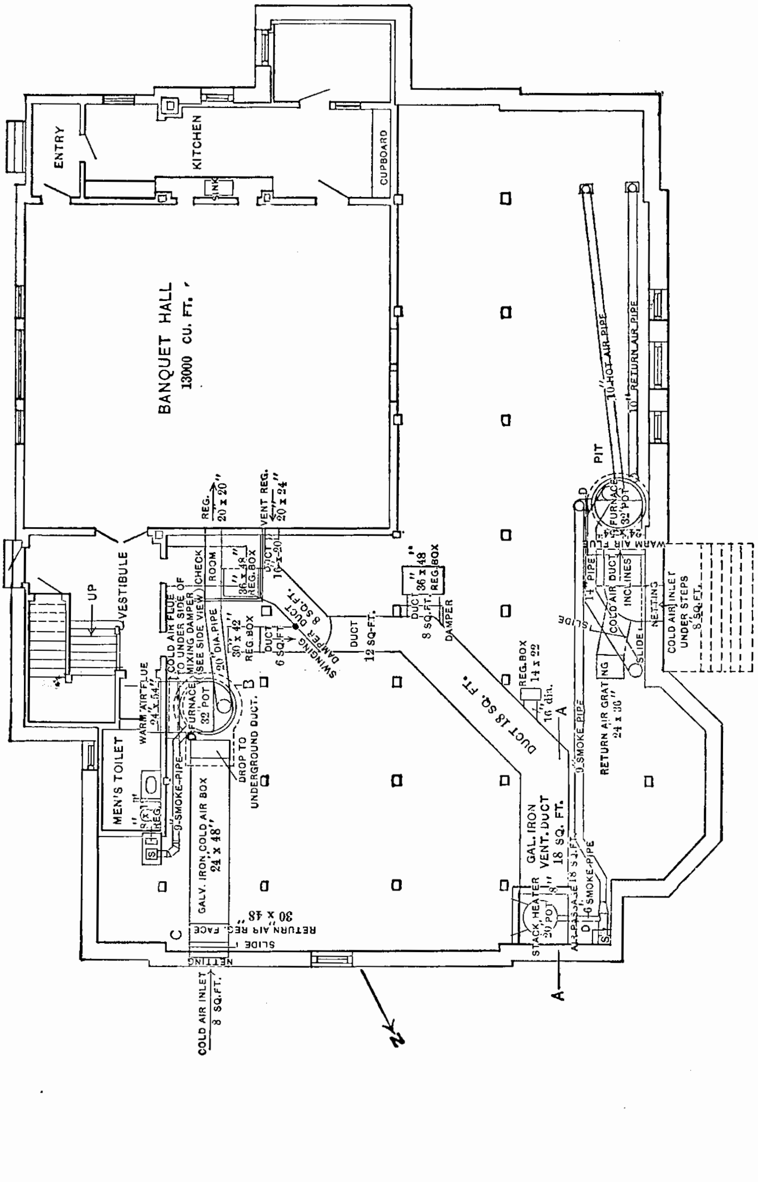

Fig. 41.—Furnace System of Heating and Ventilating a Church.

ently to the furnace, or, as more commonly arranged, may be connected with the cold air box, as shown in Fig. 42.

LOCATION OF FURNACE AND AREA OF FLUES.

The furnace should be located as nearly as possible under the warm air flues leading from it. For ordinary calculations it will be found convenient to assume a velocity of 300 feet per minute in flues leading to the first or second floors. Dividing the volume in cubic feet per minute by 300 gives the area of the flue in square feet. For more exact calculations use Table XIV. In determining the size of flues from this table it is well to select a velocity corresponding to a difference in temperature not greater than 40 to 50 degrees, in order that the flues shall be large enough to provide a proper air supply at all times.

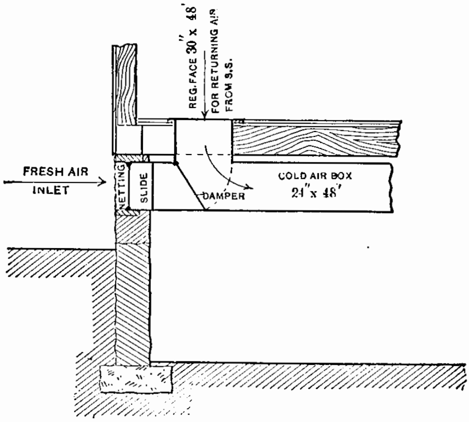

Fig. 42.—Detail of Return Air Connection at C, Fig. 41.

