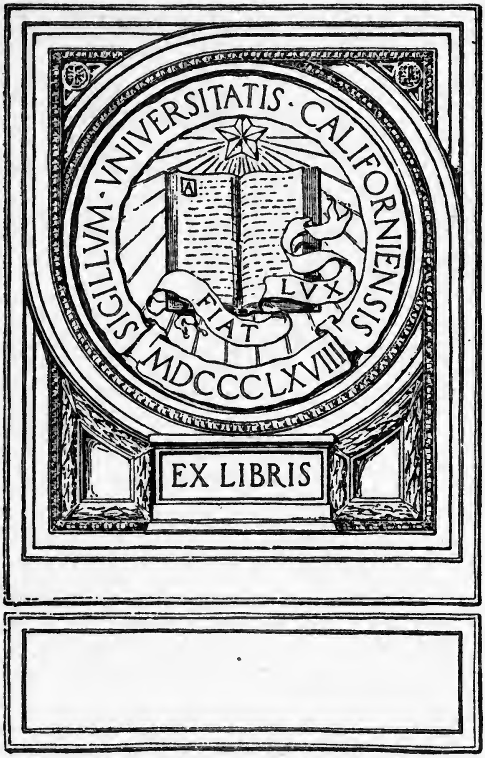
FURNACE HEATING

W. G. SNOW



FURNACE HEATING

A PRACTICAL AND COMPREHENSIVE TREATISE ON WARMING BUILDINGS WITH HOT AIR

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PREFACE.

When "Furnace Heating" was first published the heat unit basis of making heating computations was little used in connection with furnace work.

Rule of thumb methods of figuring prevailed. The author endeavored to reduce to a scientific and practical basis the computation of the grate surface necessary to meet given conditions, the proportioning of pipes and registers, the design of hot-water combination systems, the layout of fan-furnace combination systems, etc.

It was aimed, by means of tables, to make the treatise convenient for ready reference.

Furnace Heating has been twice revised since its original publication, and it is hoped that this revision will supply much material for which there has been a demand.

The work has been considerably increased in size, many new illustrations have been added, and the latter part of the book is devoted to a collection of articles by others to whom it has been intended to give due credit in each case.

WILLIAM G. SNOW.

BOSTON, 1915.

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CHAPTER I.

FURNACES.

A furnace consists essentially of a stove within a casing. Air is admitted to the space between the two, where it becomes heated, rises, and flows through the pipes to the various rooms.

The earlier forms of furnaces were practically ordinary heating stoves incased in brick work. Such furnaces were very deficient in heating surface, and consequently were wasteful in the consumption of fuel. Various methods were adopted to increase their heating surface and efficiency. Radiators were added through which the gases would pass and lose a considerable portion of their heat before reaching the smoke pipe. Projections or extended surface in the form of pins or ribs were cast on the fire pot, or the pot, in some cases, was made corrugated. In other furnaces flues were added, through which the fresh air supply would pass, surrounded by hot gases.

Small air flues, pins and ribs retard the flow of air over the heating surface, hence are not so effective as, at first thought, they appear.

AREA OF AIR PASSAGES.

Furnaces with sufficient heating surface properly arranged and having the area of the air passages not greatly in excess of the combined area of the warm air pipes will, with a steady fire, deliver air at a fairly uniform temperature, even during strong winds.

When the passages are too large the wind will force an excessive amount of air through the furnace, much of which will fail to come in contact with the heating surface, with the result that the air issuing from the registers will vary greatly in velocity and in temperature.

The examination of a number of well proportioned furnaces showed the average area for the passage of air to be about 180 square inches per square foot of grate surface, equal to about 1¼ square inches of free air-way to each square inch of grate surface.

JOINTS.

A furnace should have as few joints as possible, consistent with proper provision for expansion and contraction. These forces are practically irresistible, and if proper allowance for their action is not made, something must give way, causing, as a rule, the leakage of gas. Where the sections join, a deep cup joint packed with kaolin, asbestos cement or other suitable material should be used, permitting a reasonable amount of "play" without the escape of gas.

MATERIALS EMPLOYED.

The materials chiefly used in the construction of furnaces are cast iron and wrought iron or steel plate. Much has been stated (especially by the makers of steel plate furnaces) as to the ease with which gases pass through cast iron at high temperatures. The experiments most quoted, however, were made on thin plates and under conditions unlike those existing in a furnace. The best authorities on heating and ventilation agree that the danger of contamination from this source is very slight, and is not to be compared with that from ill fitting joints and other leaks due to bad workmanship, or to causes having nothing whatever to do with the kind of materials used.

CAST IRON VS. STEEL PLATE.

Cast iron furnaces may be built in almost any desired form and arranged to present large radiating surfaces with few joints.

The variety in design with wrought iron or steel plate is much more limited. The superior weight of cast iron furnaces over those of other materials renders them less susceptible to sudden variations in temperature with changes in the condition of the fire. When once heated, the castings take longer to cool than thin steel plate; consequently the temperature of the air passing through the furnace is maintained more nearly constant. In point of durability cast iron is thicker and less subject to corrosion than wrought iron or steel plate. It is, therefore, more suitable for use in damp places.

Steel plate furnaces transmit heat readily, and with thoroughly riveted seams and well packed joints afford little opportunity for gas leakage.

TYPES OF FURNACES.

The better class of cast iron furnaces have a radiator, generally placed at the top, through which the gases pass and become cooled before reaching the smoke pipe. They have but one damper, combined as a rule with a cold air check. Many of the cheaper furnaces have no radiator whatever, in the true sense of the term; the gases passing directly to the smoke pipe, carrying with them much heat that should be utilized. Such direct draft furnaces are very wasteful, but find a market among certain builders, whose chief requirement is that a furnace shall have a large casing to deceive prospective purchasers as to its actual capacity.

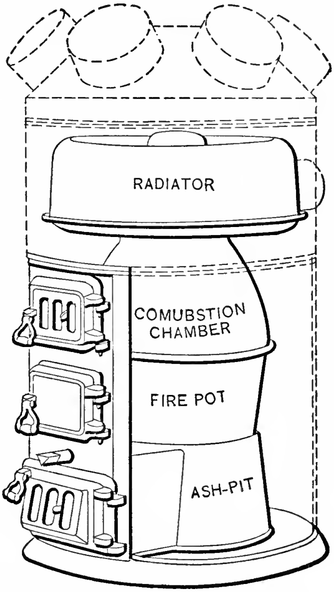

Fig. 1.—Cast Iron Furnace with Radiator at Top.

DOME FURNACE.

Fig. 2 shows a furnace of extremely simple construction. A cast iron fire pot surmounted by a steel plate dome. Furnaces of this general type are often used in the cheaper classes of dwellings. There is practically no flue travel for the gases.

While furnaces of this general design may be effective heaters, they are not as economical in the use of fuel as are those having a radiator of some sort through which the gases must travel in passing from the combustion chamber to the smoke pipe.

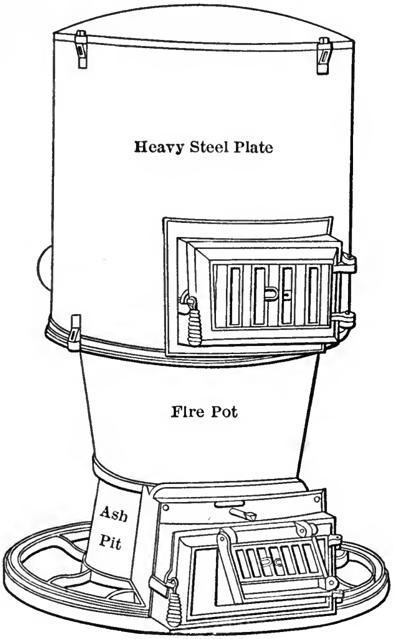

Fig. 2.—Furnace with Cast-iron Fire Pot and Steel Plate Dome.

TWO SECTION FIRE POT FURNACE.

Fig. 3 shows a cast iron furnace with a two-section corrugated fire pot and a corrugated combustion chamber on which rests a cast iron radiator; a popular furnace in certain localities, the principal advantage claimed being less likelihood of fire pot cracking than if made in a single piece. All gases must pass through the radiator enroute to the chimney giving up a large portion of their heat.

STEEL PLATE FURNACES.

In the ordinary steel plate furnaces (see Fig. 3), the gases pass downward through a radiator located below the top of the furnace. In addition to the damper in the smoke pipe, a direct draft damper is used, to give a direct connection with the funnel when coal is put on, to prevent the escape of gas to the cellar.

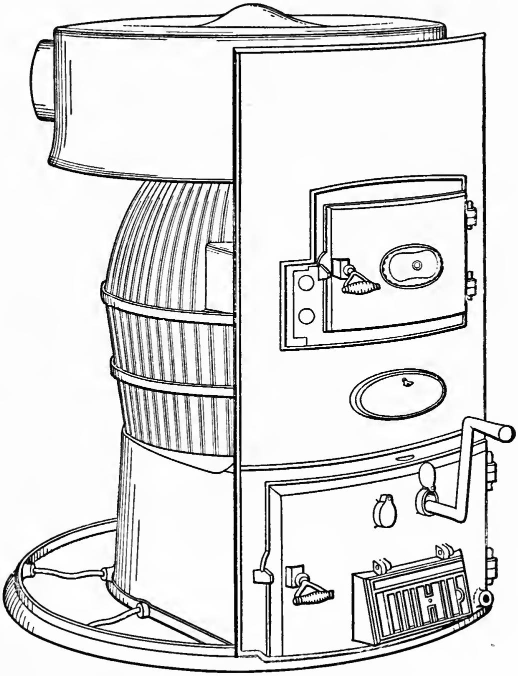

Fig. 3.—Cast-iron Furnace with Two Section Corrugated Fire Pot and Corrugated Combustion Chamber.

GRATES.

No part of a furnace is more important to the user than the grate. That much study has been put into their design is shown by the many styles that have been put on the market.

The plain grate, oscillating about a center pin, was for a long time the one most commonly used. Such grates were usually provided with a clinker door through which a poker could be introduced to remove any refuse too large to pass between the grate bars.

Grates of the draw center and dump center type followed. In all these the removal of ashes takes place principally around the circumference, decreasing toward the center, where the motion ceases. The action of such grates tends to leave a cone of ashes in the center of the fire, causing it to burn more freely around the edges. Vigorous shaking often results in depositing a considerable quantity of unconsumed coal in the ash pit before the ashes near the center of the grate can be dislodged. Different forms of rocking grates have been used, which, though easy to shake, have not proved effective in breaking up clinkers, and have been liable to clog and restrict the passage of air through the fire.

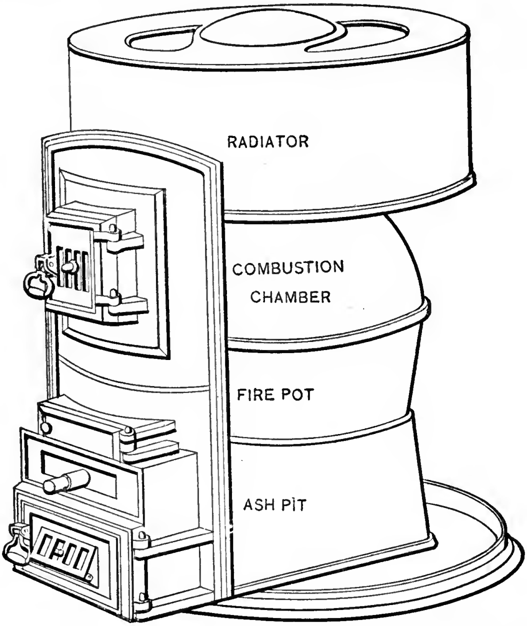

Fig. 4.—Cast-iron Furnace (Less Casing) with Steel Radiator.

The most common type, the revolving triangular pattern, is now used in many of the leading furnaces. It consists of a series of triangular bars, having teeth. The bars are connected by gears and are turned by means of a detachable lever. If properly used when the fire is of proper thickness, this grate will cut off a slice of ashes and clinkers over its entire area, with little, if any, loss of unconsumed coal. Its action tends to break up the mass of fuel, permitting the air to pass freely through the fire and causing fresh coal to ignite quickly.

THE FIRE POT.

Fire pots are generally made of cast iron or of steel plate lined with fire brick. The depth varies considerably, ranging from about 12 to 18 inches. In cast iron furnaces of the better class the fire pot is made very heavy to insure durability and to render it less likely to become red hot. Many furnaces have the fire pot made in two sections, the makers claiming less liability of cracking, and in case of repairs less expense, than with a pot made in one piece. On the other hand, the latter presents fewer joints, and in point of durability often lasts, with good management, more than 20 years.

The heating surface of cast iron fire pots is often increased, as previously stated, by corrugations, pins or ribs. Clinkers never adhere to cast iron. To facilitate molding, a slight taper is necessary in all cast iron fire pots. An excessive taper is unnecessary and misleading. In comparing the size of furnaces the average diameter of the fire pot should be used as a basis, in order to allow for the difference in taper that may exist.

A fire brick lining is essential in a wrought iron or steel plate furnace to protect the thin shell from the intense heat of the fire. It is claimed for such fire pots that more perfect combustion is obtained than in a cast iron pot due to the fact that the unburned carbon escaping from the fire is entirely consumed by this intense heat before coming in contact with the comparatively cold surface of the radiator. The fire requires less attention and the air passing through the furnace is not likely to become overheated. Brick lined pots are generally of the same diameter throughout, no taper being necessary.

BRICK LINED VS. CAST IRON FIRE POTS.

Since brick lined fire pots are much less effective than cast iron in heat transmitting power, such furnaces depend to a great extent for their efficiency on the heating surface in the dome and the radiator. This is much greater as a rule than in cast iron furnaces.

When coal is put on, the direct draft damper is opened, which cuts out all the heating surface in the radiator; the radiant heat from the top of the fire is checked by the layer of fresh coal, and as the heat from the fire pot must pass through about 2 inches of fire brick, it is obvious that until the gas has burned off and the direct draft damper can be closed, comparatively little heat is given off by the furnace, with the result that the temperature at the registers will fall. Under similar conditions, with a direct draft furnace having a cast iron fire pot, the heat of

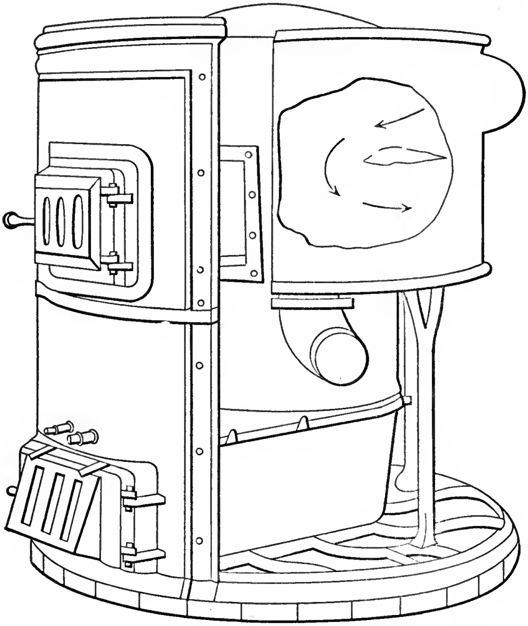

Fig. 5.—Steel Plate, Brick Lined, Indirect Draft Furnace.

the fire will be readily transmitted through the sides of the pot while the fresh coal is becoming ignited. No part of the heating surface being cut off during this period, a more even temperature at the registers will be maintained.

The overheating of the air may be avoided in any furnace by selecting one so large that it will never be necessary to force it to the extent that the surfaces become red hot. A fire hot enough to heat a heavy cast iron fire pot to redness would be likely to have the same effect on a portion of the thin dome of a wrought iron furnace.

COMBUSTION CHAMBER.

The body of the furnace above the fire pot, commonly called the dome or feed section, provides a combustion chamber, which should be of sufficient capacity to permit the gases to become thoroughly mixed with the air passing up through the fire or entering through openings provided for the purpose in or around the feed door. In most furnaces this space is somewhat larger than the capacity of the fire pot. In many of the cheaper ones, however, it is very much restricted, resulting in incomplete combustion of the gases and waste of heat.

RADIATOR.

The radiator, so-called, with which all furnaces of the better class are provided, is separate from the dome or combustion chamber and affords a sort of reservoir in which the gases are retained in contact with the air passing through the furnace until they have parted with a considerable portion of their heat. The design of the radiator materially affects the efficiency of the furnace.

Radiators are built of cast iron, of steel plate or of a combination of the two. The former material is more durable, and can be made with fewer joints, but owing to difficulties in casting radiators of considerable hight, steel plate is often used for the sides.

Fig. 6 shows a top view or plan of a cast iron radiator showing the course of the gases which pass from the dome through the short connection, then divide and pass in opposite direction around the radiator to the smokepipe.

In some furnaces the connection between the dome and the radiator is nearly opposite the smoke outlet, the gases passing around the entire ring instead of dividing as shown in Fig. 6, one-half the gases going each way.

Steel radiators may be made any desired hight, and cast iron for the top and bottom. The effectiveness of a radiator depends on its form, its heating surface and the difference between the temperature of the gases and the surrounding air. Its form should be such that a thorough contact with the air passing through the furnace will be secured. Owing to the accumulation of soot, the bottom surface becomes practically worthless for heating after the furnace has been in use a short time, hence surfaces to be continuously effective must be self cleaning.

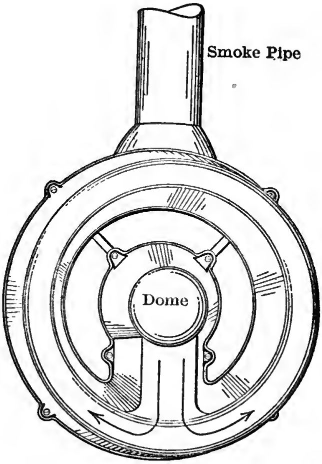

Fig. 6.—Plan of Cast-iron Radiator Showing Course of Gases.

As to the location of the radiator, if placed low down the gases are surrounded by air at relatively low temperature, which renders the radiator, foot for foot, more effective than if placed near the top and surrounded by warmer air. If the radiator is placed too low the cold air surrounding it near the base of a furnace is likely to cause condensation of the gases and corrosion. This also has the tendency of decreasing the efficiency of the furnace.

EVAPORATING PAN.

The evaporating pan, with which nearly all furnaces are provided, is sometimes placed where it will be of little service, It is usually placed, however, above the level of the grate, where there is sufficient heat to cause a rapid evaporation. Care should be taken to keep the evaporating pan clean or the action of the heat on the sediment in the bottom, in case the pan becomes dry, is likely to cause a nauseating odor to pervade the house. To insure a supply of water in the pan at all times a plumber's tank and ball cock, properly connected, may be used with convenience. The author considers it desirable to have the ball cock outside the furnace where it is accessible rather than inside the casing.

OTHER TYPES OF FURNACES.

Several types of furnaces in common use differ materially from those illustrated here, and it may be of interest to mention that one has an unusually large amount of heating surface secured by surrounding the fire pot by a number of vertical castings triangular in section through which the air passes; another has a revolving fire pot made up of vertical bars, scraping the ashes off by rotating the fire around a fixed grate; still another form has a tubular radiator at the rear through which the gases pass. This construction permits the furnace to be very low and allows a good pitch to the pipe. Square fire pot furnaces are also used to a considerable extent.

FURNACES FOR OTHER FUELS.

Thus far we have discussed only furnaces for burning hard coal. In certain districts, however, this fuel is so expensive, as compared with soft coal, natural gas or wood, that furnaces designed to burn such fuels are in demand. Furnaces for burning soft coal are designed to admit a quantity of heated air above the fire to combine with the gases, to diminish the waste of heat and the escape of free carbon, as soot, in the smoke. With all the precautions that may be taken the deposit of soot is much greater than with hard coal, necessitating more frequent cleaning of the furnace and smoke pipe. On account of the large volume of smoke the pipe is made 1 or 2 inches greater in diameter than for hard coal furnaces of the same size. A cold air check should not be used, as it increases the deposit of soot by cooling the smoke.

In the natural gas districts furnaces are commonly arranged to burn this most convenient of fuels. Such furnaces should have a grate for burning coal, in case the supply of gas should, from any cause, be cut off.

Wood furnaces, Fig. 7, are generally very simple in construction, little attention being paid, as a rule, to their efficiency, since the cost of fuel where they are used is generally very low. The smoke should be made to pass through a radiator as in ordinary hard coal furnaces. The larger sizes are built to take ordinary cord wood sticks 4 feet long. Smaller furnaces may be had for burning sticks 2 to 3 feet in length. The smoke pipe must be made larger than for hard coal furnaces of the same heating capacity.

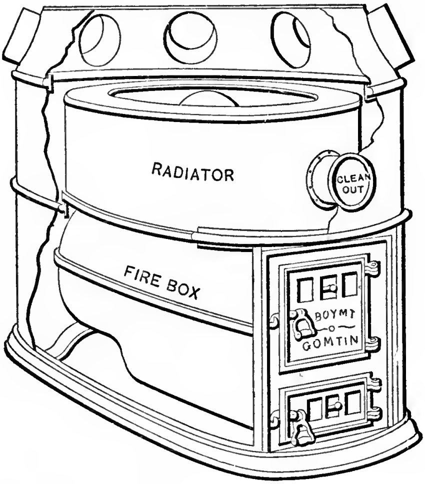

Fig. 7.—Portable Wood Furnace with Steel Radiator.

Coke may be burned in ordinary hard coal furnaces, but this fuel is very bulky for a given weight as compared with coal, and must be fed more frequently to keep the fire in good condition.

GAS FURNACES.

Furnaces specially designed for burning artificial and natural gas have a gas burning chamber from which the pot products of combustion are made to pass through a series of sheet metal flues so as to expose a large amount of surface for heating air

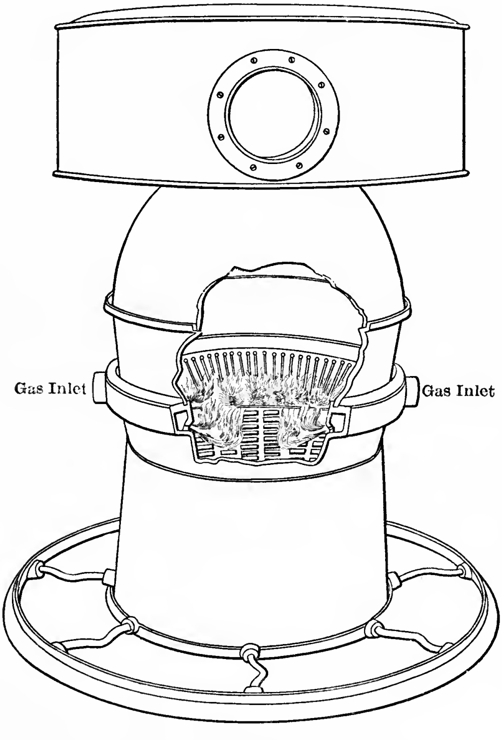

Fig. 8.—Gas Burning Ring in Place.

and to insure the extraction of their principal heat. For Fall and Spring service their use with artificial gas for a few hours per day has been found practicable in relation to fuel cost. For continuous service natural gas at its low cost may be used with economy and convenience. Hard coal furnaces are in many instances arranged to burn natural gas by the insertion of a gas burning ring as a part of the fire pot.

Fig. 8 illustrates the application of a "gas burning ring" to a coal furnace.

The maker's description is as follows: The Ring occupies a position in the center of the fire pot and with it the furnace will burn either coal or gas or both without any changes whatever and without disconnecting the gas pipes. It is so made that the gas outlets cannot become clogged with ashes.

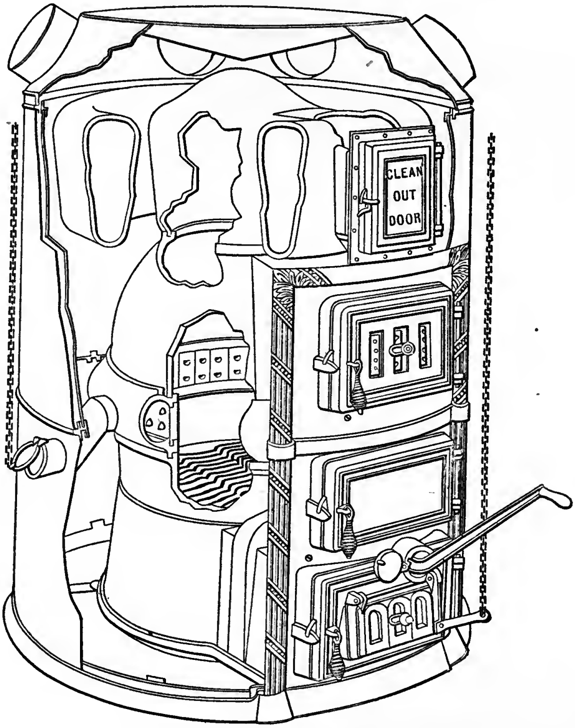

Fig. 9.—Soft-coal Furnace with Air-blast Attachment.

SOFT COAL AND GAS FURNACES.

In the case of soft coal furnaces ample space must be provided in the combustion chamber.

The castings must be exceptionally heavy to withstand the effect of the intense heat.

Fresh air is in some types admitted around the fire pot just above the level of the fire, this air being first heated.

Fig. 9 shows a soft coal furnace with an air-blast attachment. The cut clearly shows the course of the air and the method of heating it. The hotter the air admitted to the combustion chamber the more effective the air-blast attachment.

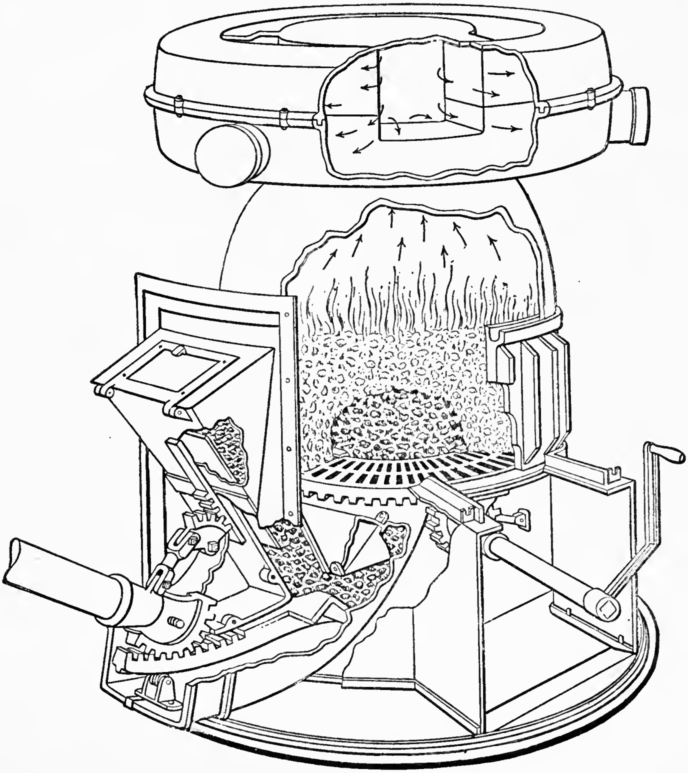

Fig. 10.—Underfeed Furnace.

Fig. 10 shows an underfeed furnace used principally for soft coal. When used for hard coal the makers recommend that pea, buckwheat or chestnut sizes be used.

The operation of the furnace is described as follows in the literature published by the manufacturer:

By means of a plunger which slides in this coal-chute, and a light hickory lever, which operates the plunger, coal, which has been placed in the hopper, is "pumped," or forced through the chute, up onto the grate and underneath the body of burning coal.

In forcing the fresh coal into the furnace the fire is pushed upward and outward, the fresh coal being surrounded on the top and sides by fire. In this way the fire is brought into direct contact with the sides of the fire pot and dome—the most effective radiating surfaces of the furnace.

The combustion is more rapid along the sides of the fire pot, because of the air admitted through the grate, and as the combustibles are entirely burned out of the coal, the refuse-ash is on grate, which encircles the feed-chute, and is readily and easily shaken down into the ash-pit.

HEATING SURFACE.

Taking up again the discussion of hard coal furnaces we come to the question of heating surface. Many furnaces having ample grate area for the work intended, fall short from lack of heating surface. In cold weather such furnaces have to be forced, causing red hot surfaces, intensely heated air and lessened efficiency. Surfaces unlike in character and location vary greatly in heating power, therefore the kind, form and location of the heating surface, as well as its area, must be considered in comparing furnaces. It is by no means certain that of several furnaces having the same grate area the one having the greatest heating surface will be the most economical heater. In some furnaces having an unusually large amount of surface it will be found on inspection that a considerable portion would soon become almost useless from the accumulation of soot. In others a large portion of the surface is lined with fire brick, or is so situated that the air currents are not likely to strike it.

Heating surfaces may be classified as follows:

1. Fire pot surface, lined or unlined.
2. Surfaces acted upon by the direct rays of heat from the fire, such as the dome or combustion chamber.
3. Gas or smoke heated surfaces, such as flues or radiators.
4. Extended surfaces, such as pins or ribs.

Table I.—The Area of Heating Surface and the Ratio of Heating to Grate Surface in Furnaces of Common Types.

	CAST IRON FURNACES.												WROUGHT IRON FURNACES. Drop flues and radiator at the bottom.				
	No radiator. Dome top.		Radiator at top.										Brick lined fire pot.				Cast iron fire pot
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Average diameter of fire pot	15¾	18	16½	17	19	20½	20½	25	26½	30	30	R'tan'lar	20	22	22	24	27
Average area of fire pot = sq. ft. grate surface	1.35	1.76	1.48	1.58	1.96	2.29	2.29	3.4	3.82	4.9	4.9	5.5	2.18	2.64	2.64	3.13	4
Total heating surface in square feet	23	14.6	21.5	32.6	35.1	30.2	44.4	53.2	46.3	51.2	68.5	71.5	54	57	52.4	61	69.5
Heating surface per square foot grate surface	17	8.3	14.5	20.6	18	13.2	19.4	15.7	12.1	10.4	14	13	24.8	21.6	19.9	19.5	17.4
Heating surface in radiator, square feet	None	None	12	18.3	19.5	17.2	24.6	28.8	29.6	30.8	37.5	53.5	33.8	34.8	26.6	36.7	36
Brick lined heating surface, square feet	....	....	....	....	....	....	....	....	....	....	....	....	11.2	11.8	11.8	12.5	....

A furnace of peculiar construction of the vertical flue type that cannot be classified under any of the headings in the above table measured as follows: Fire pot 21 inches, total heating surface 111 square feet, heating surface per square foot grate surface 46.2. It will be noticed that these surfaces are much greater than any given in the table, due principally to the large amount of extended surface included. **Much of the latter** is of doubtful efficiency.

Their relative value is an interesting question, on which available data are lacking.

The total heating surface, as compared with that of the grate, based on actual measurements of a number of furnaces of different makes sold in New England, is shown in Table I.

Various writers on heating recommend furnace proportions ranging from about 50 to 70 square feet of heating surface per square foot of grate. These proportions are much in excess of those found in ordinary house heating furnaces, as shown in Table I. Assuming a maximum rate of combustion of 5 pounds of coal per square foot of grate surface per hour the above mentioned ratios give 10 to 14 square feet of heating surface per pound of coal burned per hour.

Common furnace proportions would give about 10 square feet of heating surface per pound of coal burned per hour at the average rate throughout the heating season. By using larger furnaces than customary to heat a given space the same ratio may be obtained during cold winter weather, since by increasing the size of the furnace the rate of combustion is diminished and the heating surface per pound of coal burned increased.

In any line of furnaces of the same make and style it will be found that the heating surface per square foot of grate is less in the large sizes than in the smaller ones. For example, take two furnaces, one with a 20-inch fire pot and the other with a 30-inch pot, both 1 foot deep.

The 20-inch pot contains 2.4 square feet of heating surface per square foot of grate surface.

The 30-inch pot contains 1.6 square feet of heating surface per square foot of grate surface.

An advantage in the ratio of 3 to 2 in favor of the smaller fire pot. About the same ratio will hold for the total heating surface in the furnaces.

The great advantage in point of heating surface in small furnaces, as compared with larger ones, explains their greater proportional heating capacity.

SECONDARY HEATING SURFACE.

In addition to the heating surface stated in Table I, the inner casing of black iron forms a valuable secondary heating surface, absorbing the heat radiated from the body of the furnace and imparting it again by convection to the air passing over it. This secondary heating surface is very important. Since the air passing through the furnace is heated only by convection—*i. e.*, by bringing it in contact with a heated surface, unless the radiant heat from the furnace proper is absorbed by some secondary surface, which in turn imparts it to the air, much of the heat radiated from the body of the furnace will be wasted in overheating the cellar.

RADIATION AND CONVECTION.

With highly heated surfaces the loss of heat by radiation is greatly in excess of that by convection.

Sir Wm. Thomson is credited with the statement that a stove heated to 1200 odd degrees gives off 92 per cent. of its heat by radiation and 8 per cent. by convection.

The formulas of Dulong show that with heated body at temperature of 780 degrees and surrounding air and objects 60 degrees, loss of heat by radiation, as compared with that by convection, will be as 7.17 is to 2.23, and with temperature of 960 degrees and surrounding air and objects 60 degrees, loss of heat by radiation, as compared with that by convection, will be as 12.68 is to 2.348. The higher the temperature of the heated surface the greater will be the loss of heat by radiation as compared with that by convection.

HEATING SURFACES OF FURNACES AND BOILERS.

It may be of interest to compare the proportions given in Table I with those in hot water heaters and steam boilers. In such apparatus designed for house heating the amount of heating surface per square foot of grate generally ranges from about 15 to 1 in the smaller sizes to 25 to 1 in the larger ones.

EFFICIENCY.

One of the first items to be determined in estimating the heating capacity of a furnace is its efficiency, or the percentage of the heat in the coal that may be utilized. The efficiency depends chiefly on the area of the heating surface as compared with the grate, on its character and arrangement and on the rate of combustion. The proportions commonly found in furnaces of different types are shown in Table I. The rate of combustion required to maintain a temperature of 70 degrees in the house varies, of course, with the outside temperature. Taken for the entire season the rate is generally less than 2 pounds of coal per square foot of grate per hour. In severe weather, however, a rate of 4 to 5 pounds per hour must be maintained. In tapered fire pots the grate surface should be considered equivalent to the average area of the pot.