The remarks in Chapter IV with regard to the material of flues and the arrangement of mixing dampers (see Fig. 43) apply here equally well.

LOCATION OF REGISTERS.

It has long been the custom to locate the registers in the aisles, placing the furnaces directly under them. There are several objections to this arrangement. The hot air ascends immediately to the ceiling, causing an excessively high temperature at the top of the room and a correspondingly great loss of heat through the roof. The registers become the receptacles of dust and filth, over which the fresh air must pass. It is better practice to discharge the warm air through openings placed 7 or 8 feet above the floor, as in schoolhouses.

The ventilating registers are placed, as in Fig. 44, in or near the floors, in the best position to secure a thorough distribution of the air throughout the seating space. Foot warmers should be located in the entrance hall or near the doors.

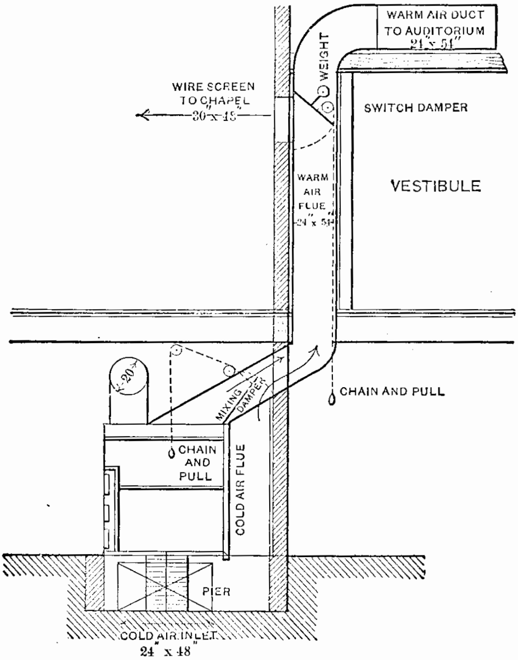

Fig. 43.—Section at B B, Showing Mixing Damper and Switch Damper.

VENTILATION.

Ceiling ventilators are generally provided, but should be no larger than is necessary to remove the products of combustion from the gas lights. If made too large much of the warmest and purest air will escape through them.

The ventilating system should be connected with a duct leading to a shaft, having a stack heater (Fig. 45) or a fan to accelerate the air current. In cold weather the natural draft will in most cases be found sufficient. The construction and arrangement of stack heaters has been fully discussed in the preceding chapter.

SIZE OF STACK HEATER.

To determine the size of the stack heater is a simple matter. Knowing the hight and area of the shaft and the volume of air in cubic feet per minute to be moved, divide the volume by the area expressed in square feet; the quotient is the velocity with which the air must be moved. Next look in Table XIV in the line corresponding to the hight of the shaft and find the number most nearly corresponding with the estimated velocity. At the head of this column is given the excess of temperature that must be maintained in the shaft.

For example, suppose we have a shaft 60 feet high, of 8 feet square area, and' that 3000 cubic feet must be discharged per minute; $\frac{3000 \text{ cubic feet}}{8 \text{ square feet}} = 375$ feet velocity. Following along the line in Table XIV, opposite the hight of 60 feet in the column at the left we come to the number 383, which most nearly corresponds to the required velocity, 375. At the head of the column in which the number 383 is found is the number 20, indicating the excess of temperature that must be maintained in the flue.

Having determined the number of degrees through which the air must be heated to secure a constant air removal regardless of the outside temperature, the next step is to calculate the amount of heat that must be supplied by the stack heater.

One heat unit will heat 55 cubic feet of air at 70 degrees through 1 degree F., hence the amount of heat required to raise a given volume through any number of degrees will be expressed by the equation: $\frac{\text{Volume of air in cubic feet per hour}}{55} \times$ Number of degrees temperature must be raised = Heat units required per hour. This divided by 40,000 (the heat utilized per hour per square foot of grate) gives the area of grate required, from which the diameter of fire pot may be readily determined.

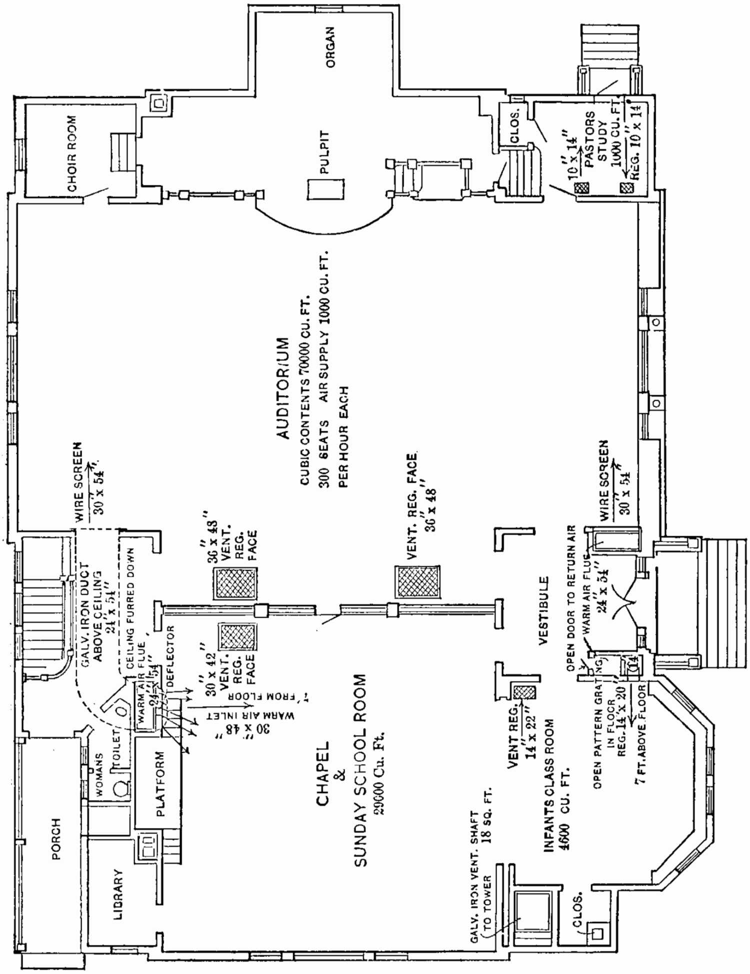

Fig. 44.—Furnace System of Heating and Ventilating a Church.—First-Floor Plan.

JANITORIAL SHORTCOMINGS.

The importance of the stack heater is very apt to be overlooked by the janitor, who generally considers the heating as the all-important matter. Unless his work is under intelligent supervision, which is seldom the case, the stack heater is quite likely to remain idle and the flow of air through the ventilating registers to be very sluggish.

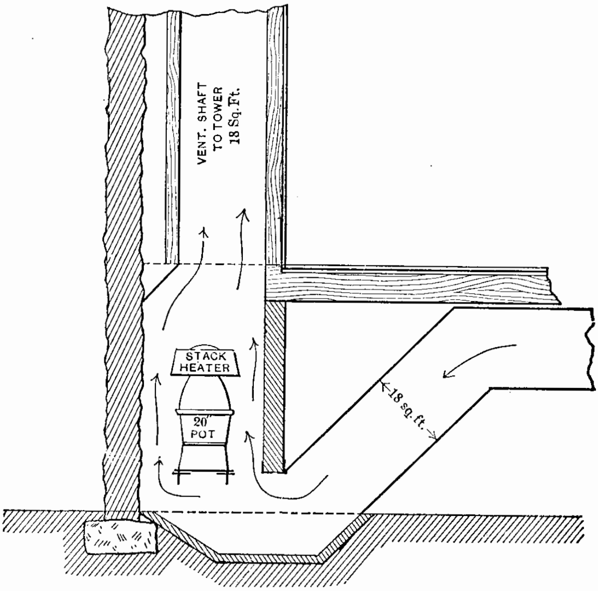

Fig. 45.—Section at A A, Showing Arrangement of Stack Heater

Among other shortcomings of the janitor may be mentioned taking the air supply from the cellar or from the return duct instead of from out of doors, which should be the only source of supply while the rooms are occupied; also, allowing insufficient time to warm the building after a period of disuse, forcing the fires until they are hottest about the time the occupants assemble, resulting in overheating during the session.