It is apparent that the efficiency of a furnace decreases with an increase in the rate of combustion to the point of forcing since the more rapid the rate the less will be the amount of heating surface per pound of coal burned, and the hotter will be the gases passing to the chimney. On the other hand, a very slow fire is wasteful, due to incomplete combustion resulting from insufficient air supply. In the absence of definite available data based on tests, it is necessary in making calculations of the heating capacity to assume an efficiency that may reasonably be expected in practice. One pound of good anthracite coal allowing 10% ash will give off about 13,000 heat units. Of this amount a furnace should utilize from 50 to 70%, according to conditions.

A heat unit may be defined with sufficient accuracy for the purposes of this work, as the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit.

The writer has assumed in the following calculations that 8000 heat units may be utilized per pound of coal burned at a maximum rate of 5 pounds per square foot of grate per hour. This allowance corresponds to an efficiency of about 60 per cent.

HEATING CAPACITY.

The heating capacity of a furnace is generally stated in terms of the cubic space it is capable of warming. This measure is used from custom, but since its relation to the exposure varies with the size and shape of the building, it is more accurate to base the capacity directly on the exposed wall surface.

The variation in the relation between the exposure and the cubic space may be readily shown. For example, suppose we have a house of plan shown in diagram A and another of the same cubic contents shown in B:

The relative exposure of A to B is as 160 to 200 = 4:5. That is, while the cubic contents is the same in each the exposure of B is 25 per cent. greater than that of A. The fact that the exposure is used by many of the best engineers in calculating the proportions of steam and hot water heating apparatus should be a sufficient guarantee of its fitness. To determine the size of the furnace required for a given exposure the latter should first be reduced to equivalent glass surface (E. G. S.). To do this we must know the heat transmitting power of walls of different kinds and thickness, as compared with that of glass.

It is convenient and sufficiently accurate for ordinary calculations to consider 1 square foot of glass equivalent to 4 square feet of well constructed wood and plaster, or brick walls. Hence to reduce the area of the solid walls to E. G. S. divide by 4. Add to this the glass surface in the windows and one-half the area of outside doors. The sum is the total E. G. S. of the outside exposure. Since 1 square foot of glass will transmit about 85 heat units per hour when the difference between the inside and outside temperature is 70 degrees (A. R. Wolff), to ascertain the total loss of heat by transmission multiply the E. G. S. by 85. As to allowances for houses in exposed locations see note below Table II. To this must be added the loss of heat by ventilation or change of air.

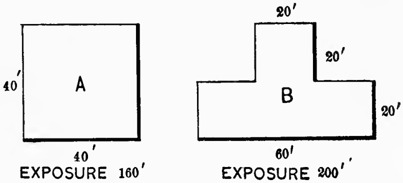

Fig. 11.—Relative Exposures.

If the air enters through the register at 140 degrees, which may be considered a maximum temperature under zero conditions, it is plain that one-half the heat supplied is carried away by the air escaping at 70 degrees, the other half (neglecting floors and ceilings) being lost through walls and windows. Therefore, twice the amount of heat lost by transmission must be supplied by the furnace.

In these computations it has been assumed that the factor 85 is large enough to cover air leakage losses, since other authorities use 70 B. t. u. per square foot of glass per hour with 70° difference in temperature. Wolff originally used this allowance but increased it to 85.

The leakage loss is really more affected by the character and extent of the exposed surface of a room than by its cubic contents, although the latter is commonly used as a basis for computing the loss of heat by leakage, allowing an air change once an hour for example.

Assuming that with a rate of combustion of 5 pounds of coal per hour per square foot of grate surface 8000 heat units are utilized per pound of coal burned in a well proportioned house heating furnace, (grate surface being considered equivalent to average fire pot area in the case of tapering pots), we have $8000 \times 5 = 40{,}000$ heat units per hour per square foot of grate surface transmitted to the air passing through the furnace. Dividing the total loss of heat per hour (E. G. S. × 85 × 2) by 40,000 gives the required grate surface in square feet, from which the diameter of the fire pot in inches may be readily determined. Expressed as an equation this becomes

$$\frac{\text{E. G. S.} \times 85 \times 2}{40{,}000} = \text{grate surface in square feet } (a).$$

Now, reversing this process and assuming different grate areas, we may compute a table showing the heating capacity of furnaces expressed in the area of exposed wall to which they are adapted. The glass surface, as compared with the total exposure, may vary considerably in different houses, but from the inspection of a number of plans the writer has adopted, as a fair average for those with windows of generous size, a glass surface equivalent to one-sixth the total exposure of glass and walls combined. Outside doors are reckoned as equivalent to one-half their area in glass.

With a glass surface equal to one-sixth the total exposure, and with solid walls equal to one-fourth their area in glass in their power for transmitting heat, we have

$$\text{E. G. S. of house} = \left\{\frac{1}{6} + \left(\frac{1}{4} \times \frac{5}{6}\right)\right\} \text{ exposure.}$$

$$= 0.375 \text{ exposure of glass and wall combined.}$$

Substituting in equation (*a*) this value of E. G. S. we have

$$\frac{0.375 \text{ exposure} \times 85 \times 2}{40{,}000} = \text{grate surface in square feet.}$$

Or transposing: Total exposure = grate surface in square

$$\text{feet} \times \frac{40{,}000}{0.375 \times 85 \times 2} = \text{G. S.} \times 627.4,$$

from which equation Table II is derived.

Table II.—The Capacity of Furnaces Expressed in Terms of the Exposed Wall Surface to Which They Are Adapted, to Maintain an Inside Temperature of 70 Degrees with an Outside Temperature of 0 Degrees. Temperature of Entering Air, 140 Degrees Rate of Combustion, 5 Pounds Coal per Square Foot of Grate Surface per Hour.*

Average diameter of fire pot in inches.	Corresponding area in square feet.	Total exposure in square feet to which furnace is adapted.
18	1.77	1,110
20	2.18	1,370
22	2.64	1,655
24	3.14	1,970
26	3.69	2,310
28	4.27	2,680
30	4.91	3,080
32	5.58	3,500

In exposed locations add from 10 to 15 per cent., according to the conditions, to the actual exposure of the house and select a furnace with a rating corresponding most nearly to the corrected exposure.

Note in connection with Table II, in calculating the gross exposure, to measure the entire distance around the house; multiply this by the combined clear hights of the several floors to be heated. The product will be the total exposure in square feet. The kitchen walls are included, simply to serve as a rough allowance for the loss of heat through floors and ceilings, which if estimated separately would make the calculation less simple. Where but a single room on a floor is to be heated, as for example an attic chamber, add its exposed wall surface, making proper allowances for any adjacent unheated space.

SIZE OF FURNACES FOR BLOCKS.

In estimating the size of furnaces for double houses, flats, or houses in blocks, it should be borne in mind that in case an

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* In this table no allowance has been made for the higher efficiency of the smaller sizes, due to their greater ratio of heating surface to grate surface. It has been assumed that this advantage is to a great extent offset by the more rapid combustion common in large furnaces and by the better care they generally receive.

adjoining house is unoccupied the loss of heat will be considerably increased. It is well, therefore, to provide for such a contingency by adding to the actual exposure of the house one-third the area of the party wall or one-third of the floor area, as the case may be. In city houses, which may stand apart from others for some time before the adjoining lots are built upon, the loss of heat through the party walls must be taken into consideration in estimating the size of the furnace. A solid brick wall of this nature will transmit about two-thirds as much heat as an ordinary wall having an average amount of glass. Hence add to the area of front and rear walls two-thirds the area of the party walls. Select a furnace having a rating in Table II most nearly corresponding to the total exposure thus obtained.

MANUFACTURERS' RATINGS.

It may be of interest to note the rated capacity of furnaces as stated in manufacturers' catalogues, the capacity being expressed in terms of the cubic space in frame dwellings the furnaces are rated to heat. Table III gives a fair average of the minimum ratings of furnaces of the better class. Column *d* shows the exposure corresponding to a given cubic space, assuming the house to be square and the clear hights of the first and second floors to be 9 feet and 8 feet 6 inches respectively. These exposures are considerably in excess of those in Table II, indicating a tendency on the part of manufacturers to overrate their furnaces:

Table III.

Diameter of fire pot in inches. (*a.*)	**Area of fire pot in square fee** (*b.*)	**Rated capacity in cubic feet for frame dwelling.** (*c*)	**Exposed wall surface corresponding.** (*d.*)
18	1.8	8,000	1,500
20	2.2	10,000	1,670
22	2.6	14,000	1,980
24	3.1	19,000	2,300
26	3.7	26,000	2,700
28	4.3	33,000	3,040
30	4.9	40,000	3,340
32	5.6	50,000	3,740

CHAPTER II.

HOUSE HEATING.

COMPARATIVE MERITS OF FURNACES AND OTHER SYSTEMS.

In first cost furnace heating is less expensive than steam or hot water heating. The amount of fuel required is greater than with either of the latter when direct radiation is used. Indirect steam or hot water systems deliver air at a lower temperature, as a rule, than furnaces and consume more fuel.

As to the objections raised against furnaces, it may be said that when installed in accordance with the building laws of most cities the risk of fire is practically eliminated. The leakage of gas and dust is more frequently due to faulty installation and management than to any defect in the furnace. The gas and dust are allowed to escape to the cellar, whence they are drawn up into the rooms through the cracks in the cold air box, the joints in the casing or the spaces around the pipes. For this reason the cold air box should be carefully constructed.

With modern methods of proportioning the size of furnace, pipes and cold air box, and with the more general use of fire places and wide openings between rooms, good results are obtained. The force causing air to flow through the pipes is, at best, slight. They must, therefore, be carefully proportioned and the furnace suitably located to secure a proper distribution under adverse conditions. For warming country or seashore houses occupied only part of the year, furnaces are particularly convenient. They are always ready for use, and at the end of the season may be left without precautions being taken against damage, as with hot water or steam apparatus. Where wood is cheap excellent results may be obtained with furnaces designed to burn that fuel.

LOCATION OF THE FURNACE.

A furnace should be so placed that the warm air pipes will be of nearly the same length.

The air travels most readily through pipes leading toward the sheltered side of the house and to upper rooms. Hence pipes leading toward the north or west, or to rooms on the first floor, should be given a preference in respect to length and size. The furnace should be placed somewhat to the north or west of the center of the house, or toward the points of the compass from which the prevailing cold winds blow. See Figs. 29, 30, and 31.

FOUNDATION.

Having determined the location of the furnace, see that a suitable foundation is provided of concrete or of brick. Excavate and place the furnace in a pit, if necessary to obtain a proper pitch to the pipes.

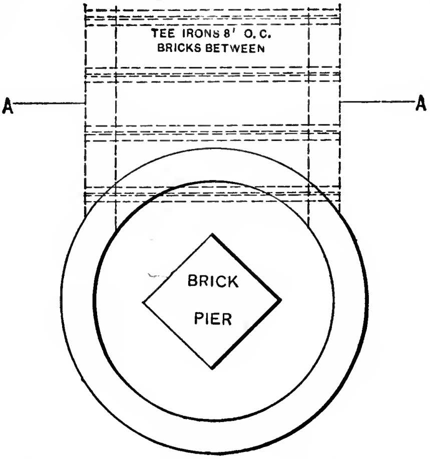


Fig. 12.—Brick Furnace Foundation with Underground Cold Air Box.

FURNACE PIT.

If a pit under the furnace is to be used, because of the better distribution of the air around the furnace, care must be taken to see that it is properly drained. All underground work should be built of hard burnt brick laid in cement having two parts of sand to one of cement. The thickness of the walls of the pit may be 4 or 8 inches, according to its diameter and depth. A large pier on which the furnace will rest should be built in the center of the pit. The size of this pier will vary with the size of the furnace. One 16 x 16 inches is common. The pier should be set diagonally with reference to the opening from the cold air box, to divide the current of entering air.

BRICK SETTING.

Having prepared the foundation and pier, set the bottom casting carefully in place, so that its center will coincide with that of the foundation. Continue erecting the castings, packing the joints with kaolin or other suitable material. This done, bolt the front or shield firmly in place. Pack the joints around the door frames with suitable cement or putty to prevent the leakage of gas or dust. The inner and outer brick walls, each 4 inches in thickness, with not less than 2 inches clear space between them, may now be carried up (see Fig. 13), keeping the courses level. Place irons over the openings for the cold air box, man-door and front or shield.

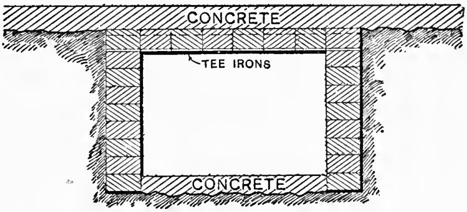


Fig. 13.—Section on Line A A of Fig. 12.

The inside diameter of the circular wall is generally made 4 to 8 inches greater than the diameter of the radiator. The air passage through the furnace should be equivalent to the combined area of the warm air pipes. Light, hard bricks may be used for the setting, to be well bedded in cement mortar consisting of not less than one part of cement to three of lime mortar. The inner circular wall should have a thin coating of cement applied.

When the walls have reached the proper hight, set a thimble about 3 inches larger than the diameter of the smoke pipe, and place the hot air pipes in position with their tops level. Give them as sharp a pitch as possible. Build in carefully around them and trim off their inner ends to conform to the circlar wall; then lay on covering bars about 8 inches "on centers," with strips of tin or galvanized iron between. Lay on these one course of bricks dry, then another course in cement mortar, and plaster the top. Another method of covering is to use two sets of bars with one course of bricks on each, leaving a dead air space between them.

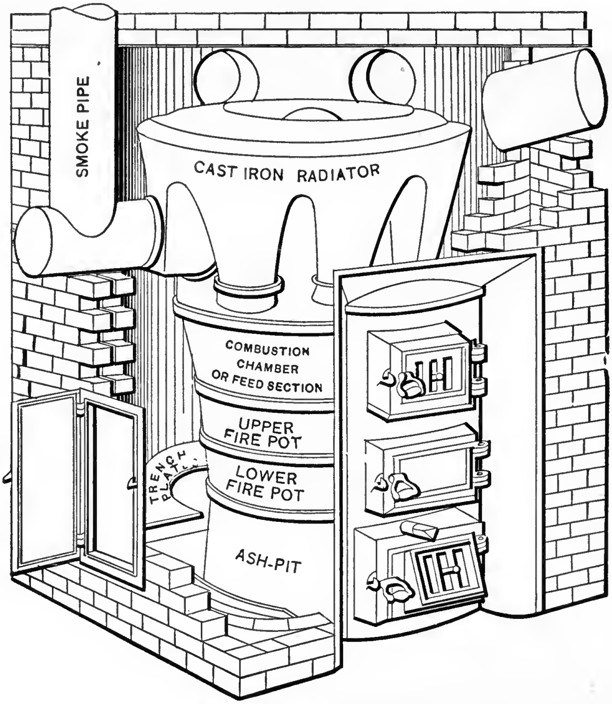


Fig. 14.—Brick Set Furnace.

A better and more expensive method than either of those just described is to use an inverted cone built of 22 or 24 inch galvanized iron (see Fig. 15). Rest this on the inner wall and lay one or two courses of brick above on iron bars. The air chamber above the top of the furnace castings should be at least 10 inches high, to permit a free distribution of the air to the various pipes.

In some furnaces the cold air enters beneath cast iron trench plates. In others they are omitted, the air entering through a series of "pigeon holes" extending around the bottom of the inner wall. An even distribution is thus secured.

PORTABLE SETTING.

The setting of a portable furnace is generally a very simple matter. After the bottom casting has been properly set on a suitable foundation the other sections are placed in position, allowing each to find its own bearing in the cup joints filled with kaolin or other suitable material. This done the front or shield is bolted on with joints cemented. The inner and outer casings are next adjusted, then the collars are set in the top, and the furnace is ready for the pipes. Building laws sometimes require a sheet iron shield to be suspended from the ceiling above the furnace.

PORTABLE VS. BRICK SETTING.

Portable furnaces with galvanized iron casings have almost entirely superseded those set in brick work. When properly arranged with a double casing the loss of heat is no greater than is necessary to keep the cellar of a country house at a proper temperature. They occupy less space and are more accessible in case of repairs than those set in brick. In city houses, with the basement well protected, the loss of heat from the furnace casing is objectionable, and since the transmission of heat is less with a brick setting the latter is sometimes used, although a metal casing covered with non-conducting material would perhaps be better. A brick setting has another advantage in its ability to store heat, acting as a sort of temperature equalizer, absorbing heat when the fire is intense and giving it out again when it becomes low. Cracks in the circular wall are liable to occur, however, which with certain forms of setting produce harmful effects.

Fig. 15.—Section through Cone for Brick Set Furnace.

TWIN FURNACES.

In large houses it is often a question whether to use one large furnace or two smaller ones having a single top, known as twin furnaces (see Fig. 16). These will be somewhat more expensive, but have certain advantages.

It has been pointed out in Chapter I that small furnaces have more heating surface per square foot of grate than larger ones, hence two small furnaces will present more heating surface than one large one having their combined grate area. With furnaces of the same make and type the greater the ratio of heating surface to grate area the greater the efficiency.

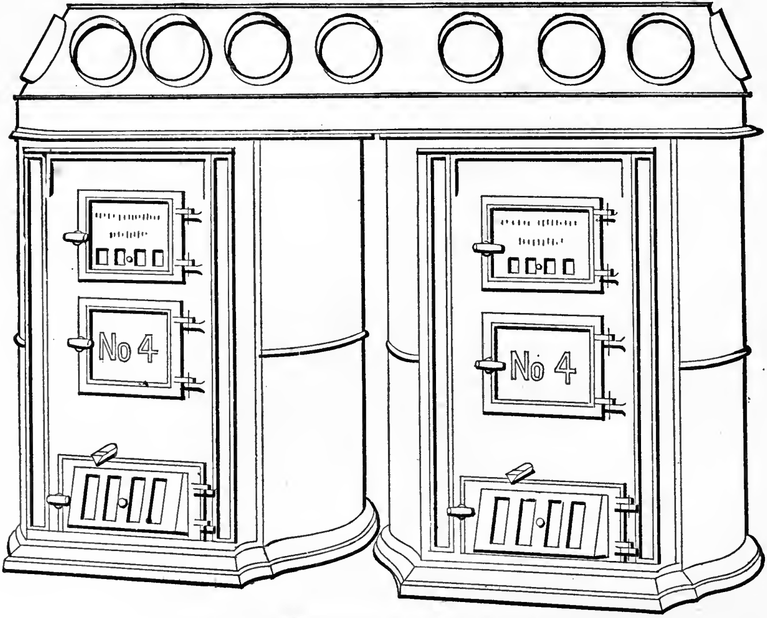


Fig. 16.—Twin Furnaces or Battery System.

An advantage claimed for twin furnaces is the greater range in heating capacity obtained by using one or both fires to suit conditions. A single furnace of sufficient capacity to warm a house in the coldest weather will require considerable skill in its management to avoid overheating at other times. It is from lack of such skill that houses are usually too warm during spring and fall. In twin furnaces it is especially important that the air chamber above them be roomy, to permit the easy flow of air to the pipes. It can hardly be expected that the distribution of air throughout the house will be as even in mild weather, when running but a single fire, as when both are in use, since the space for the passage of air through the single furnace is not large enough to admit a sufficient volume to fill all the pipes.

It is hardly necessary, however, that the distribution should be perfect in mild weather, for with open doors the warm air admitted to the living rooms will soon become diffused throughout the house. The pipes to the more important rooms should, if possible, be connected with the hood above the same furnace, so that the air will flow directly to them when running a single fire. It is often advisable to combine two furnaces of different sizes under the same top. The larger one can then be used until late in the fall, when the smaller one can be added as an auxiliary.

The cold air box should separate in two branches before reaching twin furnaces, each to have a slide or damper.

TWIN FURNACES VS. SEPARATE ONES.

It is often a question whether to use twin furnaces or two furnaces placed separately. If it is found on laying out the system with twin furnaces that some of the pipes must be made of excessive length, it would be far better to discard this system and use two separate furnaces placed some distance apart. These will be somewhat less convenient to care for than twin furnaces, but the shorter pipes will insure a more even distribution of warm air. Unless the cellar is unusually high, permitting a sharp rise, the length of the pipes should not greatly exceed 15 feet.

SMOKE PIPES.

Furnace smoke pipes range in size from about 6 inches in the smaller sizes to 8 or 9 inches in the larger ones. They are generally made of galvanized iron of No. 24 gauge or heavier. The pipe should be carried to the chimney as directly as possible, avoiding bends, which increase the resistance and diminish the draft. When the draft is known to be good the smoke pipe may purposely be made longer to allow the gases to part with more of their heat before reaching the chimney. Where a smoke pipe passes through a partition it should be protected by soapstone of the thickness of the partition and extending not less than 4 inches from the pipe in all directions. A double perforated metal collar may be used instead of the soapstone if desired, making it at least 8 inches greater in diameter than the pipe.

The top of the smoke pipe should not be placed within 8 inches of unprotected beams nor less than 6 inches under beams protected by asbestos or plaster, with a metal shield beneath. The connection between the smoke pipe and the chimney is frequently very loose, allowing cold air to be drawn in, thus diminishing the draft. A collar to make the connection tight should be riveted to the pipe about 5 inches from the end, to prevent its being pushed too far into the flue.

Where the pipe is of unusual length it is well to cover it to prevent loss of heat and the condensation of gases.

CHIMNEY FLUES.

Chimney flues, if built of brick, should have walls 8 inches in thickness, unless terra cotta linings are used, when only 4 inches of brick work is required. Except in small cottage houses, where an 8 x 8 flue may be used, the nominal size of the smoke flue should be at least 8 x 12, to allow a margin for possible contractions at offsets, for undersized brick or for a thick coating of plaster which is not necessary but which nevertheless is sometimes applied. A clean out door should be placed at the bottom. A square flue cannot be reckoned at its full area, as the corners are of little value. An 8 x 8 flue is practically no more effective than one of circular form 8 inches in diameter. To avoid down drafts the top of the chimney should be carried above the highest point of the roof.

AREA OF COLD AIR BOX.

The cold air box should be large enough to supply a volume of air sufficient to fill all the hot air pipes at the same time.

If the supply is inadequate the distribution is sure to be unequal, the cellar will become overheated from lack of air to carry away the heat generated and the life of the furnace will be shortened. These points in many cases are not appreciated, if one may judge by the absurdly small cold air boxes frequently used. If a box is made so small or is throttled down so that the volume of air entering the furnace is not large enough to fill all the pipes, it will be found that those leading to the lee side of the house or to rooms on upper floors will take the entire supply, and that additional air to supply the deficiency will be drawn down through registers in rooms less favorably situated.

Common "thumb rules" are to make the cold air box two-thirds or three-quarters the combined area of the hot air pipes. The area of the box is governed by the capacity of the pipes and the expansion of the air. In zero weather the maximum temperature of the air leaving the furnace in a well proportioned system should not exceed 140 degrees.

Each cubic foot of air admitted at 0 degree when heated to the latter temperature is expanded to 1.325 cubic feet, or is increased in volume about one-third; hence the cold air box need be only three-quarters the area of the hot air pipes to fill them under the conditions stated. A box the full area of the pipes would insure an ample supply of air at all seasons, and its effective area could be almost as easily regulated by the slide or damper as a smaller one. Such a box would be of great assistance to avoid overheating in mild weather.

LOCATION OF COLD AIR BOX.

The cold air inlet should be placed where the prevailing cold winds will blow into it, commonly on the north or west side of the house. When the inlet is on the lee side, warm air from the furnace is likely to be sucked out through the cold air box. Avoid taking the air supply from narrow passageways between houses from fear of the same action during strong winds. Whatever may be the location of the entrance to the cold air box, reversals in the direction of the air current therein may take place in the case of very high winds blowing from a direction that brings the entrance on the lee side of the house. The flow of air in the proper direction may be re-established by closing the slide in the cold air box and taking air temporarily from the cellar. A well designed hot air system may oftentimes turn out to be a failure due to improper location of the cold air inlet. For this reason the existing conditions should be carefully studied before the location is fixed.

MATERIAL OF COLD AIR BOX.

The cold air box is generally built of matched boards. However well such a box may be put together, the wood soon shrinks and joints open, allowing dust and cellar air to be drawn into the furnace and discharged to the rooms. The wood work should be kept at least 1 foot from the furnace and protected from radiant heat. The connection between the wooden cold air box and the furnace should be of galvanized iron or brick.

Galvanized iron is probably the best material to use. It may be made practically air and dust tight, is fire proof, durable and in harmony with the other parts of the apparatus. A cold air box of this material costs more than a wooden one, but for first-class work is worth the additional expense. In case the galvanized iron cold air box is of considerable length, or passes through a kitchen or laundry, it should be covered with non-conducting material.

For an underground cold air box, hard burnt brick laid in cement should be the materials used. The bottom should be of brick or concrete. The top may be covered with bluestone with close joints or with bricks laid between covering bars and concreted over the top flush with the cellar floor. (See Fig. 13.) Glazed drain tile is often used for cold air ducts, especially in connection with small furnaces. It is not advisable to use an underground duct or pit where the ground is damp, for even if drained the walls of the duct are apt to become mouldy and the air to be unwholesome. If such conditions are encountered the duct should be carefully protected with waterproofing.

COLD AIR ROOM.

A small room into which the air flows before entering the duct leading to the furnace is sometimes provided. It acts as an equalizing chamber and overcomes to a great extent the effect of sudden gusts of wind, making the flow of air through the pipes much more uniform than with an ordinary cold air box. With this arrangement less attention is required in regulating the slide. A cold air room 6 x 6 feet in size is ample for a good sized house.

When the wind is likely to blow with unusual force baffle plates may be used, as in Fig. 17.

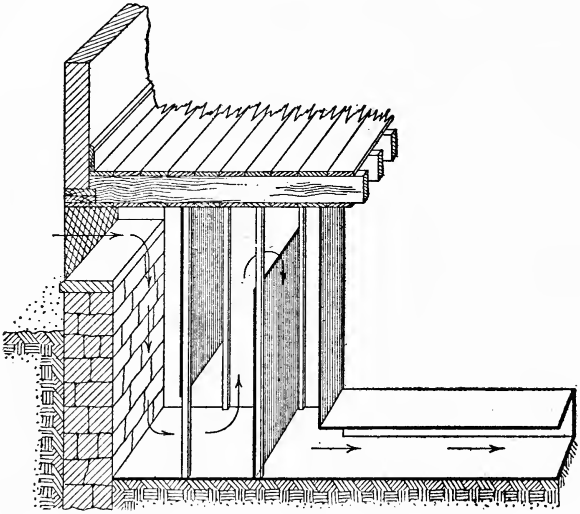


Fig. 17.—Fresh Air Room with Dust Collector.

COLD AIR INLET.

The galvanized iron wire netting at the cold air inlet should be at least ⅜-inch mesh; a finer netting is unnecessary and cuts off too much area. The frame to which it is attached should be no smaller than the inside dimensions of the cold air box. The air is frequently much restricted at this point. A door to admit air from the cellar to the cold air box is generally provided. As a rule air should be taken from this source only during high winds, extremely cold weather or when the house is temporarily unoccupied.

AIR FILTERS.

When the air supply is likely to be laden with dust, filtering screens of cheese cloth or similar materials may be used. They may be made in the shape of conical bags suspended in the cold air room, or the cheese cloth may be attached to frames arranged for convenient removal. The area of the screen should be at least 15 times the area of the cold air box. At best they are a bother and must be frequently cleaned, but when properly arranged they afford considerable relief from dust contained in the outside air.

RETURN DUCT AND AIR SUPPLY.

In some cases it is advisable to return air to the furnace to be reheated. Ducts for this purpose are common in places where the winter temperature is frequently below zero. Return ducts, when used, should be in addition to the regular cold air box. The great amount of air supplied to a house by a well arranged furnace may not be generally realized. Take, for example, an ordinary frame house with seven or eight registers of average size. From data at hand the air supply to such a house in winter weather is 800 or 900 cubic feet per minute, corresponding to a change of air about once in 15 minutes. With the ordinary number of occupants this volume gives so large a per capita air supply that during the daytime a portion of the air may be returned to the furnace without harm. In the evening, however, with gas burning, each jet vitiating the air as much as five or six persons, the air supply stated is not any too much. It is apparent, therefore, that to obtain proper ventilation at all times with a system arranged to take air from either indoors or out, intelligent management is necessary. Because such management cannot be assured the return duct is not to

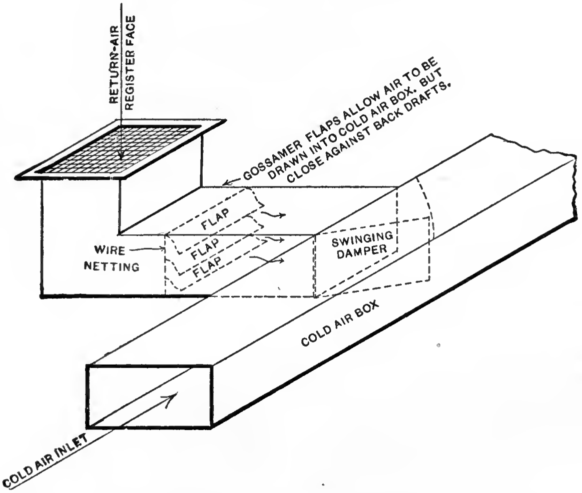


Fig. 18.—Return Air Duct with Damper and Back Draft Checks.

be generally recommended except where the climate is very severe, when the best results are sought. Its use certainly reduces the amount of fuel required, but the tendency to economize too much by taking all the air from indoors is a serious objection.

There are several methods of arranging a return duct. A separate connection may be made with the base of the furnace, or a branch may be run from the main cold air box to the first floor, with a mixing damper at the junction of the two arranged to shut off a portion of the outside supply while admitting air from the rooms above.

With the arrangement shown in Fig. 18 a portion of the air supply for the furnace may be taken from out of doors, the remainder being drawn through the register from the house. The gossamer check dampers are essential to the proper working of this device, for without them back drafts would be likely to occur during winds.

RECIRCULATED AIR.

With the increase in the price of coal, greater attention is paid than formerly to the recirculation of air. A house heating furnace as commonly arranged supplies far more air than is necessary for ventilation; for example, suppose a furnace with a 24-inch grate (average fire pot area) supplies 1 square inch pipe area to each square inch grate surface, 24-inch diameter= 452 square inches=3.14 square feet. With air velocities in pipes ranging from say 250-350 feet per minute to first floor, 350-450 to second floor and 450-550 to third floor, or say 350 as average velocity to first and second floors, no heat on third, gives 3.14 square feet × 350 = 1109 cubic feet of air per minute supplied to first and second floor rooms combined. On the usual basis of 30 cubic feet of air per minute supplied to each person, this volume would provide for 37 persons, whereas there would be hardly ten persons in a house heated by this size furnace.

During the night when sleeping room windows are supposed to be open, as is the rule nowadays, there appears to be no valid objection to returning the air from the house, shutting off the outside air and saving fuel.

During the day time in severe weather there is no objection to supplying at least one-half the air supply to the furnace through the recirculating duct from the house, which considerably reduces the coal consumption.

It is difficult to arrange this so that air can be taken from both outdoors and indoors at the same time and have no back drafts of cold air through the recirculating register. Fig. 18 shows one method by which this may be accomplished.

To avoid overheating the furnace in case nearly all registers and the cold air box happen to be closed at the same time, it is well to omit the pipe damper and the register blades or shutters from one of the rooms, say the first floor hall.

SIZE OF AIR PIPES.

Much larger furnace pipes are now used than formerly. This involves a greater original outlay and an increased running expense for fuel, but the householder is repaid by the more healthful conditions secured through the supply of an ample volume of warm air in place of a small volume of intensely heated air. The pipes should be so proportioned that the several floors will be heated equally.

Table IV, calculated as explained below, will be found useful in determining their size. It must be borne in mind, however, that in heating and ventilating work no rule or table can be successfully used without a certain " coefficient of common sense " to allow for varying conditions.

The main steps involved in the calculation of the table are:

1. The determination of the loss of heat through the walls, windows and floor or ceiling of the room.
2. The volume of warm air required to offset this loss.
3. The velocity of air in the pipes.

The loss of heat is calculated by first reducing the total exposure to equivalent glass surface. This is done by adding to the actual glass surface one-quarter the area of exposed wood and plaster or brick walls and one-twentieth the area of floor or ceiling to cover the loss of heat to non-heated basement or attic. At least ten per cent. is added where the exposure is severe, to cover the increased loss of heat by transmission and by the leakage of air. The window area assumed in calculating the table is

Table IV, Showing the Proper Size of Furnace Pipes to Heat Rooms of Various Dimensions When Two Sides Are Exposed. Temperature at Register 140°, Room 70°, Outside 0°. Rooms 8 to 17 Feet in Width Assumed to be 9 Feet High. Rooms 18 to 20 Feet in Width Assumed to be 10 Feet High. For Other Hights, Temperatures or Exposures Make a Suitable Allowance. When First-Floor Pipes Are Longer Than 15 Feet Use One Size Larger Than That Stated. Provide Liberally for Room on Exposed Corners.

	Length of room.																						
Width of room.	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
8...	7 8	7 8	7 8	7 8	7 8	7 8	8 9	8 9	8 9	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
9...	.. ..	7 8	7 8	7 8	7 8	8 9	8 9	8 9	8 9	8 10	8 10	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
10...	.. ..		7 8	7 8	8 9	8 9	8 9	8 9	8 10	8 10	8 10	9 10	9 10	.. .	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
11...	.. ..	.. ..	..	8 9	8 9	8 9	8 9	8 10	8 10	8 10	9 10	9 10	9 11	9 11	9 11	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
12...	.. ..	.. ..	.. ..	.. ..	8 9	8 9	8 10	8 10	8 10	9 10	9 10	9 11	9 11	9 11	9 11	10 12	10 12	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
13...	.. ..	.. ..	.. ..	.. ..	.. ..	8 10	8 10	8 10	9 10	9 10	9 11	9 11	9 11	9 11	10 12	10 12	10 12	10 12	10 13	.. ..	.. ..	.. ..	.. ..
14...	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	8 10	9 10	9 10	9 11	9 11	9 11	9 11	10 12	10 12	10 12	10 12	10 13	10 13	10 13	10 13	.. ..	.. ..
15...	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	9 10	9 11	9 11	9 11	9 11	10 12	10 12	10 12	10 12	10 13	10 13	10 13	10 13	11 13	11 13	11 13
16...	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	9 11	9 11	9 11	10 12	10 12	10 12	10 12	10 13	10 13	10 13	10 13	11 13	11 13	11 13	11 13
17...	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	9 11	10 12	10 12	10 12	10 12	10 13	10 13	10 13	10 13	11 13	11 13	11 13	11 13	12 14
18...	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	10 12	10 12	10 12	11 13	11 13	11 13	11 13	11 13	11 13	12 14	12 14	12 14	12 14
19...	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	10 12	11 13	11 13	11 13	11 13	11 13	11 13	12 14	12 14	12 14	12 14	12 14
20...	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	11 13	11 13	11 13	11 13	11 13	12 14	12 14	12 14	12 14	12 14	12 14

One 12-inch pipe .... = two 9-inch pipes.
One 13-inch pipe .... = two 10-inch pipes.
One 14-inch pipe .... = two 11-inch pipes.
One 15-inch pipe .... = two 12-inch pipes.
One 16-inch pipe .... = two 12-inch pipes.
One 17-inch pipe .... = two 13-inch pipes.

In the space opposite the numbers indicating the length and width of room, the lower number shows the size pipe for first floor, the upper number the size pipe for second floor.

For third floor use one size smaller than for second floor.

For rooms with three exposures increase pipe given in table in proportion to the exposure.

For halls use pipe of ample size to allow for loss of heat to second floor.

one-fifth, or 20 per cent., of the entire exposure of the room. From the inspection of a number of plans this ratio was found to represent a liberal allowance for glass surface.

Having obtained the equivalent glass surface (E. G. S.), multiply by 85 (the loss of heat per square foot of glass per hour with 70 degrees difference in temperature). The product will be the total loss of heat by transmission per hour.

Double windows when tightly put in transmit about three-fifths as much heat as a single window.

The volume of warm air required to offset this loss depends on its temperature, which generally ranges from 120 to 140 degrees in zero weather. Assuming the temperature of the entering air to be 140 degrees and that of the room to be 70 degrees, the air escaping at approximately the latter temperature will carry away one-half the heat brought in. The other half, corresponding to the drop in temperature from 140 to 70 degrees, is lost by transmission. With outside temperature zero, each cubic foot of air at 140 degrees brings into the room 2.2 heat units. Since only one-half of this, or 1.1 heat units, can be utilized to offset the loss by transmission, to ascertain the volume of air per hour at 140 degrees required to heat a given room, divide the loss of heat by transmission by 1.1; the quotient is the volume sought. This result divided by 60 gives the number of cubic feet per minute. Having determined the volume of air required per minute, if we know the velocity with which it will travel through the pipes, their area in square feet is readily determined by dividing the volume by the velocity in feet per minute. This area is easily reduced to square inches, from which the diameter of the pipe may be obtained. The table avoids the bother of working out separately the size of each pipe.

To illustrate the method just stated, take for example a room two sides exposed, 14 x 16 feet x 9 feet high, on first floor, loss of heat through floor neglected, cellar being warmed by waste heat from the furnace and pipes. Glass $=$ 20% total exposure $(14 + 16)\ 9 =$ 20% of 270 square feet $=$ 54 square feet, leaving $270 - 54 = 216$ wall, which divided by $4 = 54$ square feet E. G. S. Adding this to the actual glass, 54 square feet gives total E. G. S. of 108 square feet. 108 square feet $\times$ 85 (the loss of heat per square foot of glass per hour with 70° temperature difference) = 9180 B. t. u.

Add say 10% to allow for exposure. Total = 10098 B. t. u. per hour by transmission.

As stated above with 0° outside, 70° inside and 140° temperature of entering air, each cubic foot of warm entering air brings in 1.1 B. t. u. available to offset loss by transmission, therefore 10098 ÷ 1.1 = 9180 cubic feet air per hour must be supplied = 153 cubic feet per minute. With a velocity of 280 feet per minute through the pipe, $\frac{153}{280} \times 144 = 79$ square inches = 10 diameter pipe the same as in space opposite 14 in left hand column and under 16 in upper line of Table IV.

(Weight of cubic feet of air at 140 degrees), 0.066 pound × (increase in temperature from zero), 140 degrees ÷ (specific heat of air), 0.238 = approximately 2.2 heat units.

The specific heat of a body is the quantity of heat required to raise the temperature of the body through 1 degree F., as compared with that required to raise the temperature of an equal weight of water 1 degree. The specific heat of air (at constant pressure) is 0.2377; that is, approximately one-fourth as much heat is required to raise 1 pound of air through 1 degree F. as would be necessary to raise the temperature of 1 pound of water the same amount.

VELOCITY OF AIR IN PIPES.

In calculating the table maximum velocities of 280 and 400 feet were used for pipes leading to the first and second floors, respectively. These velocities are readily attainable in practice. They are lower than those commonly assumed for straight vertical flues, but this is accounted for by the greater resistance to the passage of air through the nearly horizontal basement pipes, and through elbows, nettings and registers. The size of the smaller pipes was based on lower velocities, according to their size, to allow for their greater resistance and loss of temperature.

LENGTH OF HOT AIR PIPES.

Since long horizontal runs of pipe increase the resistance and loss of heat it is unwise to extend them much over 15 feet in length. This rule applies especially to pipes leading to rooms on the first floor or to those on the cold side of the house. Air tends to move with the wind, not against it, hence pipes leading to exposed rooms should be favored. Rooms having a fire place or ventilating flue are more easily warmed than others.

Pipes of excessive length should be increased in size to allow for the additional resistance. The loss of heat from them may be diminished by a covering of asbestos or other nonconducting material or by making them double, leaving an air space of ½ to 1 inch between the two.

Long pipes or those leading to exposed rooms are sometimes favored by attaching them to the furnace top near the center, where the air is hottest, and by placing at their extremity inside the casing an inverted funnel or hood.

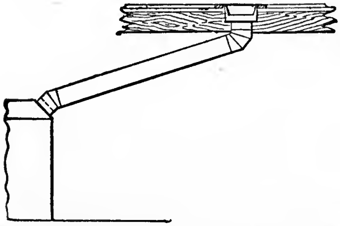


Fig. 18*a*.—Cone Top Furnace and Pipe with Bevel Elbows.

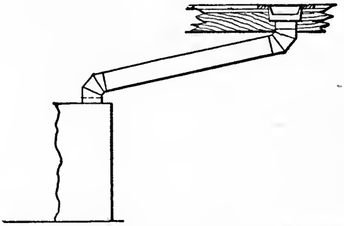


Fig. 19.—Flat Top Furnace and Pipe with Bevel Elbows.

The pipes should pitch upward as sharply as possible, for the greater the angle the less the resistance.

METHODS OF PIPING.

Several methods of piping are illustrated in the cuts. An inspection of each will show that less pipe is required in Figs. 18*a* and 19 than in the others. More careful measurements are necessary, however, as each turn requires a special bevel elbow, so called, made to suit the angle at which the pipe is placed. This angle is fixed by the hight of the cellar and the distance from the furnace to the register or riser. Lack of head room in low cellars with long runs of pipe sometimes interferes with the adoption of this method.

Figs. 20 and 21 show a cone or pitch top and a flat top furnace piped with regular stock pattern square and 45-degree elbows. This is a simple and fairly direct method of piping and presents a neat appearance. Somewhat more pipe is required than in Figs. 18 and 19, but this is offset by the convenience of using stock elbows. Slip joints provide sufficient "come and go" to make up for slight errors in measurements or in the making of the pipes.

Fig. 22 shows a method used chiefly in low cellars to secure the maximum amount of head room. It is the most roundabout method and increases the resistance to the flow of air and is not recommended.

Pipes should be kept at least 4 inches from the edge of the flat top. This is especially important in furnaces having a large space between the body and the casing, in order to cause the air to hug the heating surface.

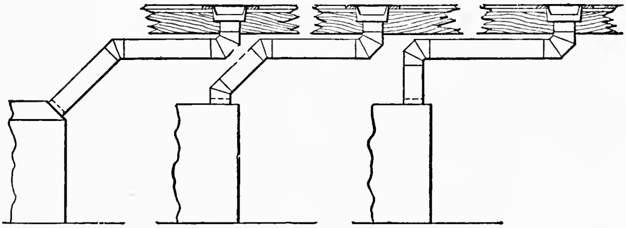


Fig. 20.—Cone Top Fqrnace and Pipe with Stock Elbows.

Fig. 21.—Flat Top Furnace and Pipe with Stock Elbows.

Fig. 22.—Flat Top Furnace and Pipe with Square Four Piece Elbows.

Generally pipes may be placed near the center of a flat top than of a cone or pitch top. A damper should be put in each pipe near the furnace.

TRUNK LINE SYSTEMS.

The method of piping illustrated in Fig. 23 has been used successfully in certain sections and possesses these advantages over separate pipes: (*a*) The friction is reduced; (*b*) the loss of heat from the pipes is reduced; (*c*) less sheet metal is required; (*d*) the appearance of the job is improved.

In designing this system the trunk lines have been subdivided as follows:

One 14-inch pipe supplies one 8-inch and one 11-inch.
One 16-inch pipe supplies one 13-inch and one 9-inch.
One 13-inch pipe supplies two 9-inch.
One 11-inch pipe supplies two 8-inch.

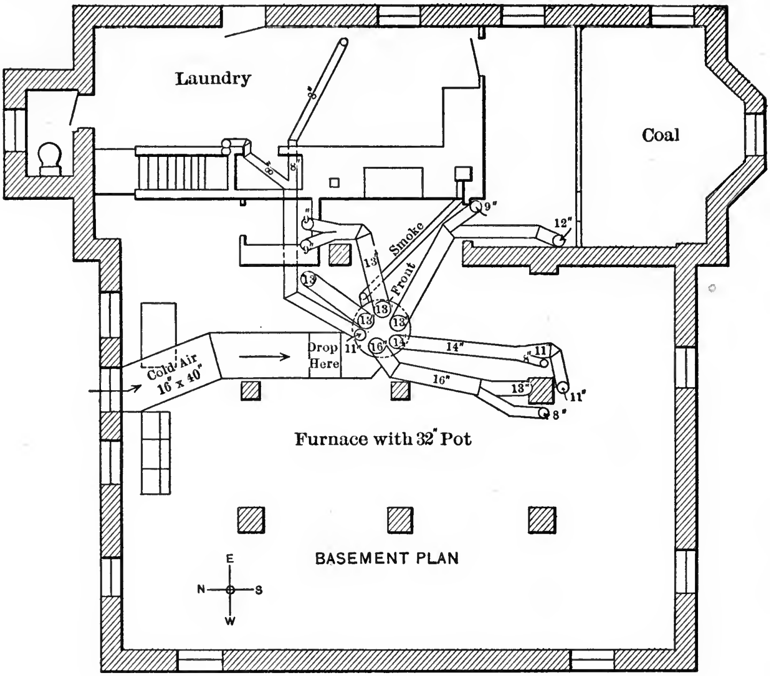


Fig. 23. Trunk Line System.

The relative areas are

14″ = 154 sq.in., 8″ + 11″ diameter = 145 sq.in.
16″ = 201 sq.in., 9″ + 13″ diameter = 197 sq.in.
13″ = 133 sq.in., two 9″ = 128 sq.in.
11″ = 95 sq.in., two 8″ = 100 sq.in.

The relative approximate frictional surface for a given length is

14″ = 44 8″ + 11″ = 6[illegible].
16″ = 50 9″ + 13″ = 69.
13″ = 41 two 9″ = 56.
11″ = 35 two 8″ = 50.

The above tabulation shows very clearly the great difference in frictional surface in trunk lines and in a pair of smaller pipes of approximately the same aggregate area.

RELATION BETWEEN GRATE SURFACE AND PIPE AREA.

Furnace catalogs often give ratings expressed in aggregate pipe area to which the furnace is adapted.

These ratings commonly allow from 1 to 1¼ square inches pipe area to each square inch grate surface (average fire pot area).

On a heat unit basis, if 1 square foot G. S. is good for 1 square foot pipe area, and 1 square foot grate gives off 40,000 B. t. u. per hour that are utilized in heating the air. then since 1 B. t. u. will heat 50 cubic feet of air from 0° through 1°, 40,000 B. t. u. will heat $40{,}000 \times 50 = 2{,}000{,}000$ cubic feet per hour through 1°, or if air is raised 140° will heat $2{,}000{,}000 \div 140 = 14{,}300$ cubic feet per hour through 140°. To discharge this volume, equal to $\frac{14{,}300}{60}$ or 238 cubic feet per minute, measured at 0° F. through an area of 1 square foot would require a velocity of 311 feet per minute.

The volume 14,300 cubic feet at 0° is expanded to $\frac{460+140}{460+0} = \frac{600}{460}$, its volume at 0° when heated to $140° = 18{,}652$ cubic feet. This volume per hour would pass through a pipe 1 square foot in area at a velocity of 311 feet per minute.

This corresponds well with the velocity of air in pipes to first floor rooms, hence theoretically the rule to allow 1 square inch pipe area to each square inch grate area (average fire pot area) is shown to be approximately correct.

RISERS OR VERTICAL FLUES.

Some architects appreciate the advantages of round risers instead of the usual shallow oblong, rectangular or oval form, and provide partitions of sufficient depth to permit them to be run. When such risers are located near the furnace they may best be made the same size as the cellar pipes connected with them. When they are some distance away the horizontal pipes are generally made larger than the uprights. When vertical pipes must be placed in single partitions, an important economy in fuel and a much better efficiency attends making the studding

5 or 6 inches deep and a much better job can be done than where the ordinary 2 x 4 studs are used. The shallower the pipes the greater the loss of heat and the greater the friction. For these reasons risers should never be carried up in partitions having a nominal thickness less than 4 inches. Studs 2 x 4 inches will shrink to a depth of 3¾ inches, leaving only 3½ inches for the flue, allowing a trifle for clearance.

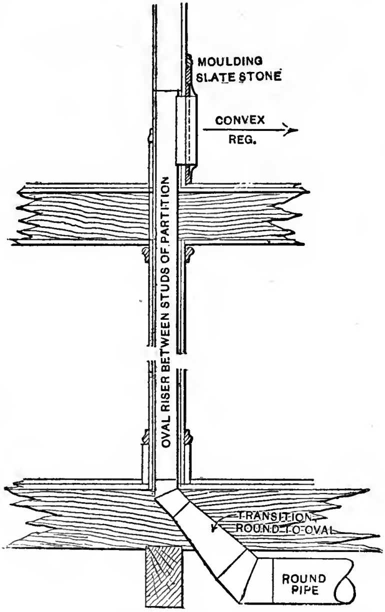


Fig. 24.—Oval Riser with Convex Register.

It is often difficult to provide spaces for flues of proper area to run up in ordinary partitions with studs 16 inches on centers. To run a riser large enough to heat a good sized room on the second floor the studs would have to be set so far apart that the plastering between them would not be firm unless very stiff metal lathing were used. To give space for large risers the partition may be thickened by nailing on furring strips, or in some cases a breast can be built of sufficient size to contain a round pipe of the full area required.

SEPARATE RISERS.

Each room should be heated by a separate riser. In some cases, however, it is permissible to run a single riser, connected with a tee or header at the top, to heat two rooms on an upper floor, if a riser of sufficient size is provided. The distribution with this arrangement is likely to be unequal during winds, the air going more freely to the less exposed room.

A single flue is sometimes used to heat two rooms on different floors, but such an arrangement should be avoided, if good service is desired in both rooms at all times. When used a damper is generally placed just above the lower register.

LOCATION OF RISERS.

A clear space of ½ to 1 inch should be left between the risers and the studs. The latter should be carefully tinned and the space between them on both sides of the pipe covered with tin, asbestos or metal lath. In some of the best work the risers are made double throughout with an air space of ½ inch or so between the inner and outer shells. In other cases they are wrapped with heavy asbestos paper. Protection of this character, however, should never interfere with the main object of heating, which is of great importance to the health and comfort of the family for a large portion of the year. If necessary use deeper studs or resort to any method that will insure heating as well as protection. It sometimes happens that the cellar pipes are carelessly pushed so far into the foot of the risers that the area of the flue is seriously diminished. This should be guarded against by beading the pipe a proper distance from the end.

If it can be avoided oval pipes should not be placed in partitions opposite sliding doors from fear of warping the latter.

At the level of the first floor the space around each riser should be stopped off with tin to prevent dust and cold air being drawn up from the cellar.

Risers should be placed in inside partitions if possible. Where they must be run in outside walls they should be made of larger size as well as double, and if the wall is not back plastered the outside boarding should be lined with asbestos sheathing. An air space should be left between the outside wall and the riser.

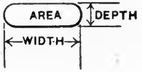


TABLE V, Showing the Dimensions and Area of Oval Pipes.

Diameter of round pipes.	Oval pipes.	Depth of oval pipes in inches. 3½	4	5	6	7	8	9	10	11	12	14
6	Width	7⅝	7⅛	6⅝	.	.....	.....	.....	..	.....	.	.....
	Area	23	25	27	.	.	.	. ..	.	.	.....	.
7	Width	9	8¾	8⅛	7⅝	.....	.. ..	. ..	.....	. . .	.....	.....
	Area	29	31	35	38	.	.....	.....	.	.		....
8	Width	10⅝	10¼	9¾	9⅛	8⅝	. ...	. ...	.....	.	.....	.
	Area	34	39	43	47	49	.....	.....	.....	.	. .	.. ..
9	Width	12⅛	11⅞	11¼	10¾	10⅛	9⅝	. ..	.....	. ...	.....	.....
	Area	40	45	51	57	60	63	. .	.....	.. ..	.....	.....
10	Width	13¾	13⅜	12⅞	12¼	11¾	11⅛	10⅝	. ...	.....	.....	.....
	Area	46	51	59	67	72	75	78	....	.	.	. .
11	Width	15¼	15	14⅜	13⅞	13¼	12¾	12⅛	11⅝	.....	.....	.....
	Area	51	58	67	75	82	88	92	94	. ...	.. ..	.....
12	Width	16⅞	16⅝	16	15⅜	14⅞	14¼	13¾	13⅛	12⅝	.....	... .
	Area	55	64	75	85	93	101	106	110	112	.	....
14	Width	20	19¾	19⅛	18⅝	18	17⅜	16⅞	16¼	15¾	15⅛	. ..
	Area	68	76	90	104	115	126	134	141	147	151	....
16	Width	23⅛	22⅞	22¼	21¾	21⅛	20⅝	20	19⅜	18⅞	18¼	17⅛
	Area	78	89	106	123	137	151	163	173	181	188	198

Round pipes of diameter stated in left hand column, when ovaled to the depths indicated on upper line, have a width and area shown by the figures in the body of the table.

TABLE VI, Showing the Sizes of Oval Pipes of Approximately the Same Carrying Capacity as Round Pipes of Sizes Stated in Left Hand Column. Friction Allowed for.

Diameter round pipes.	Size of equivalent oval pipes. Ins.	Ins.	Sq. ins.	Ins.	Ins.	Sq. ins.	Ins.	Ins.	Sq. ins.	Ins.	Ins.	Sq. ins.
6 inches = 28 square inches	....	....	.	6 ovaled	to 5	= 27	7 ovaled	to 4	= 31	7 ovaled	to 3½	= 29
7 inches = 38 square inches	7 ovaled	to 6	= 38	8 ovaled	to 5	= 43	9 ovaled	to 4	= 45	10 ovaled	to 3½	= 46
8 inches = 50 square inches	9 ovaled	to 6	= 57	9 ovaled	to 5	= 51	11 ovaled	to 4	= 58	12 ovaled	to 3½	= 55
9 inches = 64 square inches	10 ovaled	to 6	= 67	11 ovaled	to 5	= 67	14 ovaled	to 4	= 76	15 ovaled	to 3½	= 73
10 inches = 79 square inches	12 ovaled	to 6	= 85	12 ovaled	to 5	= 75	19 ovaled	to 4	= 96	20 ovaled	to 3½	= 100

In city houses most of the risers may be placed in recesses in the brick party walls. Wherever possible chimney breasts should be utilized for running risers, as they can often be built to accommodate round pipes, which are always to be preferred.

MATERIAL OF PIPES.

Bright charcoal tin is almost universally used for hot air pipes, except those of unusually large size, which are made of galvanized iron. In a dry atmosphere the tin retains its brilliancy and will radiate less heat from its surface than any other suitable material. In the best work, pipes 11 inches in diameter and smaller should be made of IX tin. Those of 12 inches in diameter and larger should be made of IXX tin or galvanized iron.

AREA AND SIZE OF REGISTERS.

The registers which control the supply of warm air to the rooms, generally have a net area equal to one-half their gross area. The net area should be 10 to 25 per cent. in excess of that of the pipe connected with it. It is common practice to use registers having the short dimension equal to and the long dimension about 50 per cent. greater than the diameter of the pipe. Thus, for a 6-inch pipe use a 6 x 10 register; for a 7-inch pipe, a 7 x 10 register; 8-inch, 8 x 12; 9-inch, 9 x 14; 10-inch, 10 x 14; 12-inch, 12 x 17; and so on.

Floor timbers are usually spaced 16 inches on centers, leaving about 14 inches clear space between them. Registers as large as 10 x 14 inches may be set with either dimension perpendicular to the timbers without the use of headers. The timbers may be trimmed slightly if necessary to give clearance.

LOCATION OF REGISTERS.

The opinion is often encountered that registers should be placed near exposed walls or the outer corners of rooms. On the contrary they should always be placed as near the furnace as may be practicable. This location will promote the natural circulation of air in the room, will permit a sharper pitch to the cellar pipes, will diminish the loss of heat, the resistance to the flow of air and the cost. When registers are located near the outer walls the resistance and loss of heat are so great that the flow of air is weak and uncertain and the temperature at the register often barely lukewarm. Registers should not be located below windows, as under certain conditions a reversal in the direction of the current of air in the pipe is likely to be induced by the current of cold air descending along the glass.

The registers on the lower floor should be located with particular care, those in north or west rooms being favored with regard to their distance from the furnace. Registers located on inside walls about two-thirds the height of the room would be in accordance with the practice in schools and public buildings. This location would be objectionable, however, in finely furnished rooms. The dust entering with the air would be likely to discolor the walls. The discharge of air from a register so placed would be more positive than from a floor register, due to the greater hight of the former.

FLOOR AND WALL REGISTERS.

Registers in the lower story are generally placed in the floor for convenience in piping. It is difficult to find space for wall registers on that story without interfering with the proper location of risers to the floor above. The registers in rooms on upper floors can often be placed in the wall to advantage. This location overcomes the necessity of cutting carpets and avoids the accumulation of dust from sweeping.

Unless registers of the convex pattern, as in Fig. 24, are used they must be boxed out to prevent the body of the register extending into the flue and cutting off a portion of its area. Wall registers are generally held in place by clips fastened to the register box. By removing the register face these clips may be turned over the edge of the body, which may then be drawn up to the face by means of the screws at the corners.

The depth of ordinary floor register boxes should be about 6 inches. Slate or cast iron borders are used in connection with floor registers. The wire netting in the register box should have the edges turned down about ¾ in. to raise it from the end of the pipe, thus avoiding a restriction of the area at that point.

PATTERN AND FINISH OF REGISTERS.

Registers may be procured in many patterns and styles of finishes, from the ordinary black japan to those of more elaborate design with faces of solid brass or bronze. They may be coated with white porcelain or be electro plated with nickel, silver or other metal to harmonize with the surroundings.

REGISTERS.

Since the publication of the first edition of this treatise in 1899 a considerable advance has been made in the variety of registers on the market, also a large increase in the number of sizes of regular stock patterns.

Table 30 gives the net area and depth of many of the sizes most commonly used; the approximate net area of others may be readily computed by multiplying the gross area by two-thirds.

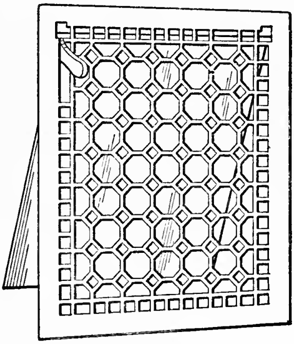


Fig. 25.—Single-valve Shallow Register for Partitions.

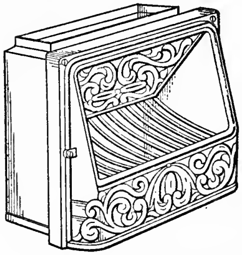


Fig. 26.—Side Wall Register.

In certain open patterns, however, the net area is fully 80 per cent of the gross.

Cast iron predominates as the material most commonly used for the construction of registers. Steel pressed into various patterns is used to a considerable extent.

For shallow flues and for thin partitions, registers like the one shown in Fig. 25 are used, these having no register box projecting into the flue, cutting down the effective area.

In cases where two rooms, one above the other, are heated from the same flue, the shutter back of the register face on the lower floor serves as a deflector, insuring the proper discharge of air. Otherwise, the upper floor is apt to "rob" the lower one.

Side wall registers in a variety of patterns have come into use, one style being shown in Fig. 26.

This is a popular type of side wall or base board register. In this make there is no grill work over the front, this being a solid casting which, when pushed back, provides the desired opening for hot air and serves as a deflector. The warm air is deflected away from the walls, keeping the dust from them.

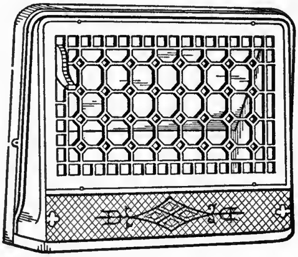


Fig. 27.—Side Wall Register.

With side wall registers of these modern types a single flue can be made to heat a first and second floor room owing to the larger bottom flue opening that it makes possible so that by using a pipe of sufficient size in basement, one furnace connection serves. No cutting of carpets is necessary and more freedom is given in the arrangement of furniture than when floor registers are used.

On the second floor either convex or extra shallow side wall registers may be used without obstructing the flue. It is well to realize the advantage that the large bottom opening or flue affords as is possible with this first floor register which takes the supply from a flue about 7 inches deep or 3 inches deeper than the studding, and fully twice the usual flue or riser capacity. In Figs. 26 and 27 it will be noted that the face of the register near the floor projects some distance in front of the base-board, which is cut away to make room for the register body.

In many cases wall registers are decidedly preferable to those located in the floor; the newer patterns satisfy this demand and eliminate the objections that apply to convex registers.

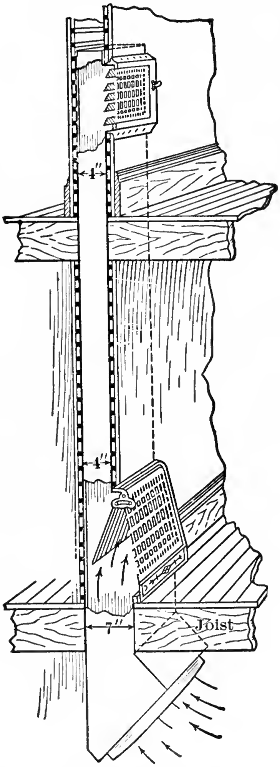


Fig. 28.—Riser and Register.

Fig. 28 shows riser with register on first and second floors.

MANAGEMENT OF A FURNACE.

The following general principles apply to the management of all hard coal furnaces and should be carefully observed if good results are desired:

The fire should be thoroughly shaken once or twice daily in cold weather.

It is well to keep the fire pot heaping full at all times. In this way a more even temperature may be maintained, less attention required and no more coal burned than when the pot is only partly filled. In mild weather the mistake is frequently made of carrying a thin fire, which requires frequent attention and is likely to die out. Instead, to diminish the temperature in the house keep the fire pot brimful and allow ashes to accumulate on the grate (not under it) by shaking less frequently or less vigorously. The ashes will hold the heat and render it an easy matter to maintain and control the fire. When feeding coal on a low fire open the drafts and neither rake nor shake it till the fresh coal becomes ignited. After the fire is well started the ashes may be shaken down and fire banked.

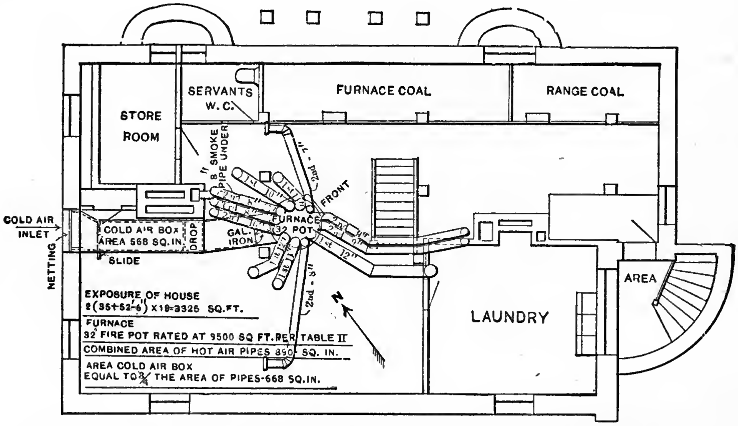


Fig. 29.—Basement Plan (8′ 0″) of a Residence Heated by a Furnace System.

The air supply to the fire is of the utmost importance. An insufficient amount results in incomplete combustion and a great loss of heat. To secure proper combustion the fire should be controlled principally by means of the ash pit, ash pit-slide or lower draft-door.

The smoke pipe damper should be opened only enough to carry off the gas or smoke and to give the necessary draft. The openings in the feed-door act as a check on the fire and should be kept closed during cold weather, except just after firing, when with a good draft they may be partly opened to aid the combustion.

Keep the ash pit clear to avoid warping or melting the grate. The cold air box should be kept wide open except during winds or when the fire is low. At such times it may be partially (never completely) closed. Too much stress cannot be laid on the importance of an adequate air supply to the furnace. The symptoms of an insufficient supply are irregular and unequal distribution through the hot air pipes, a hot furnace casing and an overheated cellar.

It costs little if any more to maintain a comfortable temperature in the house night and day than to allow the rooms to become so cold during the night than the fire must be forced in the morning, resulting in overheating the furnace, the formation of clinkers and the waste of coal.

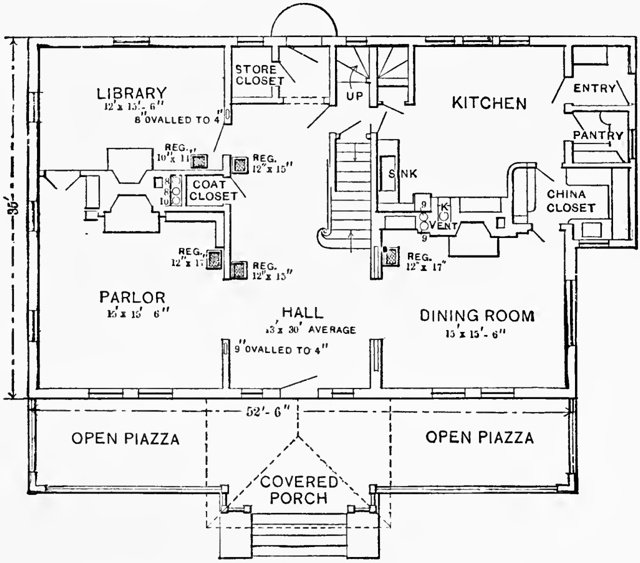


Fig. 30.—**First-Floor Plan (10′ 0″) of a Residence Heated by a Furnace System.**

In case the warm air fails at times to reach certain rooms the air may be forced into them by temporarily closing the registers in the other rooms. The current once established will generally continue after the other registers have again been opened.

It is best to burn as hard coal as the draft will warrant. Egg-size is better than larger coal, since for a given weight small lumps expose more surface and ignite more quickly than larger ones. The large lumps do not lie so closely together and allow streams of comparatively cool air to pass between them, hindering rather than promoting combustion. The furnace and smoke pipe should be thoroughly cleaned once a year. This should be done just after the fire has been allowed to go out in the spring.

SUGGESTIONS TO PURCHASERS.

In purchasing a furnace it is often wise, when competition is sharp, to select one a size larger than the dealer recommends. By so doing a larger area of heating surface is secured, hence a greater proportion of the heat generated will be utilized. The coal capacity being greater less frequent attention will be necessary, and as the fire will not require forcing, coal may be burned without the formation of clinkers. Such a furnace will last much longer and will give far better results and more general satisfaction than a smaller one. The only advantage in buying the latter is the small saving in the first cost, a saving which soon disappears in repairs and waste of fuel.

FURNACE TESTS.

The following is taken from an article by the author of this book which appeared in *The Metal Worker*, under the title, "Some Data from Furnace Tests on the Rate of Combustion and the Velocity of Air in the Pipes:"

Tests were made on the heating apparatus in a 29 x 35 foot frame house with parlor, dining room and reception room on the first floor, and four bedrooms and a bathroom on the second floor, heated during one winter season by a brick lined wrought iron furnace with a 22-inch firepot, and during the following season by a cast iron furnace with a tapering firepot having an average diameter of about 23 inches.

The brick lined furnace was tested during a 20 days' run in midwinter. The average outside temperature during this period, based on readings taken night and morning, was 26.3 degrees; total weight of coal burned, 2328 pounds; rate of combustion per square foot of grate per hour, 1.84 pounds. A cold day run was made a little later in the season, the thermometer ranging from 7 degrees below zero to 8 degrees above. During the 24-hour test coal was fed six times, the total weight amounting to 258 pounds, making the average rate of combustion 4.07 pounds per square foot of grate per hour.