HOT WATER COMBINATION.

It is often desired, when several furnaces are employed, to run but one continuously, the others being used only when the auditorium or the entire building is occupied. When some of the rooms are located at a distance from the furnace, as in Figs. 36, 37 and 38, the simplest way to heat them is by means of a hot water combination applied to the furnace, as described in Chapter III.

SMOKE PIPES AND FLUES.

If the smoke pipes are very long the smoke is likely to become so cooled that the draft will be seriously diminished, causing gas to leak from the furnace into the basement. The liquid commonly called creosote, which condenses from the smoke and oozes from the pipes, is troublesome in certain places, besides rapidly corroding the iron. These troubles may be avoided to a great extent by covering the pipe with non-conducting material.

If made tight and of ample size smoke pipes, in connection with a good chimney 60 or 70 feet high, may be run 60 to 80 feet horizontally without trouble. The smoke-flue may be run up inside the ventilating shaft to advantage, the waste heat stimulating a more rapid ascent of the air.

THE HEATING OF STORES.

For heating small isolated stores or those at the end of blocks the size of the furnace may be determined from the exposure, as stated in Table II. For inside stores exposed only at the front and rear the size of the furnace may be calculated in another way.

The space per occupant is generally so large, except in crowded districts, that the volume of fresh air to be admitted is seldom considered in estimating the size of the furnace.

If its size is to be based solely on its ability to heat a given space, regardless of the air supply, we may proceed as follows: Assume the temperature of the entering air to be 140 degrees, that of the room to be 70 degrees and that of the outside air to be at zero. One-half of the heat brought in is lost through the walls by transmission before the air escapes at 70 degrees temperature; in other words, twice as much heat is supplied as that lost by transmission. One square foot of grate burning 5 pounds of coal per hour will supply to the air passing through the furnace in zero weather about 40,000 heat units, which is equivalent to that transmitted by 470 square feet of glass. But since twice as much heat must be supplied as that lost by transmission, 2 square feet of grate surface will be required for each 470 square feet of glass, or 1 square foot to 235 square feet of glass. Hence to find the square feet of grate required, reduce the area of walls, floors and ceilings to equivalent glass surface (E. G. S.). This divided by 235 = G. S. required. The corresponding diameter of fire pot may be found in Table XXI.

In narrow, deep stores in blocks the entire front and most of the rear is generally glass. If not it should be so considered to allow for the cooling effect of frequently opened doors. To provide for quickly warming narrow, deep stores—*i.e.*, those in which the depth exceeds, say, three times the width—add 10 per cent. to the grate surface based on the exposure.

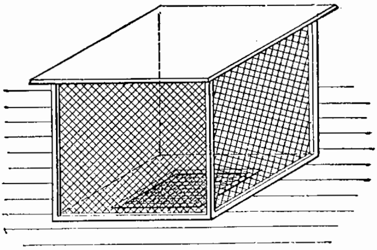

Fig 46.—Register with Guard Having Marble Top.

Where it is necessary to have basement doors open in winter for the handling of goods, the loss of heat through the floor should be added. Its equivalent glass surface equals one-twentieth its area. With a tight basement the loss of heat through the floor may be neglected. The equivalent glass surface of a ceiling with non-heated attic above is equal to one-twentieth its area. When the ceiling is directly under the roof with no attic space its equivalent glass surface may be considered equal to one-tenth its area.

COLD AIR BOX AND REGISTERS.

The cold air box should be arranged with a branch, so that the air may be used over and over to warm up quickly.

Having determined the size of the furnace the combined area of the hot air pipes may be found by allowing about 1¼ square inches of pipe area for each square inch of grate surface—*i.e.*, average fire pot area. The net area of the registers should be 10 to 25 per cent. in excess of that of the pipes which supply them.

It is well to locate the registers in the walls or in front of counters instead of in the floor. If floor registers must be used a guard similar to Fig. 46 may be placed over them to prevent their use as cuspidors. Such an arrangement is frequently found in railway stations.