The cast iron furnace was tested during a 32 days' trial, the average outside temperature, based on three readings per day, being 27½ degrees. The total weight of coal burned was 4350 pounds; the average per square foot of grate per hour being 1.97 pounds. During this test a record of room temperature was kept, the average being fully 70 degrees.

A COLD DAY TEST.

During this test a particularly severe day occurred, the temperature falling to 12 below zero. The coal burned during these 24 hours amounted to 300 pounds, giving an average rate of 4.35 pounds per square foot of grate per hour. Coal was fed seven times. The firepot was red hot while the thermometer remained below zero. The weight of ashes and unconsumed fuel passing through the grate was 10 per cent. of the weight of Lehigh egg coal supplied.

The house in which these furnaces were installed was of ordinary frame construction, shingled on building paper and plastered inside. The total cubic contents of rooms connected with the furnace was 11,674 cubic feet. The total combined exposed wall and glass surface was 1683 square feet.

It is to be noted that both furnaces used were inside the average rating given by reputable manufacturers to furnaces of their size—namely, about 14,000 cubic feet. If based on the exposure such furnaces are expected to carry approximately 1700 square feet of combined wall and glass surface when the latter does not exceed, say, one-sixth the total exposure. The exposure in this case is practically the same as the above figure. The house had storm windows on the north and west sides, yet an average rate of combustion of nearly 5 pounds per square foot of grate per hour was found necessary to keep the rooms comfortable in severe weather. This high rate requires pretty frequent attention and should be considered a maximum. The dimensions and other data of the several rooms are as follows:

Rooms. First floor.	Dimensions. Feet.	Approximate contents. Cu. ft.	Sides exposed.	Size of register and pipe.	
Dining room	13 x 18 x 8½	2,000	2	10 x 14	10
Parlor	14½ x 15 x 8½	1,850	2	10 x 14	10
Hall	14 x 18 x 8½	2,140	2	10 x 14	10
Second floor.					
Bedroom	9 x 12 x 8	864	2	8 x 12	7
Bedroom	10 x 19 x 8	1,520	2	8 x 12	8
Bedroom	10 x 12 x 8	960	1	8 x 12	7
Bedroom	13 x 13 x 8	1,350	2	9 x 12	8
Bath	6 x 7½ x 8	390	1	7 x 10	6
		11,674			

Anemometer tests were made with the following results:

Room. First floor.	Temperature at register. Deg. F.	Velocity in pipe. Feet.	Size pipe. Inches.	Horizontal run. Feet.	Elbows. 90°	45°
Dining room	116	418	10	8	1	1
Parlor	114	429	10	2	..	2
Hall	146	465	10	4	1	1
Second floor.						
Bedroom	100	252	7	16	2	2
Bedroom	104	320	8	12	2	2
Bedroom	104	510	7	2	1	1
Bedroom	127	570	8	2	1	1
Bath	103	286	6	8	1	1

The above tests were made with cold air box wide open and with little or no wind. The outside temperature was 5 degrees. The register temperatures were lower than would have been necessary to keep the rooms comfortable had it not been that they had been warmed to a temperature considerably in excess of 70 degrees, and furnace drafts were checked to reduce the heat.

Other tests were made, closing all registers on the first floor, giving velocities of over 500 feet in the rooms on the second floor most remote from the furnace. Tests were made in 34-degree weather, showing a velocity of only about 280 feet in rooms on the first floor. Anemometer readings taken in the cold air box showed a velocity of over 300 feet and a volume of 900 to 980 cubic feet per minute, corresponding to an air change in the rooms heated once in about 13 minutes.

Tests made in another house with outside temperature 24 degrees showed velocities in pipes leading to the first floor ranging from 306 to 334 feet, the temperature at the registers ranging from 104 to 109 degrees. Pipes leading to the second floor showed velocities in excess of 450 feet per minute with slightly lower register temperatures than on the first floor. The furnace in this case had a 22-inch firepot. The total volume of air supplied to the house per minute was 850 cubic feet.

TEST IN ANOTHER DWELLING.

Still another test, made in a different house, gave these results for rooms located on the second and third floors, the test being made in cold winter weather. It will be noted that the register temperatures in this case are much higher than in the previous tests:

Room.	Temperature of entering air. Deg. F.	Velocity in pipe. Feet.	Size pipe. Inches.	Horizontal run. Feet.	Elbows.
Parlor	138	250	6 x 10 oval.	9	3
Library	120	210	6 x 7½ oval.	4	2
Dining room	140	275	7 diameter.	15	2
Hall	151	450	6 x 8 oval.	7	2
Bath	108	280	6 diameter.	8	2
Bedroom	152	500	4½ x 7½ oval.	4	3
Rear bedroom	140	540	5 x 7 oval.	12	3

These tests give only a general idea of what velocities may be expected under ordinary working conditions. From the above and other data the author has adopted these velocities in making furnace heating computations.

Approximate velocity in pipes leading to first floor, 280 feet per minute; to second floor, 400 feet per minute; to third floor, 500 feet per minute.

During the test made in weather 12 degrees below zero the temperature of the air delivered by the furnace was 113 to 115 degrees. When the outside temperature rose to 6 or 8 below zero 122 degrees were indicated by the thermometer placed at register nearest the furnace. The maximum increase in temperature noted was 130 degrees. The wind was blowing strongly into a wide open cold air box. Had this been partially closed the maximum temperature would doubtless have exceeded 140 degrees, which is commonly used as a basis for computations in work of this kind.

HEATING FROM BELOW ZERO.

Calculations of the loss of heat from buildings are generally based on a difference of 70 degrees between the inside and outside temperatures. In many parts of the country, however, the heating apparatus must be capable of warming the building to 70 degrees during weather of 10, 20 or even 30 degrees below zero, corresponding to differences of 80, 90 and 100 degrees respectively between the temperatures indoors and out. To compare the loss of heat when the outside temperature is —10 degrees with that when the weather is zero we may assume, for convenience in figuring, a building having an equivalent glass surface (E. G. S.) of 1000 square feet. Now under zero conditions, with air entering the rooms at 140 degrees, one-half the heat will be carried away by the air escaping at approximately 70 degrees. The other half will escape by transmission through the walls, windows, floors and ceilings. The loss through 1000 square feet of glass surface under the conditions named is 85,000 heat units per hour (since 1 square foot of glass will transmit 85 heat units per hour when the difference in temperature on the two sides is 70 degrees). The loss of heat by leakage or the escape of air is as much more, making a total loss of 170,000 heat units per hour.

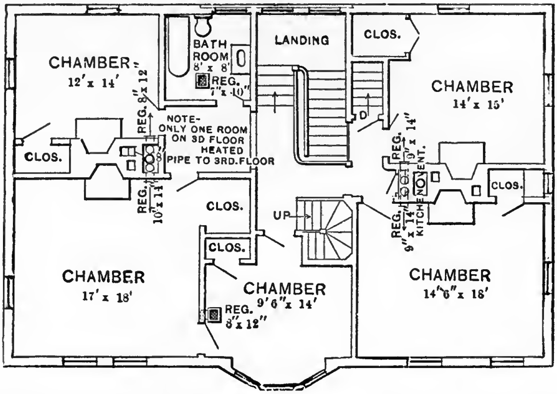


Fig. 31.—Second-Floor Plan (9′ 0″) of a Residence Heated by a Furnace System.

Now with an outside temperature of —10 degrees, other conditions remaining the same, the loss by transmission will be increased in proportion to the difference in temperature, or will be $\frac{80}{70} \times 85{,}000 = 97{,}000 +$ heat units. The air entering at 140 and escaping at 70 degrees carries away $\frac{70 + 10}{140 + 10} = \frac{80}{150}$ of the heat brought in, the remaining $\frac{70}{150}$ escaping by transmission. Each cubic foot of air admitted at 140 degrees brings in:

$$\left(\begin{matrix}\text{Weight cubic foot air}\\ \text{at } 140^\circ.\\ 0.066\end{matrix} \times \begin{matrix}\text{Rise in temper-}\\ \text{ature.}\\ (140^\circ + 10^\circ)\end{matrix} \times \begin{matrix}\text{Specific heat}\\ \text{of air.}\\ 0.238\end{matrix}\right) = 2.36 \text{ heat units.}$$

$\frac{70}{150}$ of which, or 1.1 heat units, will escape by transmission. Hence, to provide for the loss of 97,000 heat units per hour in this manner, as calculated above, $\frac{97{,}000}{1.1} = 88{,}000$ cubic feet (in round numbers) of air at 140 degrees will be required; 88,000 × 2.36 = approximately 208,000 heat units per hour, as compared with 170,000 under zero conditions.

That is, 22 per cent. more heat will be required to maintain 70 degrees inside with —10 degrees outside than to maintain the same temperature with zero outside, the air admitted to the room to be 140 degrees in each case. The increased loss of heat calculated in a similar manner for —20 and —30 degrees outside temperature will be 46 per cent. and 73 per cent. respectively.

CHAPTER III.

THE COMBINATION SYSTEM.

HOT WATER AND HOT AIR.

In the combination system of heating, where both or either air and water serve to convey heat from the furnace to the various rooms, a slight saving in fuel is effected by causing the gases to pass over water heating surface suspended above the fire. Aside from this, whatever gain is made is at the expense of ventilation, since in rooms heated by direct radiation the same air is used over and over. The main reason for employing combination hot water heating is to heat points too remote from the furnace to be successfully heated by hot air. Plans of a residence heated by a combination system are shown in Figs. 32, 33 and 34.

Living rooms should receive a continuous supply of warm fresh air. This may be furnished most conveniently in the ordinary manner through the furnace pipes, adding direct radiation if necessary in exposed corners. To deliver fresh air at points too remote from the furnace to be reached by an ordinary hot air pipe an indirect hot water radiator may be used, suspended just below the register and supplied with air from the furnace or directly from out of doors. Valves should be omitted from such radiators to avoid danger from freezing.

In finely furnished rooms indirect radiation may be used to advantage in place of direct radiation when the appearance of the latter is considered objectionable or when it is difficult to provide space for them. When so used they may be arranged with a return duct and the air in the room rotated as in direct heating. Under such conditions the heating surface is less effective than when placed in the room, hence it must be liberally proportioned. With this return air arrangement ventilation is eliminated.

DIRECT RADIATION.

The usual location for a direct radiator is near an outside wall or below a window, although good results may be obtained in rooms not too greatly exposed when the radiator is located near one of the inner walls, especially in cases where efficient weather stripping is used or tight double windows provided. Radiators should be set in as inconspicuous places as possible, provided such location will be effective. Direct radiation may properly be used in rooms where a constant supply of fresh aid is not required, as in bedrooms occupied only at night, when air may be admitted through raised windows, or in halls not used as living rooms. Unlike steam, the temperature of the water in the radiators may be gradually reduced by throttling down the supply with the valve. In rooms where heat may not be required for days at a time a small hole should be drilled through the disk of the radiator valve to prevent the heat being entirely shut off. Hot water radiators contain as a rule from 1 to 1½ pints of water per square foot of surface.

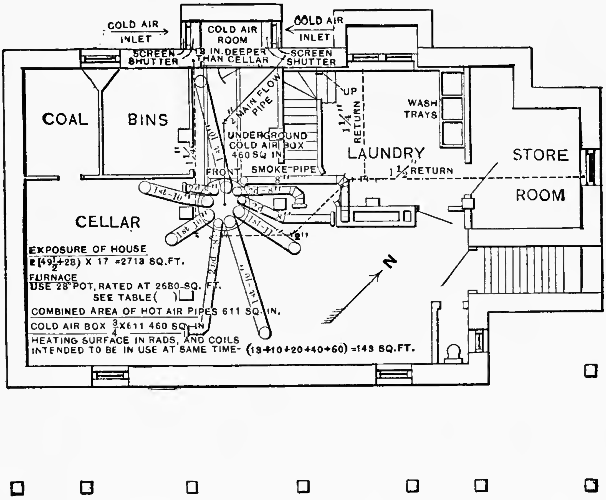


Fig. 32.—Basement Plan (8′ 10″) of a Residence Heated by a Combination System.

HOT WATER VS. HOT AIR.

Owing to the capacity of water to store heat, rooms having radiators are less subject to sudden changes in temperature than those where hot air is used. Ordinarily this is an advantage, but in living rooms which on certain occasions may contain an unusual number of occupants this feature is objectionable. It is seldom noticed that a room has become overheated until the temperature has risen considerably above the normal. Then the radiator valve is closed, but the water continues to give off its stored heat for some time thereafter, which with the heat from the lights and that from the bodies of the occupants makes it difficult to reduce the temperature quickly. The act of closing a register shuts off all the heat at once.

VALVES ON RADIATORS.

One or two radiators should be left without valves to prevent all being shut off at once, which would cause the water in the system to boil. Where the furnace is connected with but one radiator the water must be allowed to circulate through it at all times, whether heat is desired or not.

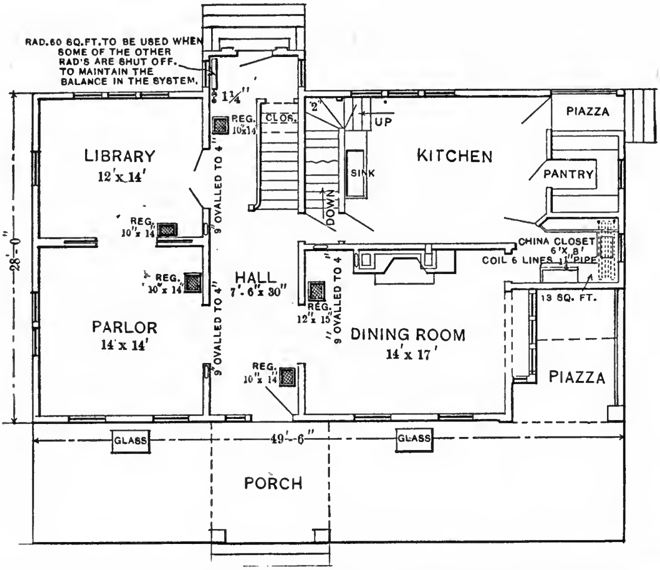


Fig. 33.—First-Floor Plan (9′ 0″) of a Residence Heated by a Combination System.

"BALANCE" OF THE SYSTEM.

One of the difficulties in a hot water combination system is to secure a proper "balance" between the hot water and the warm air, so that they will work harmoniously and one not heat at the expense of the other. It is advisable to place in the hall or other convenient room both a register and a radiator, each of sufficient size to heat the space, so that by using one or the other a proper " balance " may be maintained.

HEATING SURFACE IN FURNACE.

The water heating surface in the furnace may be placed in contact with the fire or suspended above it. In some heaters the water is first brought in contact with the surface in the fire and then ascends through a coil or cast iron section surrounded by the hot gases. The tendency of the water heating surface to deaden the fire with which it is in contact and to greatly diminish the air heating capacity of the furnace limits its use. When the heating surface is in contact with the fire, the water is maintained at a more even temperature than when heated by a coil or section suspended above it. With the latter the heating surface is acted upon chiefly by the radiant heat from the top of the fire, which amounts to little just after firing or until the fresh coal has become ignited. In the meantime the temperature of the water falls. The heating capacity of such surface may be varied to suit conditions. In severe weather by carrying a high fire in contact with the coil or section its capacity may be greatly increased.

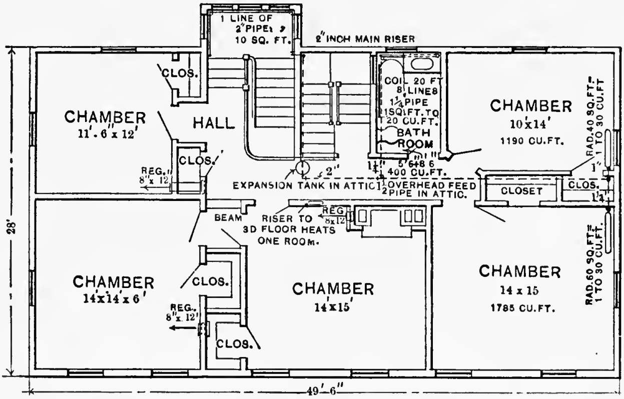


Fig. 34.—Second-Floor Plan (8′ 6″) of a Residence Heated by a Combination System.

When special castings cannot be procured for attaching a hot water combination to a furnace, coils of wrought iron pipe are often used, placed either above or partly in the fire. They are generally made of 1¼ or 1½ inch pipe, according to the radiation supplied. The rating for various types of combination heaters is shown in the following table.

HOT WATER COMBINATION HEATERS.

A few types of combination heaters are illustrated in the following figures:

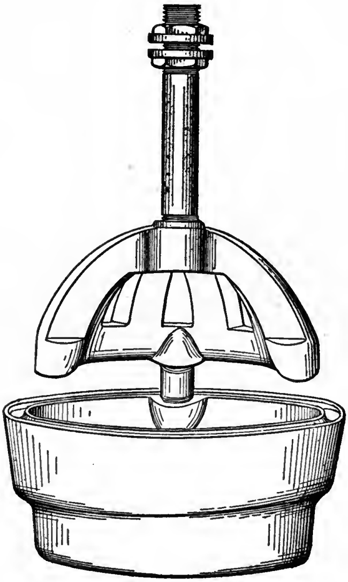


Fig. 35.—Dome Section.

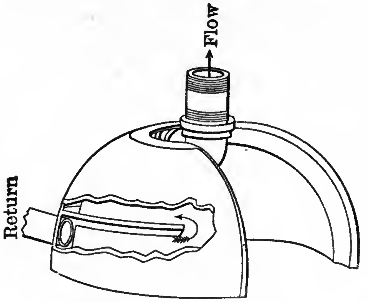


Fig. 36.—Base Section when Used without Ring Section.

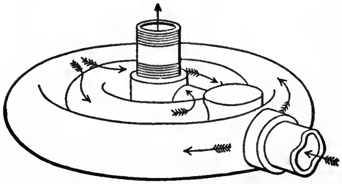


Fig. 37.—Ring Section.

Fig. 35 shows a dome section suspended over the fire. When additional heating capacity is desired one or more ring sections as shown in Fig. 37 are placed above the base section when the design of combustion chamber permits.

Figs. 38 and 39 shows another design of base section and bell section for use above the fire.

Fig. 40 shows a combination heater section designed for use in a brick lined furnace, the hollow castings being inserted around the fire pot in place of fire bricks. The discharge pipes are joined above the fire as indicated.

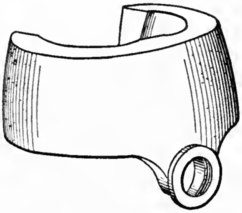


Fig. 38.—Horseshoe Only.

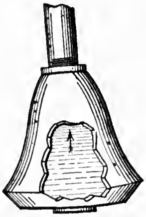


Fig. 39.—Bell Only.

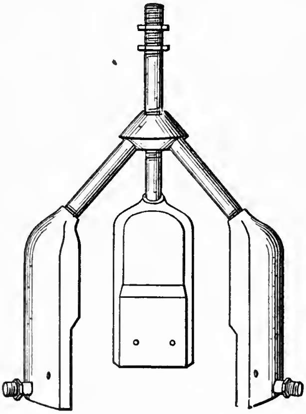


Fig. 40.—Three Long Regular Sections Connected with Pipes and Discs.

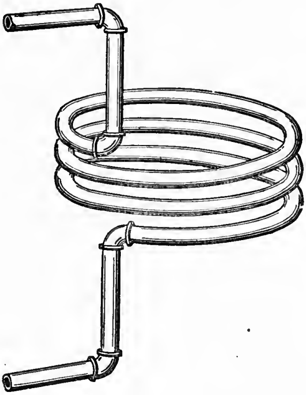


Fig. 41.—Coil Combination Heater for Furnace.

Table VIa.—Showing Capacity of Hot Water Combination Heaters in Furnaces Expressed in the Number of Square Feet of Direct Radiating Surface which May Be Kept at 160 Degrees Temperature per Square Foot of Heating Surface in the Combination Heater.

	Description.	Rating in Square Feet.
A.	Cast-iron sections suspended above the fire	15 to 20
B.	Cast-iron sections in contact with the fire	40 to 60
C.	A. and B. combined	25 to 35
D.	Pipe coil suspended above the fire	20 to 25
E.	Pipe coil buried in the fire	50 to 60
F.	D. and E. combined	30 to 40

DIRECT RADIATING SURFACE.

In estimating the total amount of radiation supplied by the furnace the surface of the supply and return pipes should be added to that in the radiators, unless the pipes are to be covered. In the combination system with open tank sufficient radiating surface should be provided to heat the rooms to 70 degrees in zero weather, with a maximum water temperature not over 190 degrees. This will leave a reasonable margin below the boiling point. If the amount of surface is calculated on the thumb rule basis of cubic space to be warmed the allowances in Table VII will be found safe under ordinary conditions. Of course in determining the amount of surface required for a given room due regard must be had for its exposure, glass surface and the character of its walls.

Table VII.

For rooms with one exposed wall, allow 1 square foot of radiation for 30 to 40 cubic feet of space.

For rooms with two exposed walls, allow 1 square foot of radiation for 25 to 30 cubic feet of space.

For rooms with three exposed walls, allow 1 square foot of radiation for 20 to 25 cubic feet of space.

For bathrooms and small exposed rooms, allow 1 square foot of radiation for 15 to 25 cubic feet of space.

Use maximum or minimum amount of surface given by above rule according to the degree of exposure. For the pressure system use about three-quarters as much surface as with an open tank. For the purpose of permitting pressure and securing hotter water without boiling use a mercury seal rather than a safety valve.

If desired the radiating surface may be based directly on the loss of heat through walls, windows, floors and ceilings. A convenient approximate method is to consider 4 square feet of ordinary wall equivalent in heat transmitting power to 1 square foot of glass; then reduce the exposure of the room to equivalent glass surface by adding to the window area one-quarter the area of the outside walls. Outside doors are to be estimated as equivalent to one-half their area in glass. If the space below or above the room is cold, add to the equivalent glass surface one-twentieth of the area of floor or ceiling. In the case of ordinary cellars or attics in the body of the house it is hardly necessary to add for heat losses through floors or ceilings. The total equivalent glass surface thus obtained divided by 1.8 will give the amount of radiation required with the open tank system. For the pressure system divide by 2.4.

The 1.8 and 2.4 above are deduced as follows: Since the heat given off per square foot of direct radiating surface per hour when placed in rooms at 70° temperature is approximately 150 B. t. u. with hot water and 250 B. t. u. with steam, it follows that with 85 as the heat loss per square foot of equivalent glass surface, E. G. S. $\frac{150}{85} = 1.8$ is the factor for hot water and $\frac{250}{85} = 2.4$ is the factor for steam.

Example computing radiation:

How much hot water radiation is required to heat a room 14 x 16 x 9, exposed 2 sides N. and W. and having 20% glass?

Exposure = 14 + 16 × 9 = 270 square feet.
Glass, 20 per cent = 54 "
Net, wall.......216 "

E.G.S. of net wall = net wall ÷ 4 = 54

Total E.G.S. = actual glass + E.G.S. of net wall = 108
Add 20 per cent for exposure factor = approx. 22
130
Allowance of 10 per cent to provide for quick heating and to cover leakage losses.............................. 26
Total E.G.S. + allowances.................................156

This total 156 ÷ 1.8 as above = 87 square feet.
Ratio = cubic contents of 2016 ÷ 87 = 1 : 23 cubic feet.

To compensate for the increased loss of heat due to winds add at least:

Fifteen to twenty per cent. for rooms having a northerly or westerly exposure.

Ten to fifteen per cent. for rooms having an easterly exposure.

To insure quick warming on cold mornings add at least ten per cent. to the transmission losses. If a room has a large cubical contents compared with the outside exposure, some allowance should be made for bringing the air in the room in addition to the wall losses. The above factors in conjunction with the liberal heat loss allowance of 85 for glass will provide for ordinary air leakage without computing this loss separately.

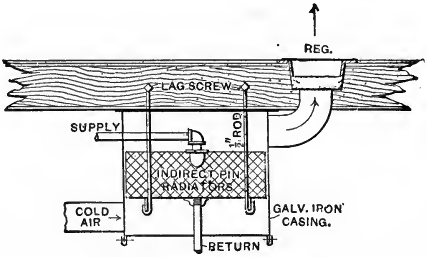


Fig. 42.—**Indirect Stack.**

INDIRECT RADIATING SURFACE.

For indirect heating with pin radiators the sections should have a depth of 10 to 12 inches to thoroughly warm the air. Fig. 42 shows the arrangement of an indirect stack.

To estimate the amount of indirect radiation when the air supply is taken from the furnace add 25 per cent. to the amount of direct radiating surface that would be required. When the air is admitted to the stack directly from out of doors add at least 50 per cent. to the amount of direct radiating surface that would be necessary. With indirect radiation for the first floor allow at least 1¼ square inches to each square foot of radiating surface surface for warm air flue, that is an indirect stack of 100 square feet surface would by this rule require 125 square inches cold air supply and 150 square inches warm air discharge pipe.

HEATING CONSERVATORIES.

For heating conservatories 1¼, 1½ or 2 inch pipes are generally used, run along the wall under the benches. Fig. 24 shows a wall coil. One square foot of radiating surface is, with open tank system, sufficient for 2 square feet of glass. In other words:

1 lineal foot of 1¼-inch pipe will carry $\frac{8}{10}$ square foot of glass.
1 lineal foot of 1½-inch pipe will carry 1 square foot of glass.
1 lineal foot of 2-inch pipe will carry 1¼ square feet of glass.

TAPPING OF RADIATORS.

Hot water radiators are commonly tapped:

1 inch for radiators containing 40 square feet and under.
1¼ inches for radiators containing 40 to 72 square feet.
1½ inches for radiators containing 72 square feet and over.

Unless otherwise ordered indirect radiators are usually tapped 2 inches, then bushed to the desired size.

SIZES OF PIPES.

The following sizes of flow pipes for the amount of radiating surface stated will be found sufficient for ordinary runs:

Table VIII.—Capacity of Hot Water Pipes for Direct and Indirect Radiation.

1-inch pipe will supply 40 square feet of direct radiating surface.
1¼-inch pipe will supply 72 square feet of direct radiating surface.
1½-inch pipe will supply 125 square feet of direct radiating surface, or 80 square feet of indirect radiating surface.
2-inch pipe will supply 225 square feet of direct radiating surface, or 150 square feet of indirect radiating surface.
2½-inch pipe will supply 350 square feet of direct radiating surface, or 240 square feet of indirect radiating surface.
3-inch pipe will supply 500 square feet of direct radiating surface, or 350 square feet of indirect radiating surface.

OPEN TANK VS. PRESSURE SYSTEMS.

The open tank system is the safer. The pressure system with closed tank and safety valve has been superseded by mercury seal systems where there is no safety valve to possibly stick on its seat and which give the advantages of the old fashioned pressure system without its disadvantages. The advantages are smaller radiators and pipes owing to the higher water temperatures that may be carried.

The open tank system is most commonly used. Under certain conditions the water may boil and overflow, but if properly arranged this will do no harm and with ample radiating surface will seldom occur. The surging in the pipes will call attention to the fact that the apparatus is not working properly, and that either more radiation must be turned on or the fire must be checked.

EXPANSION TANK AND CONNECTIONS.

The house tank is sometimes used as an expansion tank, but this is unwise, as in case of boiling rusty water is forced into the tank, rendering the house supply turbid and unfit for use.

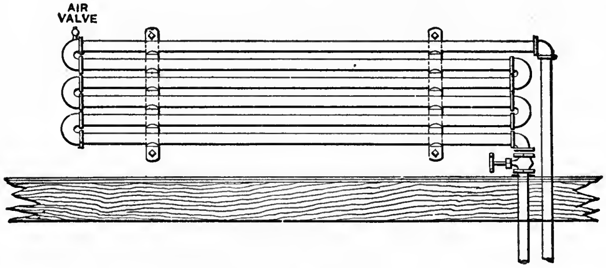


Fig. 43.—Wall Coil.

A separate tank should be used, which may be provided with a ball cock if desired to insure the proper water level being maintained. The expansion pipe must be so connected that the free expansion of the water cannot be interrupted.

Water expands about one twenty-fourth of its volume at 40 degrees when heated to 210 degrees. The expansion tank should have a capacity equal to about one-twelfth that of the entire system. The radiating surface divided by 50 gives the proper capacity of the expansion tank in gallons. Care must be taken to locate the expansion tank where there is no danger from freezing.

In the cheapest work no expansion tank whatever is provided, the system being connected directly with the street service, full city pressure of perhaps 80 pounds or more being maintained on the system. In case of leaks from any cause the damage resulting with such a pressure would be much greater than with either the closed or open tank system.

SYSTEM OF PIPING.

Two systems of piping are commonly employed. In one the mains are run through the basement, taking off supply and return connections to the various risers and connecting the expansion pipe to the return near the heater. Fig. 44 shows a radiator on a two-pipe system.

In the other, known as the "overhead feed," the flow pipe rises directly to the expansion tank, the radiators being connected with the drops or returns, as in Fig. 45, a single pipe serving for both supply and return to radiators on several floors. No air valves are required with this arrangement, since all air escapes from the expansion tank, located at the highest point. Nothing can interrupt the circulation of water through the mains. Fewer pipes and connections are necessary and the circulation is likely to be better than with the two-pipe system. An ordinary expansion tank may be used if desired, connected in the ordinary way and located above the top of the lower feed distributing main, the latter being vented.

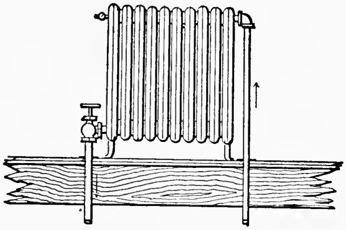


Fig. 44.—Single Valve Radiator Connection.—Two-Pipe System.

STEAM COMBINATION.

Some furnaces may be fitted with a steam heating combination. The advantages claimed for this system are quick heating ability and the use of smaller radiators and pipes than in an open tank system, with resulting economy in space and cost.

Among its disadvantages as compared with hot water may be stated its sensitiveness to changes in the condition of the fire owing to the small amount of water in the system, steam going down quickly with a deadening of the fire.

Unless vacuum valves are used there is no range of temperature in the radiators, as with hot water. With steam the boiling point

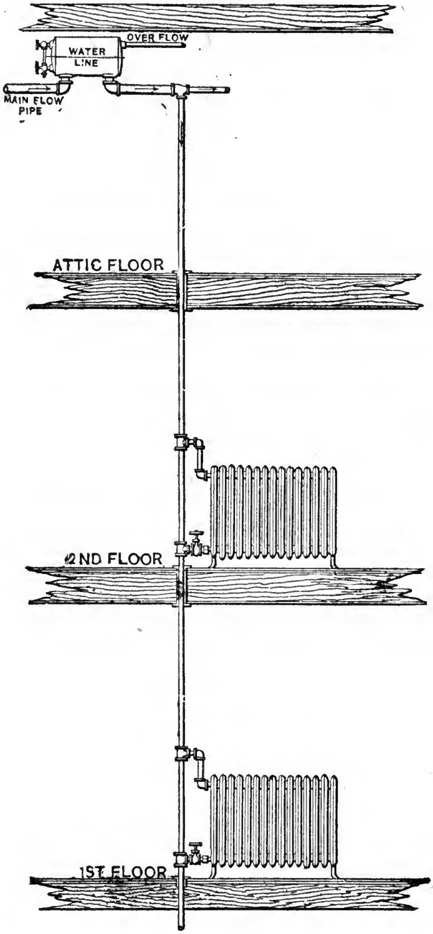


Fig. 45.—Radiator Connections.—Overhead Feed System.

(212 degrees) must be reached before the radiators become hot. The small water capacity involves frequent filling and damage is likely to result from inattention. The apparatus with its additional

valves and fittings is less simple than the hot water combination. In estimating the steam radiating surface allow about six-tenths as much surface as would be required using hot water radiators with the open tank system.

TABLE IX.—Welded Pipe, Steel or Iron.

1¼-inch and below, butt welded, proved to 300 pounds per square inch, hydraulic pressure.
1½-inch and above, lap welded, proved to 500 pounds per square inch, hydraulic pressure.

TABLE OF STANDARD SIZES.

Nominal inside diameter.	Actual outside diameter.	Thickness.	External circumference.	Length of pipe per square foot of outside surface.	Actual internal area.	External area.	Length of pipe containing 1 cubic foot. 1 cubic foot = 7½ gallons.	Weight per foot of length.	No. of threads per inch of screw.
Ins.	Ins.	Ins.	Ins.	Ft.	Ins.	Ins.	Ft.	Lbs.	
⅛	0.405	0.068	1.272	9.434	0.057	0.1288	2,500	0.24	27
¼	0.54	0.085	1.696	7.075	0.104	0.229	1,383.28	0.42	18
⅜	0.675	0.091	2.121	5.658	0.191	0.3578	754.322	0.56	18
½	0.84	0.109	2.639	4.547	0.304	0.554	473.84	0.84	14
¾	1.05	0.113	3.299	3.638	0.533	0.866	270.016	1.12	14
1	1.315	0.134	4.131	2.904	0.861	1.358	167.246	1.67	11½
1¼	1.66	0.140	5.215	2.301	1.496	2.164	96.257	2.24	11½
1½	1.9	0.145	5.969	2.01	2.036	2.835	70.727	2.68	11½
2	2.375	0.154	7.461	1.608	3.356	4.430	42.908	3.61	11½
2½	2.875	0.204	9.032	1.329	4.78	6.492	30.337	5.74	8
3	3.5	0.217	10.996	1.091	7.383	9.621	19.504	7.54	8
3½	4	0.226	12.566	0.955	9.887	12.566	14.567	9	8
4	4.5	0.237	14.137	0.849	12.73	15.904	11.312	10.66	8
4½	5	0.246	15.708	0.764	15.961	19.635	9.022	12.34	8
5	5.563	0.259	17.475	0.687	19.986	24.301	7.205	14.5	8
6	6.625	0.28	20.813	0.577	28.89	34.472	4.984	18.76	8
7	7.625	0.301	23.955	0.501	38.738	45.664	3.717	23.27	8
8	8.625	0.322	27.096	0.443	50.027	58.426	2.876	28.18	8
9	9.625	0.344	30.238	0.397	62.73	72.760	2.290	33.7	8
10	10.75	0.366	33.772	0.355	78.823	90.763	1.827	40.06	8

HEAT GIVEN OFF BY DIRECT RADIATORS.

Cast iron radiators with low pressure steam transmit approximately 250 heat units per square foot of surface per hour. Hot water radiators on open tank system transmit about 150 heat units per square foot of surface per hour.

A rate of heat emission of 1.6 B.T.U. per square foot of direct radiating surface per hour per degree difference in temperature between that of the heating medium inside the radiator and that of the air in the room is a fair average value.

CHAPTER IV.

AIR, HUMIDITY, AND VENTILATION.

COMPOSITION AND IMPURITIES OF THE ATMOSPHERE.

Atmospheric air is a mixture composed of about 79 parts of nitrogen and 21 parts of oxygen by volume, and in 10,000 volumes there are from 3 to 5 volumes of carbonic-acid gas.

This gas in moderate quantities is not harmful, but it is nearly always "found in bad company." It is mixed with the organic matter exhaled from the lungs and thrown off by the skin. In rooms having no special provision for ventilation the air must be breathed again and again, constantly becoming more foul. The porportion of carbonic acid in the air may be readily determined by several methods. It therefore forms the most convenient measure of the vitiation, since in occupied rooms the amount of harmful organic matter in the air is found to correspond with the proportion of carbonic acid. This CO_2 index or standard has long been commonly used, but the doctors of hygiene are now inclining to a conviction that high room temperature and high humidity are more to be guarded against than a slight excess of CO_2 in the atmosphere of occupied rooms. See pages 90 to 102.

When the number of parts of the latter exceeds 6 to 8 in 10,000 of air, the room seems close to one entering from out of doors and a slight odor is perceptible. By the process of dilution the air may be kept, within limits, at any desired degree of wholesomeness. To maintain in a room continuously occupied for a number of hours an atmosphere in which the carbonic acid shall not exceed 6 parts in 10,000, an air supply of about 50 cubic feet per minute per occupant must be admitted. To accomplish this, much larger heating apparatus and flues than customary would be required. The public has not yet been educated to a full appreciation of what good ventilation really is. The commonly accepted standard for schools is 30 cubic feet of fresh air supplied per minute per occupant. This allowance will keep the carbonic acid down to about 7.4 parts in 10,000 of air.

Churches generally have at least 50 per cent. more space per occupant than schools, say, 300 cubic feet, and are occupied for much shorter periods. Therefore a smaller air supply is considered sufficient for such buildings.

An allowance of 20 cubic feet per minute is common, and some authorities recommend 1000 cubic feet per person per hour. In halls, which generally have a greater number of seats to a given space than the above classes of buildings, the air supply should be based on a 20 cu. ft. per min. per capita basis, provided this allowance will not change the air so frequently that uncomfortable drafts will be produced. In standard size school rooms the air is changed, on the 30 cubic feet per capita basis. once in 7 minutes.

This is about as rapid a change as can be recommended with inlets and outlets as commonly arranged.

In halls having perhaps only 100 cubic feet of space per occupant, unless the openings were very carefully arranged, an air supply of 20 cubic feet each would be likely to give trouble from drafts.

HUMIDITY.

The amount of moisture or water vapor contained in the atmosphere is expressed in terms of Actual Humidity, meaning the number of grains of water vapor per cubic foot of space, or Relative Humidity, meaning the ratio expressed in hundredths, between the weight of moisture in the air and that contained in an equal volume of saturated air at the same temperature. The Dew Point is the point at which the saturation is complete, when the vapor can no longer be held in suspension, but is deposited in the form of dew.

The effect of humidity on bodily comfort is marked, a person feeling far more comfortable on a hot, dry day, for example, than on a muggy day with a much lower temperature. It is a well-known fact that evaporation is accompanied by cooling, which accounts for the greater comfort experienced when the evaporation from the skin is rapid, as in a dry atmosphere.

Table X.

Box says that when the air contains about—

85 per cent. water vapor we consider it	damp.
65 per cent. water vapor we consider it	moderately dry.
50 per cent. water vapor we consider it	dry.
35 per cent. water vapor we consider it	very dry.
25 per cent. water vapor we consider it	extremely dry

Billings states that no discomfort is experienced in an atmosphere with a relative humidity of 30 to 40, and that at the Boston City Hospital no ill effects were observed with a relative humidity of 15 to 21.

The air supplied by furnaces is moistened to a very limited extent by means of the water evaporating pan. The capacity of air to absorb moisture increases rapidly with rise in temperature. For example, air at 72 degrees can absorb four times as much moisture as air at 32 degrees. We commonly speak of air absorbing moisture; we really mean space.

Table XI.—The Weight of Water Vapor per Cubic Foot of Saturated Space at Different Temperatures.

Temperature.	Weight of vapor in grains per cubic foot.	Temperature.	Weight of vapor in grains per cubic foot.
0	0.54	50	4.09 = 4 approx.
10	0.84	60	5.76
15	0.99 = 1 approx.	70	7.99 = 8 approx.
20	1.30	80	10.95
30	1.97 = 2 approx.	90	14.81
40	2.88	100.	19.79 = 20 approx.

1 pound avoirdupois = 7,000 grains.

Approximately 1,000 heat units are required to evaporate a pound of water.

Since the moisture that may exist in a given space increases rapidly with a rise in temperature, as shown in Table XI, to maintain even a moderate relative humidity a great quantity of water and a considerable amount of fuel will be required to evaporate it.

Take, for example, an eight or nine room house having an air supply of about 800 cubic feet per minute = 48,000 cubic feet per hour. Outside temperature, 30 degrees.

Suppose the air entering the furnace has a relative humidity of 65. Now 1 cubic foot of saturated air at 30 degrees temperature will contain approximately 2 grains of water vapor, hence with relative humidity of 65 per cent., 1 cubic foot will contain $\frac{65}{100} \times 2 = 1.30$ grains. Each cubic foot of air entering at 30 degrees temperature will, on being heated to 70 degrees, expand to 1.08 cubic feet. A cubic foot of saturated air at the latter temperature will contain approximately 8 grains of moisture, or with relative humidity 50, for example, will contain 4 grains.

Since the 48,000 cubic feet of air entering the furnace at 30 degrees becomes expanded to $48{,}000 \times 1.08 = 51{,}840$, at 70 degrees temperature, we have as the amount of water which must be evaporated per hour to maintain a relative humidity of 50 in the air at 70 degrees

51,840 cubic feet $\times\ 4 - 48{,}000 \times 1.3 = 154{,}960$ grains $= 22.14$ pounds.

As about 1000 heat units are required to evaporate 1 pound of water, 22,140 heat units will be required per hour, and assuming that 8000 heat units are utilized per pound of coal burned, we have $\frac{22{,}140}{8000} = 2.77$ pounds coal per hour $= 66\frac{1}{2}$ pounds coal per day required merely to evaporate the water.

EXPANSION OF AIR AND ABSOLUTE TEMPERATURE.

Air expands and contracts with changes in temperature according to a known law—viz., for each degree rise or fall in temperature from 32 degrees F. air expands or contracts $^1/_{491}$ of its volume at that temperature. If a cubic foot of air be heated through 491 degrees from 32 degrees, or to 523 degrees, it will double in volume. On the other hand, if a cubic foot of air be cooled through 491 degrees from 32 degrees, or to 459 degrees below zero, it will theoretically contract $\frac{491}{491}$ of its original bulk, or will entirely disappear. This point, 459 degrees below zero, or more accurately 459.4 degrees, is known as absolute zero, and is the point from which the expansion of air is reckoned in determining its relative volume at different temperatures, the volume being proportional to the absolute temperature. For convenience in making ordinary calculations 460 degrees F. below zero may, with sufficient accuracy, be considered absolute zero. Hence the absolute temperature of a body is equivalent to 460 degrees plus its Fahrenheit temperature. Suppose, for example, we wish to determine how much space 1 cubic foot of air entering a furnace at 0 degree F. will occupy when heated to 140 degrees

F. Since the volume varies in proportion to the absolute temperature, we have:

$$\left.\begin{array}{l}\text{Absolute temperature of air at } 0^\circ \text{ F} = 0^\circ + 460^\circ = 460 \\ \text{Absolute temperature of air at } 140^\circ \text{ F} = 140^\circ + 460^\circ = 600\end{array}\right\} \text{Volume at } 0^\circ \text{ is to volume at } 140^\circ \text{ as 460 is to 600.}$$

Hence, volume at 140 degrees $= \frac{600}{460} \times$ volume at 0 degree; volume at 140 degrees = 1.3 cubic feet.

Table XII.—The Approximate Volume to Which 1 Cubic Foot of Air at 0° Will Expand When Heated to the Temperatures Stated in the Table. Volume of Air at 0° = 1 Cubic Foot.

Volume when heated to— Degrees.	Cubic feet.	Volume when heated to— Degrees.	Cubic feet.
10	= 1.02	110	= 1.24
20	= 1.04	120	= 1.26
30	= 1.06	130	= 1.28
40	= 1.09	140	= 1.30
50	= 1.10	150	= 1.33
60	= 1.13	200	= 1.44
70	= 1.15	300	= 1.65
80	= 1.17	400	= 1.87
90	= 1.20	500	= 2.09
100	= 1.22		

Table XIII.—The Weight of Dry Air per Cubic Foot at Different Temperatures.

Temperature. Degrees F.	Weight of a cubic foot in pounds.	Temperature. Degrees F.	Weight of a cubic foot in pounds.
0	0.0864	112	0.0694
12	0.0842	122	0.0682
22	0.0824	132	0.0671
32	0.0807	142	0.0660
42	0.0791	152	0.0649
52	0.0776	162	0.0638
62	0.0761	172	0.0628
72	0.0747	182	0.0618
82	0.0733	192	0.0609
92	0.0720	202	0.0600
102	0.0707	212	0.0591

THE FLOW OF AIR IN PIPES.

The resistance to the flow of air through pipes may be approximately stated as follows:

The resistance is proportional to the surface over which the air passes and to the square of its velocity. In other words, the resistance varies directly with the length of the pipe and the square of the velocity and inversely as the diameter. With pipes of the same length and air traveling at the same velocity the resistance will be inversely proportional to the diameter.

VELOCITY OF AIR IN FLUES.

The velocity of air in a flue is governed by its hight and the difference between the inside and outside temperature. Suppose we have a flue 1 square foot in area and of hight h, represented in Fig. 46.

The air in the flue is balanced by a column of colder outside air of hight H, leaving an unbalanced force represented by the hight $(h - H)$, tending to produce a velocity at the base of the flue equivalent to that developed by a body falling freely through a distance represented by the hight $(h - H)$.

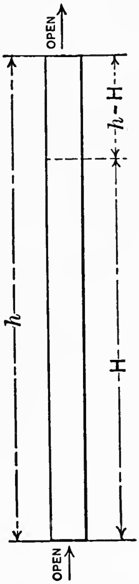


Fig. 46.—Flue Diagram.

The velocity acquired by such a body, neglecting friction, is expressed by the equation

$v = \sqrt{2gh}$ . . . . (*a*)

Here v = velocity in feet per second, g = the acceleration in feet per second due to gravity, = 32.2 feet, h = the hight through which the body falls—in this case represented by $(h - H)$.

Now let

w_O = the weight per cubic foot of outside air.
w_F = the weight per cubic foot of air in the flue.
t_O = the absolute temperature of the outside air = Fahrenheit temperature + 459.4°.
t_F = the absolute temperature of the air in the flue = Fahrenheit temperature + 459.4°.

We have seen that the velocity at which the air enters the base of the flue is expressed by

$$v = \sqrt{2g\,(h - H)} \tag{b}$$

Now since the columns of air represented by h and H balance each other we have weight of column h = weight of column H; *or,*

$$h\,w_F = H\,w_O \quad \ldots\ldots (c) \quad \text{hence} \quad H = \frac{h\,w_F}{w_O} \tag{d}$$

The density of the air, or its weight per cubic foot, varies inversely as the absolute temperature; hence we may substitute for $\frac{w_F}{w_O}$, $\frac{T_O}{T_F}$ equation (d) becoming $H = h\,\frac{T_O}{T_F}$ .... (e)

Substituting this value of H in (b) we have

$$v = \sqrt{2g\left(h - h\,\frac{T_O}{T_F}\right)} = \sqrt{2gh\left(\frac{T_F - T_O}{T_F}\right)} \tag{f}$$

Now the weight of air leaving the flue must be equal to the weight of air entering—that is,

Velocity of air leaving flue × w_F = velocity of air entering flue × w_O .... (g)

Velocity of air leaving flue =

$$\frac{\text{velocity of air entering flue} \times w_O}{w_F} \tag{h}$$

Or, since the weight varies inversely as the absolute temperature,

Velocity of air leaving flue =

$$\frac{\text{velocity of air entering flue} \times T_F}{T_O} \tag{i}$$

Equation (f) gives the velocity of the air entering the flue, hence

Velocity of air leaving or passing through the flue =

$$\frac{T_F}{T_O}\sqrt{2gh\left(\frac{T_F - T_O}{T_F}\right)}$$

Allowing 50 per cent. for friction, and substituting the value of $g = 32.2$, the velocity in feet per minute in the flue is

$$V = 240 \frac{T_F}{T_O} \sqrt{h \left(\frac{T_F - T_O}{T_F} \right)}$$

from which the following table is calculated:

Table XIV.—The Approximate Velocity of Air in Flues of Various Hights

Outside temperature 32 degrees. Allowance for friction 50 per cent. in flue one square foot in area.

Hight of flue. Feet.	Excess of temperature of air in the flue over that out doors.										
	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	120°	140°
	Velocity of air in feet per minute.											
5	77	111	136	159	179	199	216	234	250	266	296	325
10	109	156	192	226	254	281	306	330	354	376	418	460
15	133	192	236	275	312	344	376	405	432	461	513	565
20	154	221	273	319	359	398	434	467	500	532	592	650
25	173	248	305	357	402	445	485	522	560	595	660	728
30	189	271	334	390	440	487	530	572	612	652	725	798
35	204	293	360	423	475	527	574	620	662	705	783	862
40	218	311	386	452	508	562	612	662	707	753	836	920
45	231	332	408	478	538	597	650	700	750	800	887	977
50	244	350	432	503	568	630	685	740	790	843	935	1030
60	267	383	473	552	622	690	750	810	865	923	1023	1125
70	289	413	510	596	671	746	810	875	935	995	1105	1215
80	308	443	545	638	717	795	867	935	1000	1065	1182	1300
90	327	470	578	678	762	845	920	990	1060	1130	1252	1380
100	345	495	610	713	802	890	970	1045	1118	1190	1323	1455

The volume of air in cubic feet per minute discharged by a flue equals the velocity in feet per minute multiplied by the area in square feet. Knowing any two of these terms, the third may be readily found.

$$\text{Velocity} = \frac{\text{volume}}{\text{area.}} \qquad \text{Area} = \frac{\text{volume}}{\text{velocity.}}$$

Example.—Find the area of a flue 20 feet high that will discharge 3000 cubic feet per minute, when the excess of temperature in the flue over that out doors is 40 degrees.

Opposite 20 in left hand column and under 40 on upper line is the number 319, representing the velocity in feet per minute. The volume $3000 \div 319 = 9.4$ square feet, the required area. In estimating the effective hight of a warm air flue from a furnace, consider the flue to begin 2 feet above the grate.

Table XV.—Wind Velocity

Weisbach defines winds as follows:

Scarcely appreciable wind	90 feet per minute equals 1.02 miles per hour.
Very feeble wind	180 feet per minute equals 2.04 miles per hour.
Feeble wind	360 feet per minute equals 4.1 miles per hour.
Brisk wind	1080 feet per minute equals 12.3 miles per hour.
Very brisk wind	1800 feet per minute equals 20.4 miles per hour.
High wind	2700 feet per minute equals 30.7 miles per hour.
Very high wind	3600 feet per minute equals 40.1 miles per hour.
Violent wind	4200–5400 feet per minute equals 47.8–61.4 miles per hour.
Hurricane..	6000 feet per minute equals 68.1 miles per hour

The United States Weather Bureau defines a gale as a wind blowing 40 miles per hour.

IMPORTANCE OF VENTILATION.

Under modern conditions, with buildings having a tight construction and a relatively small accidental in-leakage of air, the question of providing a sufficient supply of fresh air and the removal of foul air, becomes an important one, especially in the case of rooms which are crowded or occupied continuously for many hours, with particular reference to moving picture theatres and buildings of similar character.

CAUSES OF ATMOSPHERIC VITIATION.

The accumulation of carbon dioxide is the most commonly mentioned cause of vitiation. When it is realized that this gas is increased over a hundred fold in the air passing through the lungs, it is not surprising that this component of the atmosphere accumulates rapidly in occupied rooms.

An interchange of gases takes place in the lungs, called the respiratory exchange, oxygen passing from the air to the body and carbon dioxide from the lung cells to the air about to be exhaled. The air discharged from the lungs is saturated with water vapor.

In proportion to their weight children give off about twice as much carbon dioxide as adults, hence the importance of adequate ventilation in rooms occupied by little ones. Some authorities state that the amount of air breathed may be averaged as 15 cubic feet per hour, and that 0.6 cubic feet of carbon dioxide is exhaled per hour by a person in repose; that the vapor eliminated by a person at rest is about 1½ oz. per hour, about one-fourth of the vapor elimination coming from the lungs.

A great deal of effluvia or organic matter is carried through the pores with the perspiration. It gives a foul odor to crowded or poorly ventilated rooms. The more active the perspiration the more free the effluvia elimination. An assembly of 1000 adults is said to give to the air nearly 100 lbs. of perspiration vapor per hour. Prof. Woodbridge states that "high humidity increases the amount of decomposable matter present in an occupied enclosure, it hastens its decomposition, it accelerates its diffusion and intensifies its putrefying odor."

As to the accumulation of carbon dioxide in occupied rooms to which atmosphere vitiation is commonly attributed, the late A. R. Wolff, of New York, stated: "It is not the presence of the carbon dioxide itself which causes injury, but the bad company associated with its presence. The fact is that besides the carbon dioxide exhaled with the expired air there are also organic matters and aqueous and other vapors, and at the same there are given off from the pores of the skin organic secretions and moisture, all of which taken together, and possibly acted upon and made more detrimental in effect by the heat of the room, vitiate the atmosphere and jointly are the sources of the trouble. . . . They go hand in hand with the amount of carbon dioxide in the room.

As to the degree of vitiation, the relative purity of the atmosphere is generally expressed in the number of parts by volume of carbonic-acid gas contained in 10,000 parts or volumes of air. The proportion of this gas contained in the atmosphere may be easily determined by several methods, and it affords a fairly good index of the relative number of micro-organisms present and of the efficiency of ventilation."

In crowded rooms with the usual accompanying high temperatures the water-vapor from the lungs and the perspiration vapor soon saturate the air, and it is to this combination of temperature and humidity that some writers attribute most of the discomfort experienced. The author concurs in this view.

That moisture is present in crowded rooms in cold weather is evidenced by the condensation on windows. When it is considered that this moisture is chiefly from exhalations from the lungs and the elimination from the bodies of those present, it would seem evident that such a component of the atmosphere must not only produce discomfort but be positively harmful.

Macfie, in his work, "Air and Health," says: "Air containing merely the carbon dioxide and moisture usually contained in vitiated air will not produce the effect of vitiated air, therefore must contain an additional constituent. This additional constituent, though undetected by chemists, is probably detected by the nose for it is well known that air is oppresive and harmful, not so much in proportion to the amount of carbon dioxide and moisture it contains as in proportion to its smelliness. The very fact that the nose is so sensitive to such odors would seem to suggest their harmfulness."

In addition to the carbonic-acid gas, the effluvia and the humidity mentioned, which affect the comfort and well-being of persons, are the dusts to which Dr. T. Mitchell Prudden's little book, "Dust and Its Dangers," is devoted. Outer air contains, of course, more or less dust which, when admitted to a building tends to settle. Dr. Prudden observes "that even ordinarily efficient systems of ventilation do not carry off any considerable proportion of the dust particles from closed, still rooms, . . . and that when, by a system of forced ventilation, we cause large volumes of dust-laden air from out-of-doors to pass through them, we are actually, so far as micro-organisms are concerned, cleansing the air and sending it out much freer from germs than when it entered, these having slowly settled as the air makes its way from the entrance to the exit of the ventilating openings." He says:

"When we consider the comportment of dust particles in closed rooms, we see at once that the great renovating and cleansing agencies which are so efficient out-of-doors are, except on special occasions, absent, namely, the winds and strong air currents and the more or less frequent and prolonged wettings. . . . A rainfall to a certain extent tends to free the air of its germs by washing them down. . . ."

Dr. Prudden points out that "we should always remember that bacteria do not become detached from the surfaces or materials on which they grow or are lodged while these are in a moist condition." He remarks: "Ventilation is slowly becoming recognized as important, but the removal of dust, which in crowded places is very liable to be infectious, is not systematically attended to." The most obvious means to prevent the accumulation of dust within enclosures is to remove it from the entering air.

We have briefly considered the "causes of atmospheric vitiation." Now as to the effect on health, "the doctors disagree."

EFFECTS OF FOUL AIR ON HEALTH AND COMFORT.

Billings observes in "Ventilation and Heating" that where any room is occupied by human beings there is a definite, unpleasant animal or musty odor, perceived by a person whose sense of smell is of the usual acuteness and who enters from the fresh outer air, the continued breathing of the air producing such odor will be injurious to health."

The late Mrs. E. H. Richards of the Massachusetts Institute of Technology states in her book, "Air, Water and Food," "That a permanent or habitual lowering of oxygen in inspired air must be harmful will be readily seen from a consideration of the office of this gas in the body. (To Lavoisier and Laplace we owe the knowledge that animal heat is derived from a process of combustion. . . .)

"By the union of the oxygen with the substance found in the tissues and brought to them by the circulating fluids of the body from digested food, the heat necessary for the life and work of the body is produced. This heat is needed to keep the tissues at the temperature at which they can best accomplish their work, to give mechanical power for the involuntary action of heart and lungs for the process of assimilation and to furnish the energy for all voluntary work and thought."

While the harmful effect of foul air may not be immediate other than its effect on one's comfort or mental acuteness, it is generally conceded that frequent and protracted exposure to such air, as in the case of poorly ventilated school buildings, results physiologically in a lowering of the vitality of the occupants, rendering them more susceptible to disease and, considered economically, results in a lessened efficiency on the part of both pupils and teachers.

Playfair asserts that, in modern hygiene, "nothing is more conclusively shown than the fact that vitiated atmospheres are the most fruitful sources of disease."

Tuberculosis and pneumonia are most prevalent among persons living or working in unventilated rooms. These diseases are caused by specific bacteria, which for the most part gain access to the air passages by adhering to particles which are inhaled.

Macfie, in his work, "Air and Health," says: "Any one who compares his power of mental work in a pure and in a carbonic-acid-laden atmosphere, even if the latter be dry and cool, will find in the latter a considerable diminution.

He says: "Does such vitiated air as is ordinarily breathed in human habitations cause ill health apart from the infectious germs or infectious material it may contain? . . . It is, of course, almost universally believed nowadays that indoor air rendered impure by respiration and combustion is harmful to health. To bad air we attribute most of the anaemia, the pallor, the neurasthenia, the general ill health of slum dwellers and factory workers and most persons engaged in sedentary indoor occupations."

As to the effect of dust, Dr. Prudden says:

"Very moderate amounts of dust particles in sensitive persons cause such a degree of irritation of the respiratory organs as either to deprive them of robust health or predispose them to the acquirement of various diseases which with unirritated lungs they would readily resist.

As to the bacteria . . . there are unfortunately a few species which, when they once find lodgment in one place or another in the organs of respiration, may grow and multiply, and successfully resisting all the protective agencies of the body, set up distinct and persistent and even fatal disease. Those forms of bacteria which can, or in these regions commonly do this, are insignificant in number in comparison with the harmless species with which dust is usually swarming. But few as they are they have an extreme significance. If it were not for these few species of disease-producing bacteria, most people could perhaps afford to be as indifferent as they are to dust and its dangers. . . ."

It has been pointed out among the causes of atmospheric vitiation and discomfort that high temperature and humidity have much to do with the oppressiveness of the atmosphere in occupied spaces. In this connection Dr. Henry Mitchell Smith of Brooklyn, N. Y., in a paper read before the Brooklyn Medical Society, says:

"Records of the temperature in a large number of houses showed . . . that it commonly ranged from 72 to 76°, and at times, in very cold weather, 78° F. was recorded. Nevertheless . . . rooms felt chilly when the recorded temperature indicated that they were far too hot. It was often hard to believe that the temperature was above 68° when it was actually 72° and 74°.

It was at once apparent that some unrecognized factor was responsible for this discrepancy between the temperature recorded by the thermometer and one's sensations. Moreover, it was found that the colder the weather the higher was the average temperature maintained indoors. The reason for this is the insufficient amount of moisture in our rooms in proportion to the temperature (low relative humidity). The colder the weather the lower will be the indoor relative humidity.

"The point to be emphasized is that every time we step out of our houses during the winter season we pass from an atmosphere with a relative humidity of about 30 per cent. into one with a relative humidity of an average of 70 per cent. Such a sharp and violent contrast must be productive of harm, particularly to the delicate mucous membranes of the upper air passages. Watery vapor what we term moisture, is as much a part of the air as is oxygen; absolutely dry air does not exist in nature.

The skin and mucous membranes of the respiratory passages are the principal sufferers, since these tissues are always kept moist with their own secretions; and from them water is freely abstracted to satisfy this large saturation deficit.

A moment's consideration shows that the prevailing practice of depending upon the thermometer as the sole guide in the heating of buildings is not only inadequate and unscientific, but it is often misleading. It is not sufficient to know only the temperature if we desire either comfort or health, for the same temperatures produce varying sensations of warmth or cold, depending upon the relative humidity at the time existing.

It is unscientific and arbitrary to lay down a fixed temperature as a standard for living or sleeping rooms unless the relative humidity is indicated as well.

"Records from steam-heated apartments showed that the relative humidity was sometimes as low as 25 per cent., with a temperature of 78° during a period of very cold weather. The high temperature is necessitated by the chilling of the body by the increased evaporation, evaporation being essentially a cooling process."

"Thermostatic temperature control will not fill the requirement, for a constant temperature is constant in its effect only if accompanied by a constant relative humidity. Moreover, properly moistened indoor atmosphere lacks all the oppressive dry feeling so characteristic of the average artificially heated room. The quieting effect of such an atmosphere is striking."

It was satisfactorily proved that one may live during the coldest weather with perfect comfort in a room at 65° F. where the relative humidity is kept at about 60 per cent. During the experiments upon the sensations produced by different percentages of saturation, and in order to obtain the opinion of persons having no knowledge of the existing conditions, one room was equipped with a moistening apparatus and the temperature kept at 65° to 68°, with a relative humidity of about 60 per cent. An adjoining room, without a moistening apparatus and heated by an ordinary steam radiator, had an average temperature of 72° to 74°, with a relative humidity of 30 per cent. In every instance and without at all knowing what the temperatures were in the two rooms, the opinion was unhesitatingly expressed and the first room was several degrees warmer than the second.

It is inconceivable that with otherwise perfect means of heating, provision for producing sufficient mosture to maintain a higher relative humidity should have been so disregarded in all but those elaborate systems applicable only to large halls and public buildings.

As to desirable and practical relative humidities in rooms occupied in winter by persons in health, taking into consideration the cost of maintaining a high relative humidity in cold weather and the trouble from condensation on windows. The author is inclined to favor a range from 40 to 50 per cent., according to the weather, rather than the higher relative humidity mentioned in Dr. Smith's paper, viz., 60 per cent. As to condensation on windows, this will occur during cold weather when the indoor relative humidity is 40 per cent., and even somewhat less. When double windows are used, as is common in northern latitudes, there is little or no trouble from condensation.

The improved physical conditions of teachers and pupils in moving from inadequately ventilated school buildings to those equipped with modern and efficient systems is a well-known and admitted fact. Scientific tests have been conducted which have proved these facts very conclusively.

In regard to dwellings, even though there be no method of ventilation provided, the mere abundance of space per occupant secures a certain air change, owing to the fact that no partitions, floors or ceilings are perfectly tight, hence the greater the space per occupant the greater the surface of surrounding walls, etc., and the greater the accidental air leakage, or spontaneous ventilation, as some put it.

As an example showing the results of improved ventilation, a paper by Prof. C.-E. A. Winslow calls attention to the operating room of the New England Telephone & Telegraph Co., at Cambridge, Mass., a long room having a capacity of 30,000 cu. ft., extending from front to back of a business block. Fifty or sixty women are employed in this room as operators. During the warmer months no difficulty has ever been experienced in ventilating the room by means of large windows at each end and by the use of electric fans. In winter, however, it was impossible to secure adequate natural ventilation without undue exposure to drafts.

In the spring of 1907 a simple but efficient system of artificial ventilation was installed. . . . A marked improvement in the comfort and general condition of the operators followed this change and the betterment was sufficiently marked to show itself in a notably greater regularity of work.

Statistics collected and tabulated show that prior to the installation of the ventilating system for the three winter months, January, February and March, inclusive, 4.9 per cent. of the force was absent in 1906 and 4.5 per cent. in 1907. With the ventilating system in use the absence for the same months in 1908 fell to only 1.9 per cent., a striking reduction.

NECESSITY FOR VENTILATION.

Having discussed the "causes of atmospheric vitiation" in occupied spaces and the "effects of foul air on health and comfort" it would appear that the necessity of ventilation is obvious.

Perhaps nothing has focussed the attention of the general public on the necessity of fresh air so much as the crusade now being waged against tuberculosis. Dr. Woods Hutchinson, in his book "Preventable Diseases," brings out in a most vivid manner the wonderful changes wrought in the prevention and treatment of this disease. He says: "Fifty years ago belief was that consumption and all its attendant miseries were chiefly due to exposure to cold. Now we know that, on the contrary, abundance of pure, fresh air is the best cure for the disease, and foul air and overcrowding is its chief cause. An almost equally complete aboutface has been executed in regard to pneumonia.

"This much we are certain of already: that the majority of so-called 'colds' have little or nothing to do with exposure to a low temperature, that they are entirely misnamed, and that a better term for them would be 'fouls'. . . . The best place to catch them is not out of doors, or even in drafty hallways, but in close, stuffy, infected hotel bedrooms, sleeping cars, churches and theatres.

"The frequency of colds in winter is chiefly due to the fact that, at this time of year, we crowd into houses and rooms, shutting the doors and windows in order to keep warm, and thus provide a ready-made hothouse for the cultivation and transmission from one to another of the influenza and other bacilli.

"At the same time, we take less exercise and sit far less in the open air, thus lowering our general vigor and resisting power and making us more susceptible to attack. Those who live out-of-doors, winter and summer, and who ventilate their houses properly even in cold weather, suffer comparatively little more from colds in the winter time than they do in the summer."

Dr. Hutchinson advises "living and sleeping as much as possible in the open air. This helps in several different ways: first, by increasing the vigor and resisting power of our bodies; second, by helping to burn up clean and rid our tissues of waste products which are poisons if retained; third, by greatly reducing the risks of infection."

He advises us to learn to sit or sleep in a gentle current of air all the time we are indoors.

Macfie, in his book, observes: "All the writers on ventilation assume that ventilation which causes any perceptible motion of cool air is not permissible. But why? Simply because the unnatural habits of so-called civilized peoples render them unduly sensitive to draughts; and, through erroneous reasoning, cold air and draughts are considered dangerous."

On the other hand Billings says: "We may write and talk as much as we please about the horrors of bad air and the importance of good ventilation, but we shall never induce people to sit in cold draughts and shiver for the sake of pure air."

If the people at large could be educated to sit in perceptible currents of warm air—not cold draughts by any means—the work of heating and ventilating engineers would be much simplified, for one of the limiting conditions in the ventilation of rooms is the absence of perceptible draughts which is insisted upon by the occupants and required by compulsory ventilation laws. With the opinion at present held by people as to sitting in draughts, it would be useless to expect that a ventilating system involving perceptible draughts would continue to be operated in any building where persons have to sit for any length of time. It is not pleasant to consider that in crowded unventilated rooms the air must be rebreathed, nor is it pleasant to consider the other causes of atmospheric vitiation within enclosures as pointed out.

To keep the atmosphere of an occupied room wholesome, a frequent change of air must be secured; if the space is so large, the number of occupants so few and the air leakage through walls or around windows and doors such that this accidental ventilation is sufficient, well and good. This will, however, suffice only in rare instances; some dependable means must in most cases be provided to furnish a minimum volume of fresh air per minute for each occupant to meet present day standards.

In conclusion, adequate ventilation should be considered a necessity in spite of the increased cost over heating only. It contributes to health, efficiency and happiness by making us more vigorous, keeping our bodies in a condition capable of warding off disease.

In the foregoing the author has drawn freely from a paper on "Ventilation in its Relation to Health," which he presented at Cornell University in 1910.

STANDARDS OF VENTILATION.

Ventilation may be considered good, when measured on the carbon dioxide basis, when the number of parts of CO_2 in an occupied room does not exceed from 6 to 7 parts in 10,000. With 8 parts the air appears close to one entering from out-of-doors. When the CO_2 exceeds 10 parts in 10,000 the quality of the air is noticeably bad, and produces a feeling of weariness in a person breathing it for some time. While the CO_2 basis falls far short of meeting all requirements it is still commonly used in lieu of a more comprehensive standard.

Air Supply Necessary.—The volume of fresh air that must be supplied to keep the air in the room at a certain degree of purity may be readily computed. For example: What volume of air must be supplied to an occupied room to prevent the CO_2 from exceeding 7 parts in 10,000? Taking as a basis the commonly accepted figure of 0.6 cubic foot as the amount of CO_2 given off per person per hour, and 4 parts or cubic feet in 10,000 as the proportion of CO_2 in the outside air; the fresh air admitted absorbs 3 parts to reach the standard of 7 parts allowed, 3 cubic feet of CO_2 is taken up, which is equal to that given off by $3 \div 0.6 = 5$ persons. That is, 10,000 cubic feet of air containing 4 parts CO_2 must be admitted per hour to 5 persons, or 2000 cubic feet per hour per person in order that the number of parts of CO_2 in 10,000 shall not exceed 7.

By similar computations, 6000 cubic feet per hour per person will be found necessary to dilute the air to 5 parts of CO_2 in 10,000 parts, 3000 cubic feet to dilute it to 6 parts, 1800 cubic feet for 7.33 parts, 1500 cubic feet for 8 parts, and so on.

Where gas-lights are used, an additional supply of air must be provided, since the vitiation of air caused by each jet is as great as that caused by five or six persons.

Table XVa.—The Air Supply Commonly Accepted as Sufficient for Different Classes of Buildings.

Class of Building.	Minimum, cu. ft. per hour per occupant.	Minimum, cu. ft. per min. per occupant.
Hospitals	2400	40
Halls	1200	20
Churches	1200	20
Schools	1800	30

The volume of air which should be furnished for ventilation should not be based solely on the number of occupants in the rooms. The smaller the space per person the less must be the supply per person to avoid draughts. Thirty cubic feet per minute per occupant for example in a hall having only 100 cubic feet of space per occupant would mean a change of air every 3⅓ minutes as against a 6 or 7 minute air change in a school room.

COMPULSORY VENTILATION.

Massachusetts was the pioneer in the matter of compulsory ventilation. In this State the following requirements must be included in the specifications accompanying plans for the ventilation of school buildings submitted to the Department for approval.

1. The apparatus must, with proper management, heat all the rooms, including the corridors, to 70° F. in any weather.

2. With the rooms at 70° F. and a difference of not less than 40° between the temperature of the outside air and that of the air entering the room at the warm-air inlet, the apparatus must supply at least 30 cubic feet of air per minute for each scholar accommodated in the rooms.

3. Such supply of air must so circulate in the rooms that no uncomfortable draught will be felt, and that the difference in temperature between any two points on the breathing plane in the occupied portion of a room will not exceed 3°.

4. Vitiated air in amount equal to the supply from the inlets must be removed through the vent outlets.

5. The sanitary appliances must be so ventilated that no odors therefrom will be perceived in any portion of the building.

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.

SCHOOL HOUSE HEATERS.

Fig. 47 shows a cast iron furnace designed especially for school house heating. Such furnaces are commonly used to heat two standard class rooms each.

The makers give these dimensions in their description of this furnace: Fire pot 34 inches inside diameter, 16 inches deep, over 8 cubic feet fuel capacity.

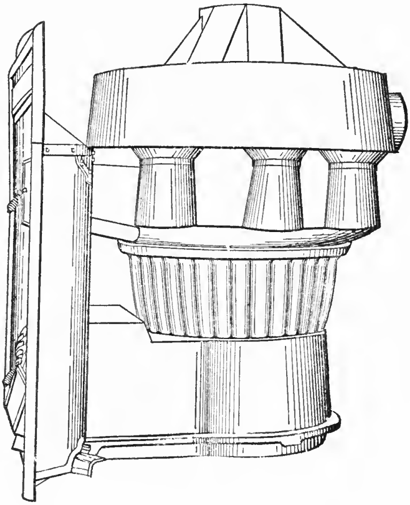


Fig. 47.—School House Heaters.

Note the corrugated fire pot and the combustion chamber with outlets around the circumference leading to the radiator at the top.

Such furnaces are rather high, but the basements of modern school buildings are of sufficient height to receive them; furthermore the furnace is placed almost directly under the flues so that the height does not affect the pitch of the pipes.

Fig. 48 shows a furnace with cast iron fire pot steel dome and steel or wrought iron radiator.

The makers state that these are made with fire pot 28 inches and 31 inches diameter.

Openings are provided in the front for access to the interior for cleaning purposes. It is of considerable importance to have these cleanout doors easily accessible, as otherwise the cleaning will be neglected.

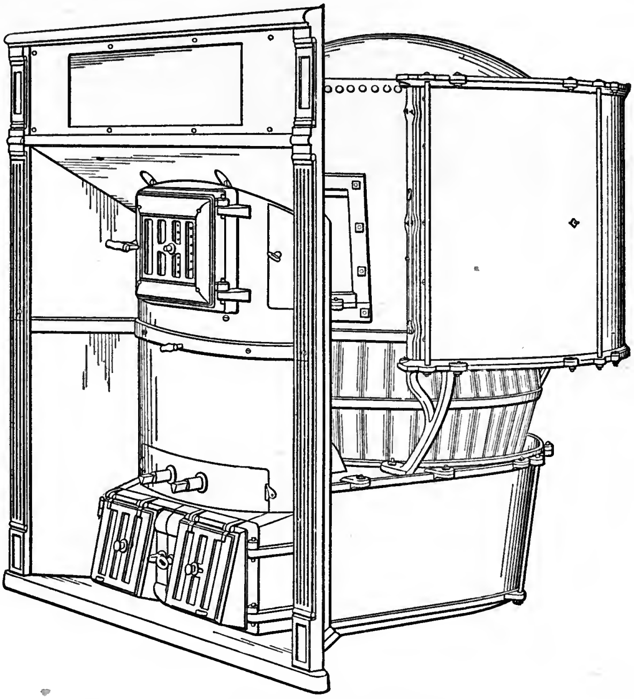


Fig. 48.—School House Heater of Steel-plate Construction.

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. Losses through exposed floors and ceilings must also be included.

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 $330 \times 85 = 28{,}050$ 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 $2\ (50 \times 30 \times 60) = 180{,}000$.

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 $180{,}000 \times 1\frac{1}{4} = 225{,}000$ 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. With a large volume of air passing through the furnace the average temperature of this air will be lower than in residence furnaces where the quantity of air is smaller with the same size of furnace. The transmission of heat and also the efficiency will therefore be slightly higher.

Granting, then, that 8000 heat units per pound of coal burned will be taken up by the air passing through the furnace we have $6 \times 8000 = 48{,}000$ heat units utilized per hour per square foot of grate surface or average fire pot area. 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 more exposed sides of buildings, add as a factor of safety 10 to 20 per cent. to the estimated loss of heat as above computed. It has been found in practice that furnaces with a 32-inch to 34-inch fire pot and 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 and unsatisfactory, 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. 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.

LOCATION OF FURNACE.

The furnaces, as in Fig. 49, 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.

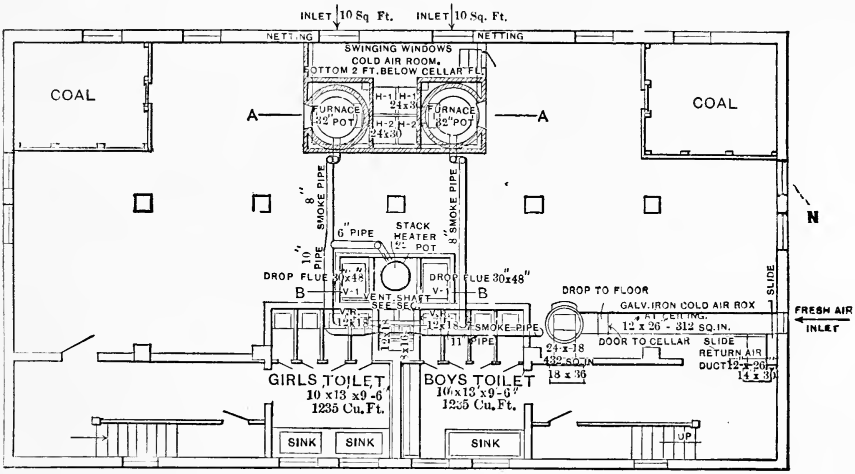


Fig. 49.—Basement Plan (9′ 6″) of School Building Heated by a Furnace System.

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 with non-conducting material to reduce the loss of heat.

FRESH AIR SUPPLY.

The net area of the cold air inlet should nearly equal 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.

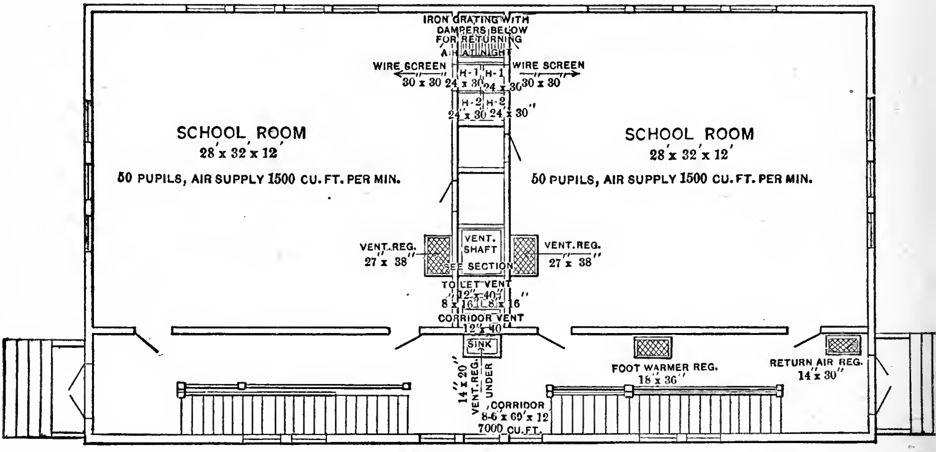


Fig. 50.—First-Floor Plan (12′ 0″) of School Building Heated by a Furnace System.

RETURN AIR OPENINGS.

A duct or opening for returning air from the rooms to the furnace, as shown in Fig. 50, 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.

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.

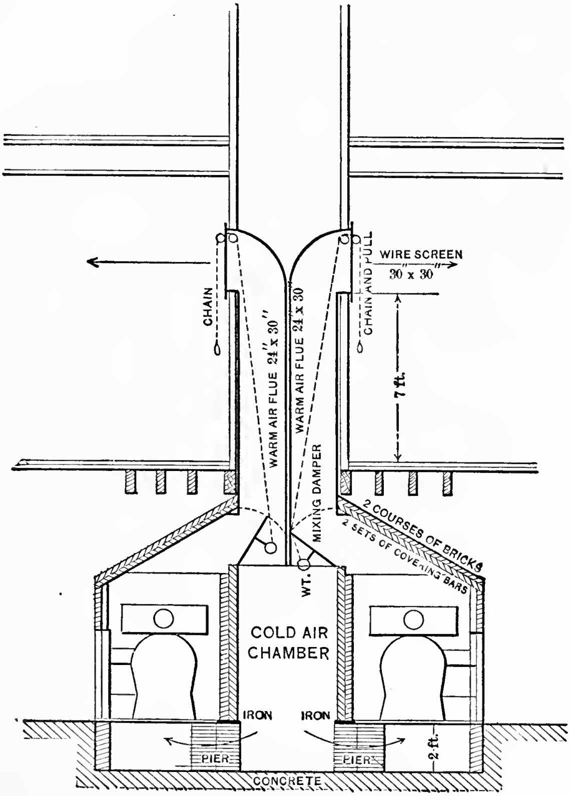


Fig 51.—Sectional View of Furnaces on Line A A of Fig. 28.

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. 51. 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. 52, 53 and 54.

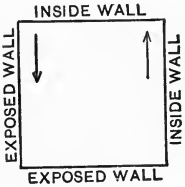


Fig. 52.

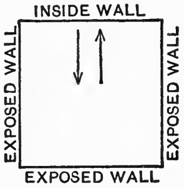


Fig. 53.

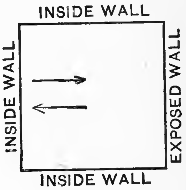


Fig. 54.

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 without any hood. Those of galvanized iron require a hood for protection during storms to keep out the rain.

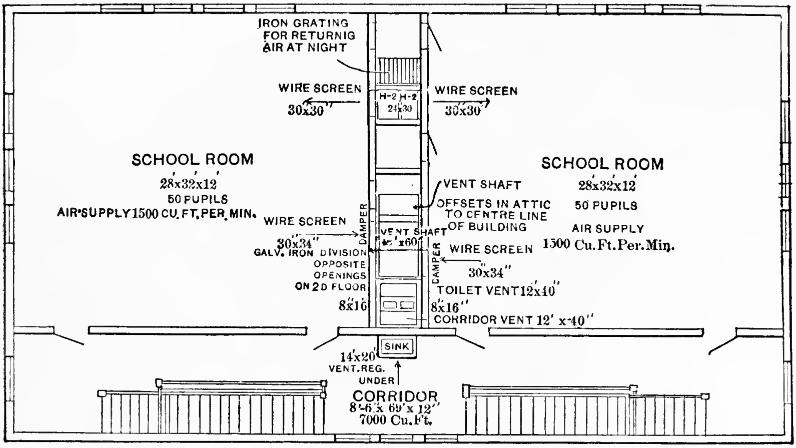


Fig. 55.—Second-Floor Plan (12′ 0″) of a School Building Heated by a Furnace System.

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 height of 9 or 10 feet above the floor of the schoolrooms, discharging through a wire screen or grill. 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.

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

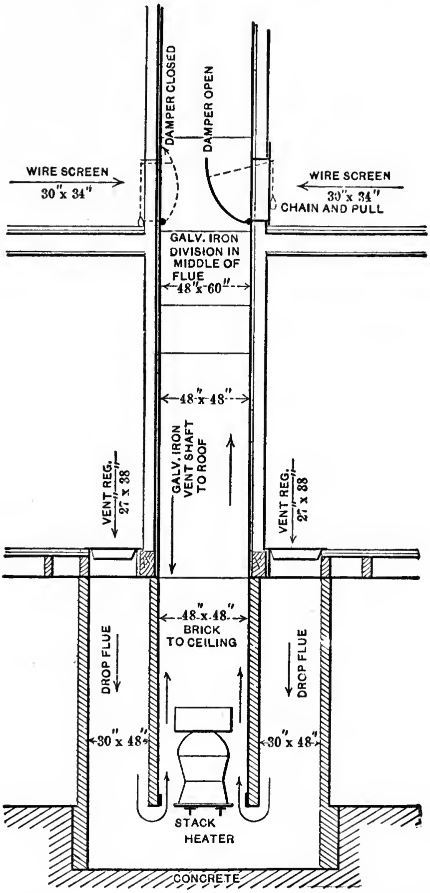


Fig. 56.—Section through Ventilating Shaft on Line B B of Fig. 28, Showing Stack Heater

floors the same size, generally about 24 x 30 inches for 50-pupil rooms requiring 1500 cubic feet of air per minute. One square foot to every 10 pupils.

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.

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 or grills 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. The frames are usually constructed of 1″ x 1″ x ⅛″ angle irons with holes drilled in one leg of the angle to receive the wires. The other leg of the angle is drilled for screws which attach the frame to the wall.

To provide for the easy discharge of air the net area of wire screens or register faces 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 located in 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 closely 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 discomfort.

ARRANGEMENT OF STACK HEATER.

It is unquestionably best to bring the vitiated air into the ventilating shaft—see Figs. 49 and 56—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. 56) 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. Also the inflow of air from the warm air flues is usually more rapid than in the first floor rooms and this tends to increase the outflow of vitiated air from the vent flues.

BOILER WITH COILS IN VENTILATING FLUES.

In large school buildings heated by furnaces, 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 at least 2.5 to give the proper boiler rating expressed in square feet of ordinary cast iron direct radiation.

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. 57 showing the basement and Figs. 58 and 59 the first and second floors, while Figs. 60 and 61 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. 57 shows basement plan of a town hall, while the first and second floor plans are shown in Figs. 58 and 59. Details and sections are shown in Figs. 60 and 61.

The basement is generally so warm that the loss of heat 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.

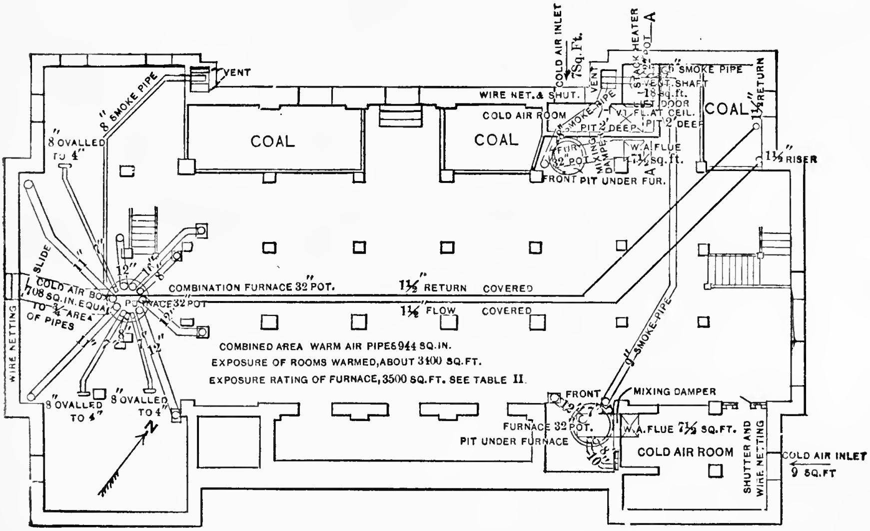


Fig. 57.—**Furnace System of Heating and Ventilating a Town Hall.—Basement Plan.**

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 $1\frac{1}{4}$ 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 the volume of air removed per hour by $1\frac{1}{4}$; 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.

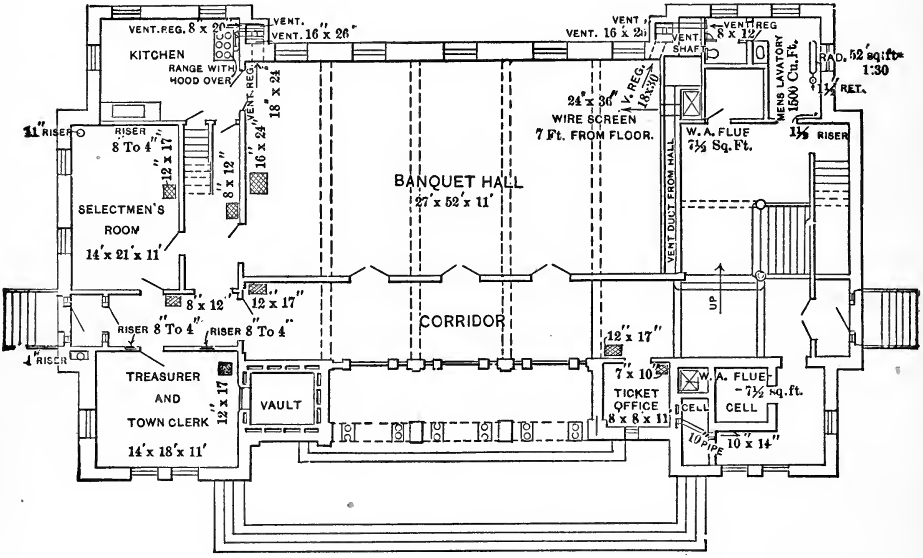


Fig. 58.—First-Floor Plan.

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.

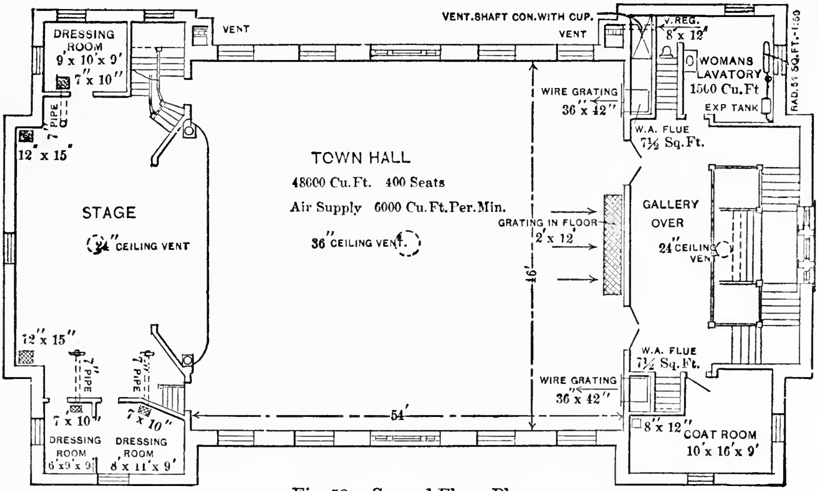


Fig. 59.—Second-Floor Plan.

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.

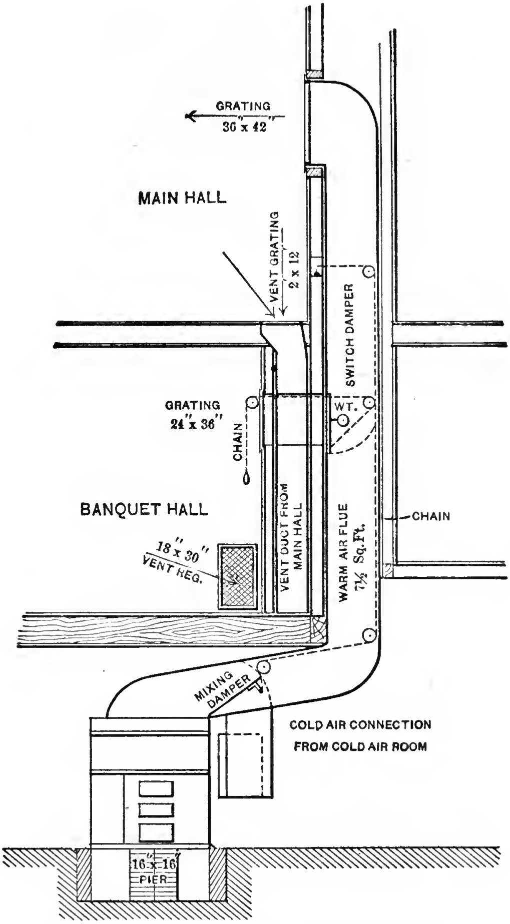


Fig. 60.—Sectional Elevation of North Furnace.

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.

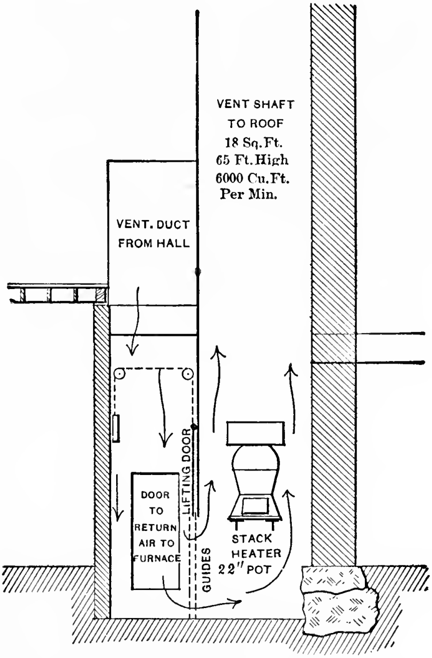


Fig. 61.—Section at A A, Showing Stack Heater and Ventilating Shaft.

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.

	Square feet grate surface required when air is changed every—		
Cubic contents.	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. 62—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. 63—materially lessens the time and fuel consumed in warming the building. This return duct may be run independ-

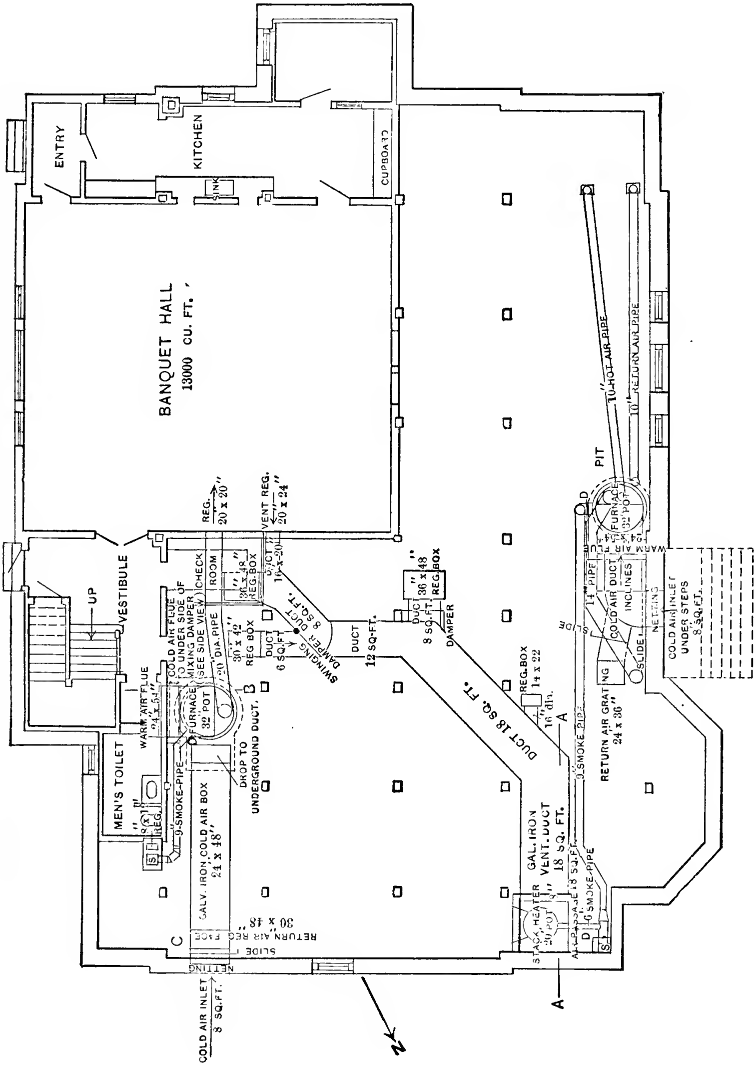


Fig. 62.—Furnace System of Heating and Ventilating a Church.

ently to the furnace, or, as more commonly arranged, may be connected with the cold air box, as shown in Fig. 63.

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.

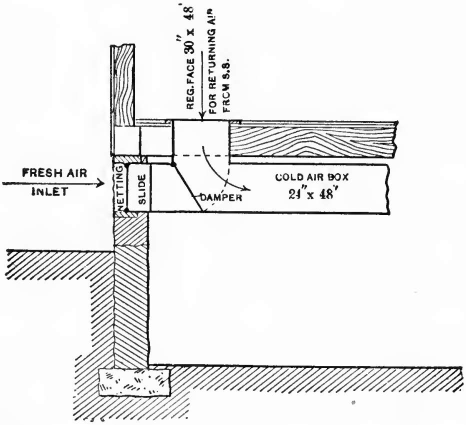


Fig. 63.—Detail of Return Air Connection at C, Fig. 41.

The remarks in Chapter IV with regard to the material of flues and the arrangement of mixing dampers (see Fig. 64) 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. 65 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, and heated by a separate furnace.

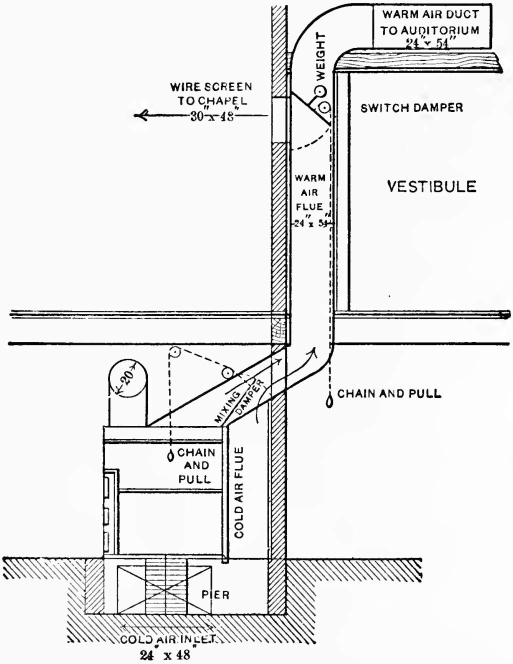


Fig. 64.—Section at B B, Showing Mixing Damper and Switch Damper.

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 these are used. 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. 66) 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 or average diameter of fire pot.

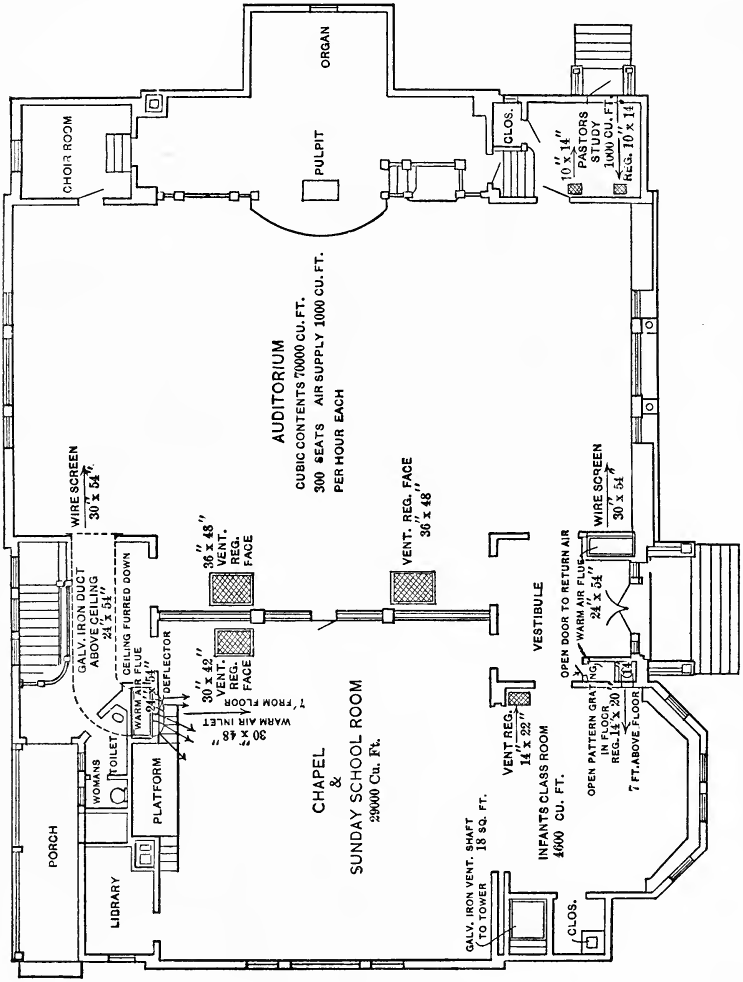


Fig. 65.—Furnace System of Heating and Ventilating a Church.—First-Floor Plan.

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.

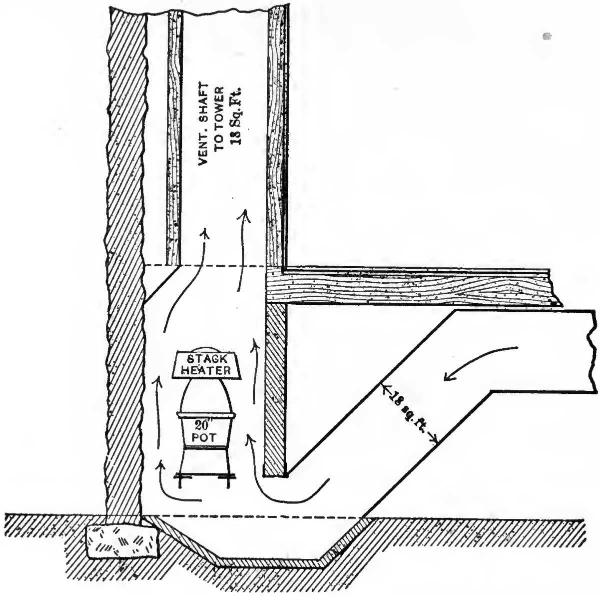


Fig. 66.—Section at A A, Showing Arrangement of Stack Heater

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. 57, 58 and 59, the simplest way to heat them is by a 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 gases 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 air supply, we may proceed as follows: Assume temperature of the entering air to be 140°, that of the room 70° and that of the outside air at zero. One-half of the heat brought in is lost through the walls, floors and ceilings by transmission before the air escapes at 70° 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 25 per cent. to the grate surface based on the exposure.

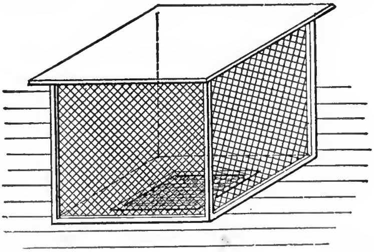


Fig 67.—Register with Guard Having Marble Top.

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. 67 may be placed over them to prevent their use as cuspidors and for scraping muddy shoes. Such an arrangement is frequently found in railway stations.

CHAPTER VII.

THE FAN-FURNACE COMBINATION SYSTEM.

ADVANTAGES.

The combination of a fan with furnaces has been successfully applied in numerous instances, especially in the heating and ventilation of churches and school buildings. The use of the fan renders this system capable of supplying a nearly constant volume of air under all conditions of wind and weather. Reversals of the air current in the flues, due to changes in the direction of the wind, which sometimes occur in the simple furnace system, are prevented.

APPLICATION OF THE SYSTEM.

The fan-furnace combination may be applied not only to churches and schools, but to hospitals, public and other buildings where a large and continuous supply of fresh air is required. In comparison with other mechanical systems this one is less expensive and simpler in its make up.

When arranged to rotate the air it is capable of warming the rooms very quickly. The system is, therefore, well adapted to buildings used intermittently. For buildings of good size, which must be kept warm night and day, this method of heating must give way to some form of steam apparatus. With the latter the cost of power for driving the fan will be less than for gas, electricity or water, and the boiler fires may be handled more easily than a number of furnaces.

LOCATION OF THE FAN.

The fan should be placed between the furnace and the fresh air inlet to the building (see Figs. 68 and 69). The air will then be forced, instead of drawn, through the furnace, as would be the case with the fan placed beyond them.

The "blow through" arrangement has several advantages over the other. At a given speed the fan will handle a greater weight of cold than of warm air; hence, to deliver a stated volume, the fan, when so arranged, may be run at a lower speed than when handling air at a higher temperature, as in the "draw through" arrangement. The lower the speed the less the noise and vibration. The air being under pressure, any leakage of gas or dust from the furnaces is prevented. Branch pipes may be taken from the main cold air duct before reaching the furnaces and be carried to the mixing dampers placed at the base of the flues.

With the "draw through" arrangement this would be impossible, as only warm air is handled by the fan.

LOCATION OF DRIVING APPARATUS.

The engine or motor and fan must be located where they will be least likely to cause trouble from noise. The best location is just outside the walls of the building in a room provided for the purpose. If the apparatus must be located in the basement, the fan and engine or motor must be placed away from piers, which are likely to transmit vibration. To prevent sounds being carried along galvanized iron ducts the following expedient is sometimes resorted to. A section of the pipe about 4 inches long is cut away and a sleeve of light canvas is slipped over the ends and fastened by means of wires drawn up tightly, thus forming a flexible air tight connection.

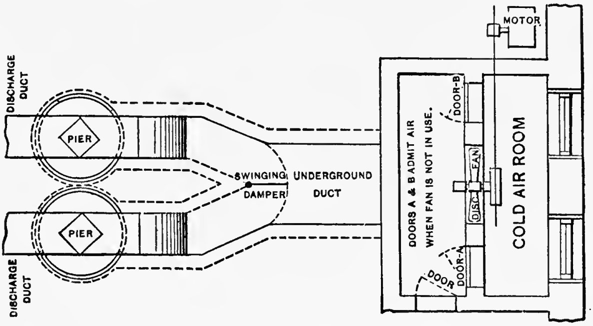


Fig. 68.—Plan of Fan-Furnace Combination.

SIZE OF FURNACES.

The size of furnaces for schools, churches and public buildings is determined as explained in the chapters under those headings. Having calculated the grate areas, bear in mind that small furnaces have more heating surface proportionally than large ones. Hence they may be used to better advantage than a single large furnace having their combined grate area.

KIND OF FURNACES.

The furnaces must be of the best materials and construction to withstand the severe strain often accompanying intermittent use. The ratio of heating to grate surface must be large. Extended surface in the form of pins and ribs may be used to advantage to break up the air current. To secure the best distribution of air around the furnace a pit should be used.

AREA OF AIR PASSAGES IN FURNACES.

When the furnaces are intended to be run, at times, independent of the fan the space for the passage of air through them should be about equal to the combined capacity of the ducts supplied, or sufficient to permit the required volume of air to pass at a velocity of about 300 feet per minute. A higher velocity, say 600-800 feet per minute, may be allowed in furnaces which are always used in connection with the fan. If the space is too great the air will be likely to be unequally heated, a portion passing through the furnaces without being brought into close contact with the heating surface.

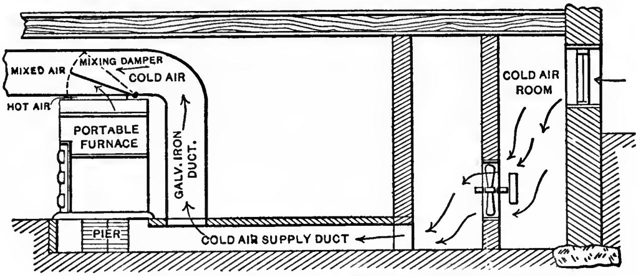


Fig. 69.—Sectional Elevation of Fan-Furnace Combination.

SETTING.

The furnaces may be set either in brick or galvanized iron, the relative merits of which have been previously discussed. The joints must be tight, to prevent the leakage of air. It is well to cover galvanized iron casings with plastic non-conducting material.

The furnaces may be placed side by side, in battery, so-called, or they may be set separately and connected with the fan by ducts. The battery arrangement facilitates firing and attendance in general, but furnaces so placed cannot be run as well independently as those located near the rooms which they heat. With either arrangement, provision should be made for returning air from the building when unoccupied.

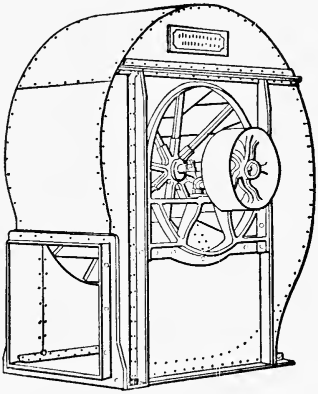


Fig. 70.—Blower Type of Fan.

TYPES OF FANS.

Two types of fans are used, the blower type, Fig. 70, like a paddle wheel, where the air leaves the fan in a direction perpendicular to the shaft, and the disk fan, Fig. 71, like a propeller, where the air leaves the fan in a direction parallel to the shaft.

When the ducts are of considerable length the blower is preferable to the disk fan, for with the former the air may be handled against resistance without excessive expenditure of power. The disk fan is adapted only to short lengths of pipe of large area.

If the resistance be increased by closing registers or dampers, the volume of air delivered will be diminished, but the power consumed by a disk fan will be greater. On the other hand, with fans of the blower type, if the resistance be similarly increased the lessened delivery of air will be accompanied by a corresponding reduction in power. Both types of fans may be pulley driven or have direct connected motor.

SPEED OF FANS.

It has been found in practice that fans of the blower type having curved floats operate quietly and give good results when run at a speed corresponding to ½ ounce pressure—*i e.,* a speed at the circumference of the wheels of about 3600 feet per minute. Higher speeds are accompanied with a greater expenditure of power and are likely to produce a roaring noise or cause vibration. A much lower speed does not provide sufficient pressure to give proper control of the distribution during strong winds.

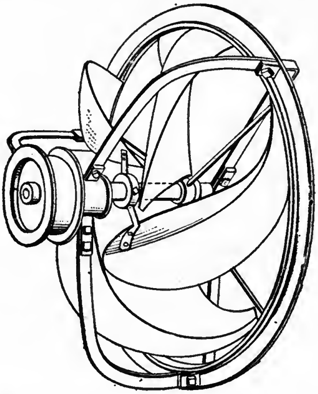


Fig. 71.—Disk Type of Fan with Pulley.

FAN CAPACITIES.

The capacities and powers given in fan manufacturers' catalogues are often different from those obtained in practice, the tables being based on other than practical working conditions. They should therefore be used with caution.

The following tables, XVIII and XIX, are intended as a guide in the selection of fans and motors, the former to be used where the ducts are of considerable length, the latter where they are short and of large area with easy turns:

Table XVIII.—Air Delivery per Minute and the Appropriate Size of Motor for Fans of the Blower Type.

Nominal size of fan. Hight of housing. Inches.	Diameter fan. wheel.	Width of fan housing.	Ordinary speed ½-ounce pressure.	Cubic feet of air delivered per minute.	For belted motor use horse-power.
40	24	12	580	1,600	1
50	30	15	465	2,600	1
60	36	18	390	4,500	2
70	42	21	333	6,000	2
80	48	24	293	8,000	3
90	54	28	260	11,000	3
100	60	32	233	12,500	5

Table XIX.—Air Delivery per Minute Against Slight Resistance and the Appropriate Size of Motor for Fans of the Disk Type.

Disk fan wheel. Inches.	Speed.	Cubic feet of air delivered per minute.	For belted motor use horse-power.
12	1,000	600	¼
18	800	1,500	½
24	500	2,300	1
30	410	3,500	1
36	380	5,700	1½
42	330	7,800	2
48	280	9,900	2
54	250	12,500	3
60	230	16,000	3

THE MOTIVE POWER.

The driving apparatus generally consists of an electric motor, although where electricity is not available a gas engine or water motor may be used. The gas engine is the most expensive in first cost, then the electric and water motors, in the order named.

The cost per hourly horse-power where the amount is less than 5 horse-power per hour would be roughly say 5 cents for the gas engine, 10 cents for the electric motor and 30 cents for the water motor. The electric motor is the most convenient machine to use. It may be easily controlled by a switch and starting box or speed regulator. The latter should have an automatic device to cut out the resistance coils whenever the current is interrupted from any cause. The motor may be connected directly to the fan shaft or it may be belted. Independent motors should be slow speed and should rest on an adjustable base for convenience in tightening the belt. In ordering always state the voltage and kind of current.

The gas engine is the least quiet of the three machines, the noise of the exhaust being difficult to overcome. This may be done, however, by leading the exhaust pipe first into a cast iron pot or equalizing chamber, thence into a pit or dry well of large capacity with a suitable outlet and vent. A water supply for cooling the cylinder is necessary, and in some locations of the engine this involves danger of damage from freezing in case of neglect.

The water motor is simple, quiet and convenient, but the cost of running one at city water rates is generally prohibitive.

AREA OF DUCTS AND FLUES.

With the blower type of fan the size of the main ducts may be based on a velocity of 1000 to 1200 feet per minute, the branches on a velocity of 800 to 1000 feet per minute, and as low as 600 to 800 feet when the pipes are small. With the disk type of fan the size of the ducts should be based on a velocity per minute not greater than 1000 feet, preferably less, in order to keep the resistance low.

Flue velocities of 500 to 700 feet per minute are permissible with the fan combination, though it is better, when possible, to keep the velocity as low as 400 feet. When the furnaces are placed separately and are intended to be run independent of the fan at times, the warm air flues should be based on a velocity of about 300 feet per minute.

The size of registers may be based on about the same velocity as last stated, adding 10 to 25 per cent. to offset the additional resistance to the passage of air through them.

CHAPTER VIII.

TEMPERATURE CONTROL.

GENERAL REMARKS.

There is, perhaps, no device that contributes more to comfort and convenience in the home during the winter months than an automatic temperature regulator. These devices in various forms give excellent results and are highly desirable. Not only may an even temperature in the house be secured, but those sudden and severe strains are avoided to which a furnace is often subjected when regulated by hand. The fire is maintained so evenly that the coal is burned to the best advantage, and few if any, clinkers are formed.

TYPES OF REGULATORS.

These devices may be divided into two classes, one comprising those in which the drafts are regulated directly by the temperature of the air passing through the furnace, and the other those in which they are governed indirectly by changes in the temperature of the rooms.

In the former the difference in the rate of expansion of certain metals is taken advantage of, to operate the dampers by means of levers connected with them by wires or chains.

In the latter the thermostat placed on the wall of one of the rooms is so constructed that a change in temperature causes a metal strip or U shaped piece to open or close an electric or pneumatic circuit connected with a motor or diaphragm which operates the dampers. Many thermostats are of the volatile liquid changed type, the pressure generated within them due to increase in room temperature serving to operate dampers directly or indirectly through pneumatic control. For large installations the pneumatic system is principally used.

The thermostat should be placed in room most nearly representing the average temperature of the house. It should be located where it will not be subjected to cold drafts or to currents of warm air from registers.

DAMPER CONNECTIONS.

To give the best results the regulator should be connected with both smoke pipe and ash pit dampers; a sufficient air supply will then be assured to promote proper combustion. The fire will respond more quickly to the action of the regulator than when the latter is connected only with the smoke pipe damper.

OPERATION OF THE REGULATORS.

Regulators acted upon by changes in the temperature of air within the furnace serve to control the fire much as an ordinary diaphragm regulator on a steam apparatus. When used with house heating furnaces, regulators of this type must be set each day with reference to the outside conditions. If these remain nearly uniform an even temperature in the house will be maintained, but with sudden changes in the weather this type of regulator, unless reset, is not capable of preventing variation in the temperature of the rooms.

Regulators run by clockwork, which open dampers at any desired time, are often used to automatically turn on the drafts in the early morning. They generally consist of a simple alarm clock with a ratchet or gear arranged to trip a lever, thus allowing the weighted damper to open.

CONTROL OF MIXING DAMPERS.

In schools, churches and public buildings where mixing dampers connected with warm and cold air ducts are used, they may best be controlled by thermostats having a gradual movement. These thermostats have no connection with the draft dampers of the furnaces.

CHAPTER IX.

ESTIMATES AND CONTRACTS.

FORMS AND BLANKS.

In laying out furnace heating work it is desirable to have the necessary items conveniently arranged on a printed form, either in an indexed book or on loose cards or sheets, which may be filed alphabetically. By the use of printed forms omissions will be avoided and the data preserved in a form convenient for reference.

It is well to make a rough sketch of the house, giving outside dimensions and showing the general arrangement of rooms and the points of the compass. The items may well include: Date, name and address of owner, location of house, name of architect, location of house in regard to exposure to cold winds, list of rooms with size and number of sides exposed, size of registers and pipes, length of hot air pipes, length of smoke pipes, clear hights of basement and floors above, square feet of exposed wall, size of furnace adapted to the estimated exposure, combined area of hot air pipes, area of air passages through furnace, area of cold air box. A form of data card, 3¾ x 8 inches, used by a Boston company, is shown herewith.

In computing the cost of furnace pipes it is convenient to allow for elbows by adding a length of straight pipe equivalent in cost. Two feet of straight pipe may be considered approximately equal in cost to one elbow of the same diameter.

ESTIMATES.

Having determined the size of the furnace, pipes and registers the cost of the job may be estimated. For an ordinary house heating apparatus the following are the principal items of expense:

Furnaces (number, kind, size, diameter fire pot, portable or brick set), covering bars and man door for brick setting, smoke pipe and check damper, fire tools, pipes and registers, stones, boxes, nettings, plaster rings, floor flanges, dampers, furnace collars, covering tin or asbestos millboard, cold air box, galvanized iron cold air neck, shield over furnace, labor in erecting, fares and expenses, freight and carting, masons' or carpenters' work and materials.

An estimate for heating schools, churches or public buildings may include, in addition to the items stated above:

Galvanized iron heating and ventilating flues, mixing dampers, chains and fixtures, regulating and shut off dampers, wrought iron smoke stack in ventilating shaft, stack heater at base of ventilating shaft, steam boiler with coils in ventilating flues in place of stack heater, pipes, valves, fittings and labor in connection with same, hood for top of galvanized iron ventilating shaft.

A hot water combination heating estimate commonly includes these items:

Water heating section or coil in furnace, radiators or coils, pipes, valves, fittings, air valves, pipe covering, expansion tank and fittings, labor of erecting, painting and bronzing, fares and expenses, freight and carting.

SPECIFICATIONS.

The specifications should be clear and to the point, leaving no opportunity for misunderstanding between the contractor and the owner. The items just enumerated form the basis of the specifications, which should describe each of them fully.

GUARANTEE.

Unless expressly stipulated to the contrary it is commonly understood that the apparatus specified in a proposal for heating is to be capable of warming rooms having registers or radiators to an average temperature of 70 degrees in zero weather, when operated continuously as directed by the contractor and that the temperatures in the different parts of the room shall not vary more than 5 degrees.

PAYMENTS.

On small jobs the entire payment is generally made on completion of the work; on larger ones payments are made as the work proceeds, on the certificate of the architect or engineer. In case a job is completed too late in the season to be tested in severe weather and the owner is unwilling to have the final payment construed to mean a final acceptance of the work, the contractor, if responsible, can generally secure a prompt settlement by giving the owner a written extension of the guarantee over another winter, allowing ample time for a thorough trial of the apparatus.

....*Date*....................
Owner...
Address. ....
Location of House..................................
Architect..

Room	Size	Sides ex-posed	Reg size	Pipe size	Length of pipes		
					Run off	Riser el. col. damp.	Total
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

On back of card show plan of house, with outside dimensions, arrangement of rooms and points of compass.

Clear h't's B'ment.........1st.........2d.........3d.........4th........
Smoke Pipe........................ft.
Exposure, Severe............Moderate............Sheltered............
Total Exposure..................sq. ft. Material.......................
Furnace; Use No....................Rated at.................. sq. ft.
Combined Area, Hot Air Pipes....................................sq. in.
Area, Air Passage in Furnace....................................sq. in.
¾ Combined Area of Pipes..sq. in.
Area, Cold Air Frame..sq. in.
Designed by..................................

The custom of allowing a portion of the contract price to remain unpaid until the apparatus has been tested in zero weather is becoming less common among responsible contractors, not from a desire to dodge responsibility, but because in some sections zero days are rare and it might be that an entire heating season would pass without opportunity for a zero day test, thus tying up the contractor's money. With a responsible contractor the owner runs little risk to take the contractor's guarantee to make good any defects that may occur in heating or in workmanship that may appear during a second heating season, provided the weather is too mild the first season to afford a proper test.

In heating contracts for schools, churches or public buildings a bond for the successful completion of the work is often required.

CHAPTER X.

FUELS.—MISCELLANEOUS TABLES AND DATA.

FUELS.

Anthracite Coal.—Anthracite or hard coal consists almost entirely of free carbon. It has a theoretical heating power of about 14,200 heat units per pound of combustible. It burns with a bluish flame tinged with yellow, with no smoke.

Bituminous Coal.—Bituminous or soft coal contains about 50 to 80 per cent. of carbon; as a rule, coal containing as much as 20 per cent. of volatile combustible is called bituminous. It has a theoretical heating power of about 13,000 to 14,000 heat units per pound of combustible. It burns with a yellow flame with smoke.

Coke.—Ordinary gas house coke, commonly used for domestic purposes, is a by-product from the distillation of gas from bituminous coal. It consists almost entirely of carbon, ignites quickly, and gives an intense clear fire. The weight of coke by the bushel may be estimated by allowing 50 bushels per ton. It is commonly sold by the chaldron, equal to 36 bushels.

Wood.—The American Society of Mechanical Engineers considers 2½ pounds of dry wood equivalent in heating power to 1 pound of coal. On this basis:

1 cord of hickory or maple is equivalent to 1800 pounds of coal.
1 cord of beech or oak is equivalent to 1300 pounds of coal.
1 cord of pine is equivalent to 800 pounds of coal.

To put it roughly, a cord of hard wood is equivalent to a ton of coal.

Gas.—Natural gas varies greatly in heating power according to its composition. For equal volumes, ordinary coal gas has about two-thirds the heating power of natural gas of average composition, water gas (uncarbureted) about 30 per cent., and producer gas about 13 per cent. In round number, 25,000 cubic feet of natural gas is equivalent in heating power to a ton of coal. Professor Jacobus states that "The number of cubic feet of water gas required to produce the same heating effect as that produced by burning 1 ton (2000 pounds) of Lackawanna coal is 91,780 cubic feet of uncarbureted gas, or 40,590 cubic feet of carbureted gas."

Petroleum.—Crude petroleum has a specific gravity of 0.83 to 0.93 (*i. e.,* for equal volumes it is $^{83}/_{100}$ to $^{93}/_{100}$ as heavy as water). The heating power of 1 pound of the crude oil is a trifle less than 21,000 heat units. Refined petroleum oils have specific gravities ranging from 0.628 to 0.792, with heating powers from 28,087 to 26,975 heat units respectively.

CHIMNEY FLUES.

Table XX.—The Appropriate Grate Surface or Fire Pot Area for Chimneys of Various Sizes and Hights, Based on a Rate of Combustion of 5 Pounds of Hard Coal per Square Foot of Grate Surface per Hour.

Diameter of chimney. Inches.	Hight of chimney in feet.					Square or rectangular Flue.
	40	50	60	70	80	
	Approximate grate surface. Square feet.					
8	4	5	6	7	8	8 x 8
10	7	8	9	11	12	8 x 12
12	9	11	13	15	16	12 x 12
14	13	15	17	19	20	12 x 16
16	17	19	21	23	24	16 x 16
18	21	23	25	27	29	16 x 20
20	27	30	33	36	38	20 x 20
22	35	39	43	47	50	20 x 24
24	44	49	54	58	62	24 x 24

Table XXI.—Area of Fire Pot in Square Feet.

Diameter. Inches.	Area. Square feet.
18	= 1.76
19	= 1.97
20	= 2.18
21	= 2.40
22	= 2.64
23	= 2.88
24	= 3.13
25	= 3.40
26	= 3.68
27	= 3.98
28	= 4.27
29	= 4.59
30	= 4.90
31	= 5.25
32	= 5.58
33	= 5.93
34	= 6.30
35	= 6.67
36	= 7.06

CAPACITY OF COAL BINS.

For convenience in estimating the capacity of coal bins, an allowance of 40 cubic feet per ton of 2000 pounds of anthracite egg coal is approximately correct. This rule is on the safe side and on this basis a ten ton bin would require 400 cubic feet or say 8 feet x 9 feet, piling the coal about 6 feet high.

According to Pouillet the following temperatures have been observed for iron at different stages of incandescence:

Table XXII.—Colors of Iron at Different Temperatures.

Faint red	525	Dark orange	1,100
Dark red	700	Bright orange	1,200
Faint cherry	800	White heat	1,300
Cherry	900	Bright white	1,400
Bright cherry	1,000	Dazzling white	1,500

Table XXIII.—Power of Various Substances to Transmit Heat.

Peclét gives the relative heat transmitting power of various substances as follows:

Copper	64.00	Pine wood, parallel to fiber	0.17
Iron	29.00	Pine wood, across fiber	0.09
Zinc	28.00	Oak, across fiber	0.25
Lead	14.00	Cork	0.14
Coke	4.96	India rubber	0.17
Marble	3.13	Brick dust	0.15
Limestone	1.82	Wood ashes	0.06
Glass	0.82	Linen	0.05
Burned clay	0.60	Cotton	0.04
Gypsum	0.48	Paper (gray), unsized	0.03

Table XXIV.—Colors of Fires.

The same authority gives the temperature of the fire corresponding to its color as follows:

Color.	Temperature. Fahrenheit.	Color.	Temperature. Fahrenheit.
Red, just visible	977	Orange, deep	2,010
Red, dull	1,290	Orange, clear	2,190
Red, cherry dull	1,470	White heat	2,370
Red, cherry full	1,650	White, bright	2,550
Red, cherry clear	1,830	White, dazzling	2,730

Table XXV.—Radiating Power of Various Substances.

According to Dulong and Petit the relative radiating power with same difference in temperature for different substances is as follows:

Polished silver	16	Rusted sheet iron	419
Polished brass	32	New cast iron	395
Red copper	20	Rusted cast iron	419
Zinc	30	Glass	373
Tin	27	Soot	500
Polished sheet iron	56	Building stones	449
Leaded sheet iron	81	Wood	449
Black sheet iron	345		

Table XXVI.—Conducting Power of Various Substances.

Representing the conducting power of gold by 1000 the conducting power of other substances is represented, according to Depretz by the following figures:

Platinum	981	Tin	303
Silver	973	Lead	180
Copper	898	Marble	23
Iron	374	Porcelain	12
Zinc	363	Brick earth	11

Table XXVII.—The Weight of Galvanized Iron Pipe, the Areas and Circumferences of Circles.

Diameter Pipe. Inches.	Approx. area. Sq. inches.	Circumference. Inches.	Weight of pipe per running foot.						
			No. 28 gauge.	No. 26 gauge.	No. 24 gauge.	No. 22 gauge.	No. 20 gauge.	No. 18 gauge.	No. 16 gauge.
1	0.7854	3.14	....	....	....	....	....	....	....
2	3.1416	6.28	. ..	....	....	....	....	.	....
3	7.07	9.42	0.7	....	....	....	....	....	....
4	12.57	12.56	1.1	.. .	....	....	....	....	....
5	19.64	15.70	**1.2**	1.4	1.8	....	....	....	....
6	28.27	18.84	**1.4**	1.7	2.1				
7	38.49	22.00	**1.7**	2.0	2.5				
8	50.27	25.13	**1.9**	2.2	2.8				
9	63.62	28.27	2 1	**2.4**	3.1				
10	78.54	31.41	2.3	**2.7**	3.4				
11	95.03	34.55	....	**2.9**	3.7				
12	113.10	37.70	....	**3.2**	**4.1**				
13	132.73	40.84	....	**3.4**	**4.4**	....	....	....	....
14	153.94	44.00	....	**3.7**	**4.7**	....	....	....	....
15	176.72	47.12	....	....	**5.0**	6.1	....	....	....
16	201.06	50.28	....	....	**5.4**	6.5	....	....	....
17	226.98	53.41	....	....	**5.7**	6.9	....	....	....
18	254.47	55 54	....	....	**6.0**	7.3	....	....	....
19	283.53	59.69	....	....	**6.3**	7.7	....	....	....
20	314.16	62.83	....	....	**6.8**	**8.2**	....	....	...
22	380.13	69.11	....	....	**7.3**	**8.9**	....	....	....
24	452.39	75.39	....	....	**8.0**	**9.7**	11.5	....	....
26	530.93	81.68	....	....	**8.7**	**10.6**	12.4		....
28	615.75	87.96	. .	....	**9.4**	**11.4**	13.4	....	....
30	706.86	94.24	...	....	**10.0**	**12.2**	14.4	18.7	....
32	804.25	100.53	....	....	. ..	**13.0**	**15 3**	20.0	....
34	907.92	106.81	....	....	....	**13.9**	**16.3**	21.2	....
36	1017.88	113.00	....	....	....	**14.6**	**17.2**	22.4	. ..
38	1134.12	119.38	....	...	....	**15.5**	**18.2**	23.7	.
40	1256.64	125.66	....	....	....	**16.2**	**19.1**	**24.9**	30.7
42	1385.45	131.94	....	....	....	....	**20.1**	**26.1**	32.2
44	1520.53	138.23	....	....	....	....	**21.0**	**27.4**	33.7
46	1661.91	144.51	....	....	....	....	**22.0**		35.2
48	1809.56	150.79	....	....	....	....	**22.9**	**29.8**	36.7
50	1963.50	157.08	....	....	....	....	**23.9**	**31.0**	38.2
52	2123.72	163.36	.	....		....	....	**32.2**	39.7
54	2290.23	169.64						**33.6**	41.4
56	2463.01	175.93						**34.9**	43.0
58	2642.09	182.21						**36.1**	44.5
60	2827.74	188.49						**37.4**	46.0

The heavy faced figures indicate the weight of pipes commonly built of the gauge stated at the head of the column in which they occur.

The diameter squared × 0.7854 = area of a circle

The diameter × 3.1416 = circumference of a circle.

Weight of Galvanized Iron Sheets in pounds per square foot, United States Government Standard.

Gauge	28	26	24	22	20	18	16
Weight in pounds	0.78	0.91	1.16	1.41	1.66	2 16	2 66

In the larger sizes of pipes the elbows are commonly made with the inner radius of the bend equal to the diameter of the pipe.

This gives an easy turn. Such elbows may be figured at double their actual weight to allow for the extra cost of making. This weight may be estimated by multiplying the diameter of the elbow in inches by $\frac{4}{10}$, which gives double the length of the elbow expressed in feet. This length multiplied by the weight of the pipe per running foot, as shown by above table, gives double the weight of the elbow.

To estimate the weight of square or rectangular pipe, it is approximately correct to find in the table the circumference corresponding most nearly to the sum of the four sides of the pipe, expressed in inches. Opposite the circumference thus found is given the weight of the pipe per running foot.

Table XXVIII.—Weight of Black Sheet Iron, United States Government Standard Gauge.

Gauge.	Thickness in inches.	Weight in pounds per square foot.
10	$\frac{9}{64}$	5.625
12	$\frac{7}{64}$	4.375
14	$\frac{5}{64}$	3.125
16	$\frac{1}{16}$	2.5
18	$\frac{1}{20}$	2.0
20	$\frac{3}{80}$	1.5
22	$\frac{1}{32}$	1.25
24	$\frac{1}{40}$	1.0
26	$\frac{3}{160}$	0.75
28	$\frac{1}{64}$	0.625

Intermediate gauges 11, 13, etc., have weights midway between the even gauges stated in table.

Table XXIX.—Weight of Plate Iron in Pounds per Square Foot.

Thickness of plate in inches.	Weight in pounds per square foot.
$\frac{3}{16}$	7.65
¼	10.20
$\frac{5}{16}$	12.75
⅜	15.30
$\frac{7}{16}$	17.85
½	20.40
$\frac{9}{16}$	22.95
⅝	25.50
¾	30.60
⅞	35.70
1	40.80

Cast iron weighs about 0.26 pound (roughly ¼-pound) per cubic inch.

Table XXX.—Showing the Size, Net Area and Depth of Registers.

Size of opening.	Net area of opening. Square inches.	Depth open. Inches.
4½ x 6½	19	1⅝
4 x 8	21	2¼
4 x 10	27	2¼
4 x 13	35	2¼
4 x 15	40	2¼
4 x 18	48	2¼
4 x 21	56	2¼
4 x 24	64	2¼
5 x 8	27	2
5 x 9	30	2
5 x 10	33	2
5 x 11	37	2
5 x 12	40	2
5 x 13	43	2
5 x 14	47	2
5 x 15	50	2
5 x 16	53	2
5 x 17	57	2
5 x 18	60	2
6 x 6	24	2⅜
6 x 8	32	2⅜
6 x 9	36	2⅜
6 x 10	40	2⅜
6 x 12	48	2⅜
6 x 14	56	2⅜
6 x 16	64	2⅜
6 x 18	72	2⅜
6 x 20	80	2⅜
6 x 22	88	2⅜
6 x 24	96	2⅜
6 x 28	112	2⅜
6 x 32	128	2⅜
7 x 7	33	2¾
7 x 10	47	2¾
7 x 12	56	2¾
7 x 14	65	2¾
8 x 8	43	3
8 x 10	53	3
8 x 12	64	3
8 x 13	69	3
8 x 14	75	3
8 x 15	80	3
8 x 16	85	3
8 x 18	96	3
8 x 21	112	3
8 x 24	128	3
8 x 27	144	3
8 x 30	160	3
9 x 9	54	3¼
9 x 12	72	3¼
9 x 13	78	3¼
9 x 14	84	3¼
9 x 15	90	3¼
9 x 16	96	3¼
9 x 17	102	3¼
9 x 18	108	3¼
9 x 19	114	3¼
9 x 20	120	3¼
9 x 22	132	3¼
9 x 24	144	3¼
9 x 25	150	3¼
9 x 26	156	3¼
9 x 28	168	3¼
9 x 30	180	3¼
10 x 10	67	3⅜
10 x 12	80	3⅜
10 x 14	93	3⅜
10 x 16	107	3⅜
10 x 18	120	3⅜
10 x 20	133	3⅜
10 x 24	160	3⅜
11 x 17	125	4
12 x 12	96	4
12 x 14	112	4
12 x 15	120	4
12 x 16	128	4
12 x 17	136	4
12 x 18	144	4
12 x 19	152	4
12 x 20	160	4
12 x 24	192	4
12 x 30	240	4
12 x 36	288	4
14 x 14	131	4
14 x 16	149	4
14 x 18	168	4
14 x 20	187	4
14 x 22	205	4
15 x 25	250	4½
16 x 16	171	4¼
16 x 18	192	4¼
16 x 20	213	4¼
16 x 22	235	4¼
16 x 24	256	4¼
16 x 28	298	4¼
16 x 32	342	4¼
18 x 18	216	4¾
18 x 21	252	4¾
18 x 24	288	4¾
18 x 27	324	4¾
18 x 30	360	4¾
18 x 36	432	4¾
20 x 20	267	5½
20 x 22	294	5½
20 x 24	320	5½
20 x 26	347	5½
20 x 28	374	5½
20 x 30	400	5½
20 x 32	428	5½
20 x 36	480	5½
21 x 21	294	5½
21 x 25	350	5½
21 x 29	406	5½
21 x 33	462	5½
21 x 37	518	5½
24 x 24	384	5⅜
24 x 27	432	5⅜
24 x 30	480	5⅜
24 x 32	512	5⅜
24 x 36	576	5⅜
24 x 45	720	5⅜
27 x 27	486	6
27 x 38	684	6½
30 x 30	600	7¾
30 x 36	720	7¾
30 x 42	840	7¾
30 x 48	960	7¾
36 x 36	864	...
36 x 40	960	...
36 x 42	1,008	...
36 x 48	1,152	...
38 x 38	963	...
38 x 40	1,013	...
38 x 42	1,064	...

Registers are made in many other sizes than those stated above.

Table XXXI—The Lowest Temperature Recorded at Various Places in the United States During a Period of ten Years from 1886–1895 inclusive. Compiled by the Author from Reports of the Weather Bureau.

	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	Lowest in ten years.
ALA.—Montgomery	15	13	18	21	21	23	20	17	13	8	8
ARIZ. Prescott	— 4	8	—12	— 8	3	..	..	..	..	..	—12
Tucson	..	..	..	..	..	11	16	22	18	..	11
ARK.—Little Rock	10	0	7	17	16	20	10	11	1	— 2	— 2
CAL. Los Angeles	36	33	31	32	34	33	35	31	32	34	31
Sacramento	34	28	19	31	29	26	26	28	26	28	19
COLO.—Denver	—11	—18	—20	— 7	— 8	— 7	—17	— 2	— 8	—15	—20
CONN.—New Haven	— 2	— 5	— 4	— 3	4	3	0	— 3	— 5	— 7	— 7
FLA.—Jacksonville	31	22	28	30	27	30	29	24	14	14	14
GA.—Atlanta	8	9	13	14	17	18	13	8	4	0	0
IDAHO Boise City	— 7	6	—28	2	— 9	..	..	..	..	.	—28
Idaho Falls	..	..	..	..	..	..	—22	—22	—28	—32	—32
ILL.—Chicago	—14	—15	—18	—11	— 5	— 8	—10	—16	— 9	—15	—18
IND.—Indianapolis	—11	—12	— 6	— 1	4	— 3	— 5	—15	— 7	—14	—15
IND. T.—Fort Sill	1	0	— 7	7	6	..	..			..	— 7
IOWA—Des Moines	—20	—24	—27	—13	—18	—10	—26	—16	—27	—18	—27
KAN.—Dodge City	—18	—17	—18	— 8	— 6	— 0	—11	— 7	—15	—14	—18
KY.—Louisville	— 5	— 5	8	6	13	7	4	—10	— 5	—10	—10
LA.—New Orleans	28	21	29	32	30	30	23	29	21	16	16
MASS.—Boston	— 2	— 5	— 6	— 1	0	+ 2	0	— 4	— 7	— 6	— 7
MD.—Baltimore	3	7	9	3	12	16	12	1	7	1	1
ME.—Portland	— 5	—15	— 12	— 8	— 4	— 4	— 5	— 9	—15	—11	—15
MICH. Detroit	—12	— 3	— 7	— 8	+ 8	2	— 3	— 10	—11	— 8	—12
Marquette	—15	— 21	—27	— 21	—12	—12	—10	—19	—17	—16	—27
MINN.—St Paul	—36	—36	—41	—25	—22	—25	—25	—26	—25	—26	—41
MISS.—Vicksburg	17	10	18	24	24	22	16	20	15	4	4
MO.—St. Louis	—10	—10	—12	0	4	4	— 2	— 2	—11	—12	—12
MONT.—Helena	—15	—40	—41	—15	—29	—24	—22	—42	—26	—17	—42
N. C.—Charlotte	11	8	16	13	19	19	18	5	2	1	1
NEB.—Omaha	—18	—22	—25	—10	—14	— 9	—26	—16	—22	—20	—26
NEV. Carson City	..	..	—10	— 7	—22	0	2	8	— 7	— 4	—22
Winnemucca	9	— 3	—28	—14	—23	— 8	3	—19	—11	—14	—28
N. D.—Bismarck	—36	—44	—37	—34	—35	—33	—34	—41	—33	—39	—44
N. H.—Manchester	..	— 4	—11	— 9	— 6	— 7	— 3	— 9		..	—11
N. J. Atlantic City	5	— 2	2	2	10	14	9	— 4	5	..	— 4
New Brunswick	..	..	..	..		..	— 1	—10	— 1	—10	—10
N. MEX.—Santa Fe	— 3	— 8	— 2	— 1	— 2	— 6	1	5	0	—11	—11
N. Y. Albany	—10	—15	—10	— 5	— 4	— 5	— 5	— 6	—11	—12	—15
New York	0	6	2	2	6	9	8	1	1	— 3	— 3
OHIO—Columbus	—11	— 5	2	1	7	5	— 5	—12	— 4	— 8	—12
OKLA.—Oklahoma City	..	..	..	..	..	10	—11	— 2	— 8	— 8	—11
ORE. Baker City	..	..	..	..	—14	—11	—12	—17	— 7	— 3	—17
Portland	17	9	— 2	23	10	23	20	8	18	25	— 2
PA. Philadelphia	0	8	2	2	9	12	10	0	4	— 3	— 3
Pittsburgh	— 9	4	1	— 1	5	9	2	— 3	— 4	— 6	— 9
R. I.—Narragansett Pier	..	..	..	..	..	..	— 1	— 4	— 7	— 7	— 7
S. C.—Charleston	22	17	26	26	25	29	25	20	14	12	12
S. D. Pierre	..	..	..	..	..	—11	—30	—26	—28	—27	—30
Yankton	—24	—29	—28	—18	—22	—19	—32	—22	..	..	—32
TENN.—Nashville	— 2	— 2	2	12	16	17	10	3	— 2	— 6	— 6
TEX.—San Antonio	26	17	11	28	21	25	19	26	16	11	11
UTAH—Salt Lake City	5	9	—17	5	— 6	0	— 1	4	— 1	0	—17
VA.—Lynchburg	4	6	11	7	19	16	10	— 6	7	— 3	— 6
VT.—Northfield	.	— 21	—24	—32	—22	—17	—19	—27	—31	—17	—32
WASH. Olympia	23	2	— 2	20	7	21	24	28	21	27	— 2
Spokane	14	—11	—30	—10	—23	—10	— 5	—19	— 2	8	—30
W. VA.—Parkersburg	..	.	12	4	4	8	0	—11	— 4	— 8	—11
WIS.—La Crosse	—25	—29	—42	—23	—23	—24	—20	—26	—19	—24	—42
WYO.—Cheyenne	—19	—13	—27	—16	2	— 7	—29	— 4	—17	—20	—29

CHAPTER XI.

FURNACE ERECTION AND FITTINGS.

This chapter is made up of a series of articles reprinted from "Metal Worker" and other sources. Some of the statements contained therein are not in full agreement with rules laid down by the author in the main portion of this treatise. Where sizes obtained by rules given by various writers in this chapter are not so large as when based on rules stated in Chapters I. to X. inclusive, the reader is cautioned to use the larger sizes.

All figure numbers in this and chapters that follow refer to illustrations in the text in which they appear.

The reader's attention is called to the fact that in the following pages the pronoun "I" or the words "the author" refer to the writer of the article and not to the author of the preceding pages, Wm. G. Snow.

FURNACE FITTINGS.

In the preparation and construction of fittings three general rules should be strictly adhered to. 1. Adaptability. 2. Construction conforming to the laws of air currents. 3. Due regard to the economy of stock and labor. What we understand by adaptability is that the fittings should be so constructed that they will be adapted to the work and not that the work must be adapted to the fittings. Again, every fitting should be so made as to adapt itself to as many different situations as possible in order to avoid the necessity of keeping a large variety on hand.

In the earlier days of furnace work, when materials of every kind were expensive and labor cheap, it was the main thought in the making up of stock to save material. But at the present time, when materials are cheap and labor comparatively high, it is often found to be economy to sacrifice material to save labor.

FURNACE CASING.

The first fitting to be used after the furnace castings have been set is the casing. We wish to say, however, before taking up the question of casing, that in these articles we shall have reference only to the style of furnace known as portable furnaces, or furnaces with sheet iron jackets or casings. The question of merit as between the portable and brick set does not enter here. We only know that a large percentage of the furnaces used are portable, and we are compelled to take things as we find them, not as we may think they should be. The making of the casing is governed somewhat by the construction of the furnace. All casings should be double, an inside and an outside one, with a space between of at least an inch, with a provision for a free circulation of air from the base to the top. But to have a proper double casing requires casing rings made for that purpose, and all manufacturers do not make them that way. Where they are not so made a substitute must be provided that will come as near to it as possible. Sheets of black iron may be suspended from the rings on the inside, or sheets of tin grooved together and hung in the same way will answer. For the double casing black iron is used for the inside and galvanized for the outside. The inside casing should be made to fit in its place on the ring the same as the outside, so that there will be no chance for it to get out of place while in use. We frequently hear complaints by those using furnaces that at times the air coming from certain registers is cold even when there is a good fire. The cause of this trouble is usually found in the fact that the top radiator of the furnace is so much larger than the body of the furnace and gives so great a space between the body of the furnace and the casing that much of the air passes up along the casing and does not come in contact with the furnace castings or body and is therefore not heated. Some manufacturers remedy this by making the lower section of the casing smaller, using a flaring ring and larger upper section. Where this is not done the difficulty may be overcome by using trench plates or deflecting plates, which are usually made in sections of sheet iron, cut on the circle of the casing and wide enough to take up a part of the space. These plates are hung just above the ash pit by straps hooked on the casing ring, or they are sometimes hung at the under side of the top radiator. In either case their object is to compel the air to come in contact with the furnace castings before passing into the pipes. Care must be taken, however, that these plates do not take up too much space and thus interfere with a free and sufficient flow of air through the furnace chamber.

COLD AIR SUPPLY.

In regard to the admission of the air supply to the furnace I think it will be generally admitted that the best way is through a pit under the furnace; but circumstances will not always allow of this, and the supply must be taken in through the casing above the base, when a chute or galvanized iron box connecting the casing with the cold air box should be used. This is a rectangular box of a size that will give sufficient capacity for the air to be supplied. This chute should never be higher than the ash pit of the furnace and of a length that will keep the wooden box connecting to it at least 1 foot away from the furnace at the nearest point. To make this chute so as to give a good connection to the casing proceed as follows in the case of a chute 10 x 30 inches to fit a 40-inch casing: Provide a sheet of iron of a width that will make the box the required length. From one end mark off 10½, then 30, then 10 and last 31 inches, as shown in Fig. 1. Draw lines at these marks, as shown. With trams set to strike a 40-inch circle strike circle, touching at points as shown. Cut notches 1 inch deep as shown and turn lock ½ inch wide up square on the 10½-inch end; also ½ inch lock way over on opposite end and in opposite direction. Now brake up the square at dotted lines and double seam at corner. Next run one of the circled edges through the crimper ¾ inch deep; then with a mallet on a stake turn this edge up square, which will bring a flange to rivet or bolt to the casing, in which punch holes about 4 inches apart, and punch similar holes on both ends.

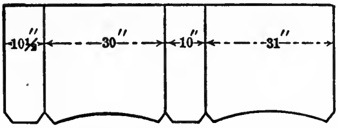


Fig. 1.—Marking Sheet for Air Chute.

There are two ways of putting on this chute. One is to bolt on and the other to rivet on. If riveted it must be put on before the casing is placed around the furnace, the work being done as follows: Set lower section of casing on the base to hold it in shape; then hold the box against the casing where it is to be put on and mark all around, also mark holes for rivets. Always have the chute close to base. Now take the casing off of base and cut hole inside the marks far enough so that the hole will be 1 inch smaller all around than the inside of chute except at the bottom, where it is cut close to base. Now rivet on, the helper holding a head on the inside of casing and the man riveting on the outside. After the chute is riveted on turn the 1 inch that the hole was cut smaller than the chute over on the inside of the chute, thus making a strong and tight job. It will be observed that, there being no flange turned on the bottom of the chute, when it was riveted on part projected through the casing. When the casing is put in its place this part of the chute projecting through the casing is turned down over the inside of the base rim, making a tight connection on the bottom as well as the top. Care must be taken when the inside casing is put on that an opening the size of the chute is cut out opposite the opening. If the chute is bolted on it is done in the same manner, only it can be left until the casing is on and the balance of the job completed. The position of the chutes should always be at the back of the furnace if possible, unless two cold air boxes are used, one entering on each side.

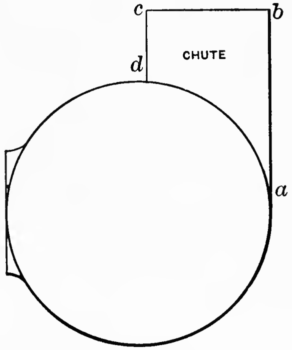


Fig. 2.—Side Connected Cold Air Chute.

But if only one box is used and it is necessary to put it on the side the chute should connect to the casing in the form shown in Fig. 2, in order to give as nearly equal distribution of air as possible. To mark out chute of this style proceed as follows for a chute 10 x 30 inches to fit 40-inch casing, opening at side on line with back: Strike a 40-inch circle on bench or floor and from any point on the circle draw tangent line *a b* indefinitely; 30 inches from and parallel to *a b* draw line *c d* at least 12 inches long. At right angles to *c d* draw line *c b*. For stretch out let *a b*, Fig. 3, represent one end of sheet of iron from which chute is to be made, 10½ inches from and parallel with *a b* draw line *c d*, equal to *c d*, Fig. 2. At right angles with *c d* draw line to *e* on *a b*; 30 inches from and parallel with *c d* draw line *f g*, equal to line *a b* in Fig. 2; 10 inches from *f g* draw line *h i* of same length. Let *j k* represent end of sheet 31 inches from *h i*. From *j* on line *j k* mark point *l*. Now with trams set for 40-inch circle strike circles *d g* and *i l*. Then will *e d g i l j a* be the pattern required. Brake at lines *c*, *f* and *h* and double seam at corner, and you have a chute the required shape. Turn flange and put on as described for the ordinary chute, only that the flange must be turned on the side of the chute that will bring it on the required side of the furnace.

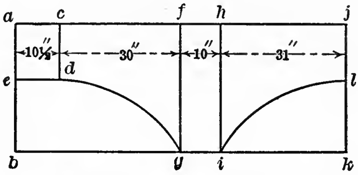


Fig. 3.—Pattern for Side Chute.

COLD AIR BOX.

If the cold air box in the cellar is made of wood, nothing but thoroughly seasoned matched lumber should be used. For if green or poor lumber is used it will soon shrink apart, and thus not only will it be useless as an air conductor, but it will allow the dust from the cellar to enter and be distributed all over the house, thus giving rise to the oft-repeated remark that furnaces are always dirty. Care also should be taken in building the box to see that its capacity is not reduced at any point of its entire length by cleats or braces inside or by making angles that reduce its efficiency, for the capacity of a box or pipe is no larger than its measurement at its smallest point.

A much more tight and satisfactory duct attends the use of galvanized sheets and then is entirely under the control of the furnaceman as to angles, shape, size, dampers, and other details.

CASING TOPS.

"Casing tops" are called by some "bonnets," by others "hoods," etc. For uniformity we will designate them "bonnets." There are two regular styles of bonnets in general use, known as the flat and pitched bonnet. The flat bonnet is one that is made low or flat with the intention of taking the pipes from the top of it, while the pitched bonnet is made higher so as to take the pipes from the sides. In both the sides or body is made more or less flaring, the difference being that in the flat bonnet the sides are made low in order to get as much room as possible on the top for the pipes, while the pitched bonnet is made high enough to take the pipes from the sides.

The hight of the flat bonnet is determined by the hight required for air space between the castings and the bonnet, it being understood that the top of the casing is on a line with the top of the furnace castings. The air space between the top of the castings and the top of the bonnet varies somewhat according to the size of the furnace. In all sizes up to and including a size requiring a 40-inch casing a 6-inch space will be sufficient; up to and in-

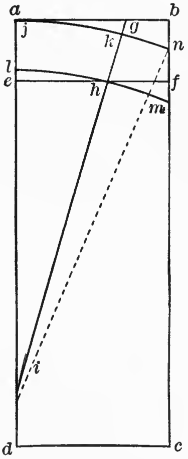


Fig. 4.—Pattern for Part of Bonnet.

cluding a 46-inch casing a 7-inch space; above that size from 9 to 10 inches.

The hight of the pitched bonnet will be determined largely by the size of pipes to be taken from it, as it is necessary to have the bonnet high enough to take out the largest size pipe to be used, and as the space required between the casting and a pitched bonnet is greater than for a flat bonnet the above rule governing the hight of the bonnet provides for this, for ordinarily the larger the furnace the larger will be the pipes used. It should be noticed here that the net slant hight of the pitched bonnet should be about 2 inches higher than the largest pipe to be used in order to give room for dovetailing in the collar.

In the construction of these bonnets the first thing to be done is to strike out a pattern for a section of the side or body. To do this proceed as follows: Required, a flat bonnet for a 40-inch casing, the flare or pitch of the side to be an angle of 23 degrees, or 5 inches to the foot (which makes a good proportioned bonnet), and 6 inches high. This will call for a body 40 inches in diameter on the bottom and 34 inches in diameter at the top. As the body of this bonnet cannot be cut in one piece it must be made in sections, and these sections, to have as little waste as possible, should be cut across the sheet and at the same time be as large as possible. As galvanized iron sheets 30 inches wide are about as wide as are generally used we will suppose that size for cutting the pattern. Referring to Fig. 4, let *a b c d* represent sheet of iron 30 inches wide; 6 inches from and parallel with the end *a b* draw line *e f*, which will represent the hight of body. From *a* on line *a b* mark point *g* one-half the diameter of bottom of body, in this case 20 inches; 17 inches from *e* on line *e f* mark point *h*, which will represent one-half the diameter of top of body. Draw line from *g* through *h* until it intersects edge of sheet *a d* at *i*. Now with *i* as center describe arcs *j k* and *e h*. Then will *j k h e* represent a section of body required. But as this section is not the full width of the sheet, by extending arcs *j k* and *e h* to edge of sheet at *m* and *n* and drawing line from *n* to *i* we will have a section cutting the full size of the sheet. This description will apply to the cutting of a pattern for a pitch bonnet as well, or for any similar pattern that is the frustum of a cone.

We now have the pattern for the bonnet, but before we proceed to construct one we must determine what kind of a flat bonnet we will have, as there are several ways of making the bonnets. One way of making them is to double seam a straight rim 2½ or 3 inches wide on the bottom to fit the casing ring, and double seam a sand ring on the top, as shown in Fig. 5. Another way is to crimp the bottom to fit the casing ring, and double seam on the sand ring, as shown in Fig. 6; others peen on the sand ring. The bonnet, as shown in Fig. 5, makes a very strong and pretty bonnet, but it requires so much labor in its construction that in these times of sharp competition beauty must be sacrificed and economy practiced wherever possible. The bonnet shown in Fig. 6 answers every purpose, and can be made much more cheaply. To make this bonnet rivet together enough sections to reach around the ring to be used, with some to spare, draw around the ring tight and mark, add 1 inch to this to allow for top, cut off and rivet together. Crimp the bottom edge 1 inch deep, sufficient to make it fit the ring snug. As every furnaceman knows, casing rings vary in size for the same size furnace. Hence the crimped edge is very convenient, as a little tapping with a hammer will vary it to suit the variations in the rings.

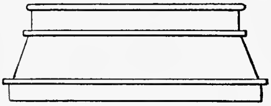


Fig. 5.—Bonnet with Double Seamed Bottom.

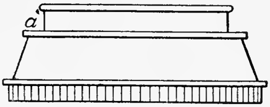


Fig. 6,—Bonnet with Crimped Bottom.

After the bottom edge is crimped and fitted to the ring turn an edge on the top with the small turner. If it is intended to double seam the sand ring on turn a small edge, then get out the cover so it will fit nicely with a small edge and peen it on. Now for the sand ring: Get out strip 2¾ inches wide, and long enough to reach around the top of the bonnet. Draw it tight around the edge of the cover, just peened on, and mark where it laps. Laying the strip out on the bench, measure back from mark just made 2½ inches, making it that much smaller, and cut off. Notch for wire and a 1-inch lap. Put in the rod or wire desired, and form up and rivet together with two rivets. Now run the edge not wired through the turner, and mark lightly ⅞ inch deep, then crimp quite heavy to this bead. Next with mallet and some solid stake lay off as a flange and square the part crimped. On this flange turn an edge with turner that will fit tight over edge of cover and peen down snug. Now turn the bonnet upside down on the bench. Then with some suitable stake or iron, held firmly in the corner on the inside, bring the bonnet over the edge of bench, and with mallet double seam cover and sand ring together to the body of the bonnet.

The object of turning so wide a flange on the sand ring is that when finished it will have a square shoulder or offset, as shown at *aa*, Fig. 6, making a much neater and stronger seam than it would if the double seam took up the whole of the flange, leaving no shoulder.

If it is not desired to double seam the sand ring on the difference in the process is simply to turn a wider edge on the body (say 3-16 inch wide), and a similar wide edge on the cover and sand ring and peen down well and leave it without double seaming. It is not necessary to lay off quite so wide a flange on the sand ring where it is not double seamed on. A workman who has never made one of these bonnets may have some difficulty at first, but with a little practice it will be found that they can be made easily and rapidly.

If it is desired to double seam a straight rim on the bottom to fit the casing ring, as shown in Fig. 5, instead of making the body 1 inch larger in circumference than the casing ring, as described above for crimping, make the body 1½ inches smaller in circumference and lap 1 inch and lay off flange on the body and double seam to rim in a manner similar to that described above in double seaming the sand ring to the body. What has been said in regard to the construction of the flat bonnet will apply as well to the construction of the pitched bonnet, as shown in Figs. 7 and 8, the only difference being that the sides are made higher.

The bonnets shown in Figs. 9 and 10 are also very similar, the only difference being that the top or cover of the bonnet is concaved and has no sand ring. The covers to these bonnets are usually pitched from 5 to 6 inches to the center. This provides room for sand, and at the same time its form is such as to have a tendency to more equally distribute the air to the pipes.

The style of bonnet shown in Fig. 10 for a pitched bonnet is the most practicable and at the same time the most economical style of all. It is simple in construction and quickly made, answers every purpose and looks well when done. In making this style of bonnet proceed the same as described for other styles of bonnet up to the point where the edge is to be turned on the body for the cover. Turn this edge now of a good width (say ⅜ inch), square and smooth, and proceed as follows to make the cover: Required, a cover 30 inches in diameter with 6-inch pitch to center. Referring to Fig. 11, draw line *a b*, equal to one-half the diameter of cover when finished, including edge of same width as on body. Let *a c* represent the pitch, then will *c b* be the slant hight. With *c* as center and *c b* as radius strike circle, as shown. Now with dividers set to *a b* step from *b* along circle six times to *d*. Draw line *d c*, cut out circle. Allow for lap and cut out piece *d c b*, join *d b*, and rivet together. Turn the edge and snap on body and peen down tight and smooth.

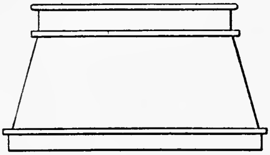


Fig. 7.—Pitched Bonnet with Double Seamed Bottom.

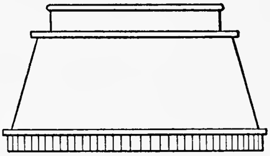


Fig. 8.—Pitched Bonnet with Crimped Bottom.

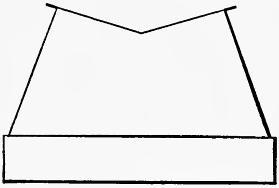


Fig. 9.—Bonnet with Concave Top.

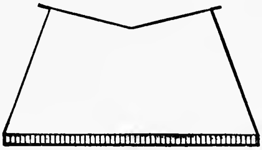


Fig. 10.—Bonnet with Concave Top and Crimped Bottom.

There are occasions when special bonnets are required, as, for instance, a bonnet from which one large pipe equal to the full capacity of the furnace is to be taken from the top. If the workman has become familiar with the principles involved in the above described bonnets he will have no trouble in applying them in the construction of any special bonnet he may require. For making a bonnet of this kind follow the instructions given above for striking out the pattern for the body of a bonnet, making the top 1 inch in diameter larger than the diameter of the pipe required to be taken from it. Then in place of putting on a cover peen or double seam on (double seam is best in this case) a collar to fit the pipe required, in the same manner as described above for putting on a sand ring.

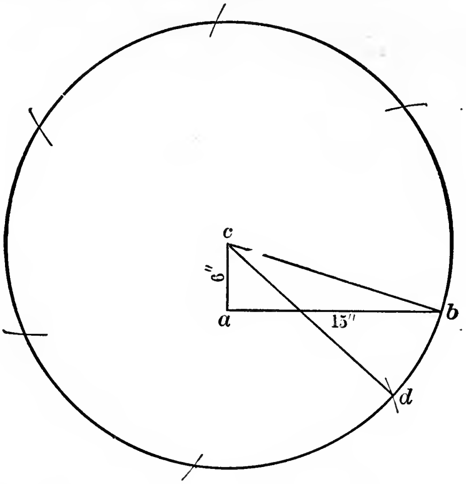


Fig. 11.—Pattern for Concave Top.

COLLARS.

The next thing in order to be considered will be the collars for connecting the pipes to the bonnet, and we will take up the styles to be used on the flat bonnet first. There are several ways of making these, all of which are so simple that our only excuse for describing them is that this article may reach some one that is in need of help in the rudiments of furnace work. One way of making these is to form up and rivet together a strip of galvanized iron about 3 inches wide to fit the required size pipe. Run through the large turner about ½ inch from edge, throwing a heavy bead or swedge out on the ring. Notch about ¾ inch wide up to bead.

Cut hole in bonnet that will just fit collar at bead. Insert the notched edge and drive them over tight on the inside of the bonnet. Another way is to turn a flange of, say, ¼ inch wide on one end of the collar, then rivet a strip of 1¼ inches wide on the inside of this end of the collar, allowing it to extend about ¾ inch beyond the flange. Notch to flange and put in bonnet as described above. Collars for the flat bonnet can be completed in the shop and put in the bonnet on the jobs as required.

Collars for the pitched bonnets have to be made somewhat different. They must be made to fit the side of the bonnet, and, as it is not known what angle the pipe will assume for which it is intended, it must be fitted on the job, hence they must be made longer to allow for trimming. For all sizes up to and including 10 inches they are made 9 or 10 inches long, larger than that 12 inches long. They are usually made flaring so they will nest together, the small end to fit the pipe. They should be riveted together, but so riveted as to be smooth on the outside to allow the pipe to slip over without catching on the rivets. This is done by forming the burr from punching on the inside, and then hammering the rivets down flat without using a set. These collars are supposed to be dovetailed in on the job in the following manner: First, the collar must be trimmed to fit the bonnet at an angle to correspond with angle of the pipe for which it is intended. This is best done by drawing a line or wire from a point opposite the center of the register box to the point on the bonnet where the collar is to be put in.

After the collar is trimmed to fit, mark around it on the bonnet with pencil and cut out the hole. Now with dividers mark around ½ inch from the trimmed end and notch ½ inch apart to this mark. Then with pliers turn every other one of these notches out square. Then insert the remaining ones in the hole in the body and hammer them over tight on the inside of bonnet. Time was when they were taken on the job and fitted and marked, and then taken back to the shop and flanges turned on them and strips riveted in and taken back and put in the bonnet. That made a good job "all right." But then that was "befo' de wah," when furnace work was not done for nothing and a year's supply of coal thrown in.

The constant cry heard by the workman nowadays is, "Get there," and he must provide ways and means to do it. It is considered quite a "trick of the trade" to trim a collar for a pitched bonnet and do it nicely and quickly. Again, it requires some skill and good judgment to locate the collars properly. For there are several things to be taken into consideration: First, they must be so located that all the pipes can be taken out, which is sometimes quite difficult to do. Then they should as far as possible be so located as to have the pipes run direct to the box or stack without an angle. Again, the pipes having the most work to do should have the preference of location on the furnace. It is not so difficult to locate the collars on a flat bonnet, as the pipes can be swung around one way or the other as desired. They should, however, be put in a circle around and as close to the center as possible. If it is desired to give some long pipe a decided preference the collar may be put in the center. Avoid having a collar directly over the feed chute. The hottest part of the furnace is usually at the back side; put the longest pipes there if possible.

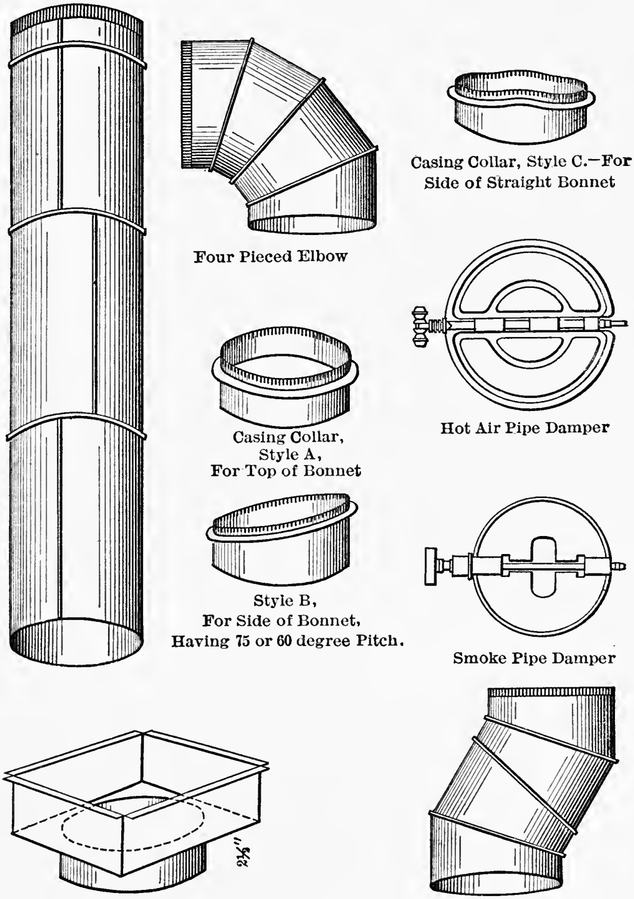
In connection with putting in collars in pitched bonnets it is recommended that the collars should all be trimmed and fitted and marked before any of the holes are cut, so that if necessary to make a change it can be done, and after all are fitted the bonnet may be taken off and the collars put on the cellar bottom. But before taking the bonnet off be sure to mark it in some way so it will go back in exactly the same place. The next fitting in order is the round pipe and elbows.

It is impossible to show every type of fitting in the limited space available in this chapter. Those who would like further information on the layout and erection of furnace work are referred to "Piping and Heavy Iron Work" and "Furnace and Tinshop Work," two of the volumes in the series entitled "Practical Sheet Metal Work and Demonstated Patterns." The "New Worker Pattern Book" also gives the principles by which any pattern problem may be developed.

STOCK FITTINGS.

Two groups of stock fittings for furnace work are shown in group Figs. 12*a* and 12*b*.

The dampers shown herewith are particularly recommended as often the ones made in the shop are not equipped with a suitable device for adjusting them in any desired position.



Four Pieced Elbow

Casing Collar, Style C.—For Side of Straight Bonnet

Hot Air Pipe Damper

Casing Collar, Style A, For Top of Bonnet

Style B, For Side of Bonnet, Having 75 or 60 degree Pitch.

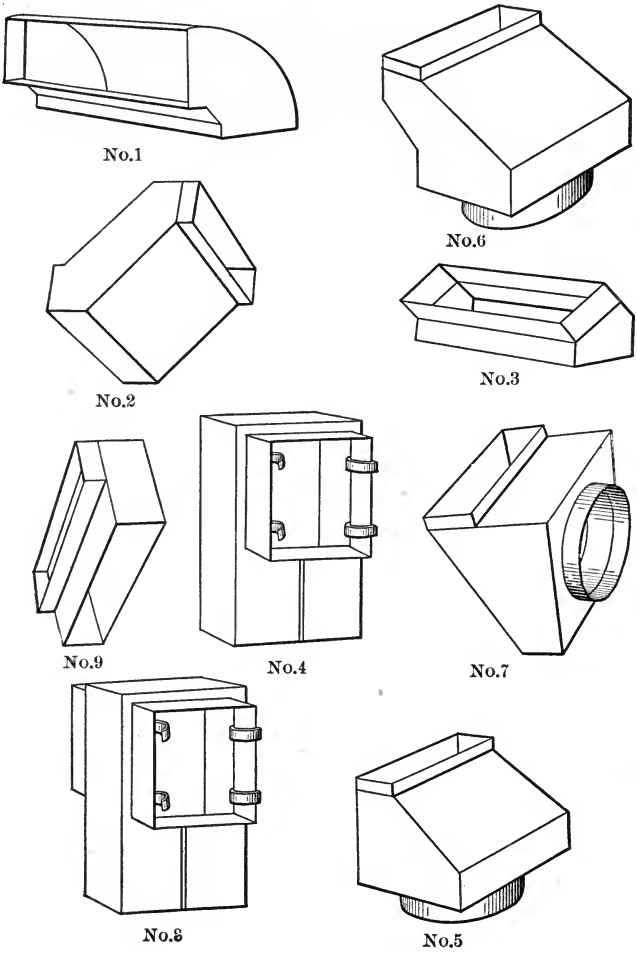
Smoke Pipe Damper

Adjustable Elbow

Group Fig. 12*a*.—Stock Fittings.

The adjustable elbow is also a very convenient fitting, and register boxes for setting in the floor may as well be purchased ready made.

These stock fittings will be found very convenient and will save much labor which under certain conditions can be better employed otherwise, then in case of a fall rush of furnace business these fittings enable the furnace man to make prompt deliveries.



Group Fig. 12*b*.—Stock Fittings.

The clips shown in Figs. 4 and 8 are perhaps the most convenient method of holding in place registers which must be set vertically.

GENERAL HINTS ON FURNACE ERECTION AND PIPING.

The following methods are used quite generally in the Central and Western States:

CASING.

The first fitting to be used after the furnace has been set, is the casing. This applies to the furnace that is generally used, and called a Portable Furnace, by which is understood a furnace encased in sheet iron jackets or casings. The question of merit between the portable furnace or one encased in masonry, will not enter into this subject. The style of the casing is governed by the construction of the furnace. Most furnaces, have the base ring and one casing ring through the center of the furnace, and another below the bonnet.

The width of the sheets that the different sections of the casing is to be made of, is governed entirely by the size and style of the furnace, and the position of the casing rings. Extra care should be given to the base ring of the furnace to see that this is absolutely plumb and level, as this is the real foundation of the casing itself. Much depends on the casing being made absolutely tight, as fine ashes, dust and dirt will pass through very small openings in the casing, and from there be discharged through the pipes and into the rooms above.

Complaints of dirty furnaces, can generally be attributed to the careless casing of same.

The first, or lower section of the casing should be cut the proper width between the casing ring and the second ring. If a solid front is on furnace, it should be attached to the one side, properly bolted up, and brought around the casing ring very tightly, and bolted to the other side. The same process should be followed with the second section. The second section of the casing is generally made double, with some furnaces a double ring is sent, so that an inside casing can be put in place. Where a double ring is not sent, corrugated metal should be bolted or riveted to the inside of sheet. The object of this inner casing is to prevent the heat from penetrating the casing, and being lost in the cellar, the space between this double casing or the outside casing and corrugated sheet, allows a circulation of air between them.

HOOD OR BONNET.

The upper section of the casing is the hood or bonnet. This, in every instance, comes above the front and therefore is complete in itself. Much depends on the construction of the furnace bonnet. Experience has shown that the bonnet should be of sufficient height to act as a reservoir for the accumulation of warm air to be distributed through the pipes that are attached to same. Bonnets are made in many different styles, some with straight sides and flat top, others with straight sides and concave tops. Some are made with flaring sides, and these have both flat and concave tops. Bonnets with flaring sides are used more generally on account of the angle of same, providing a proper elevation for the pipes. With the flat top bonnet, the collars can be taken out of the top. This is very satisfactory in high cellars, but can not very well be used in shallow cellars. The top of the bonnet should be at least 8″ over the castings. Where collars are taken from the side, the bonnet must be high enough to admit of the larger pipe that may be used, and care should be taken that the collars are all as near to the top of the bonnet as possible. and that all of them are on a line at the top.

To prevent the heat from going through the top of bonnet, it is generally covered with sand or an asbestos fibre.

CASING COLLARS.

The next thing to be considered is the casing collar. This is a short tube or pipe to be attached to the bonnet of the casing. They are usually made flaring, so that the pipe will readily fit the same. They should not be any larger than is necessary to make a good joint; anywhere from 2″ to 6″ is the proper length.

After cutting the sheet of the proper length for the size of collar to be made, it should be formed and riveted, and an edge turned on the large end, with turning or burring machine. Next a strip of metal should be inserted in the large end, projecting about ½″ below the edge. This strip to be riveted. Then the projecting part of this strip should be notched in, so that it can readily be turned over on the inside of the bonnet.

For flat tops, this casing collar is made straight.

For side collars, this should be cut to the radius of the casing ring.

Formerly, it was a practice to fit these casing collars after the furnace had been set, cutting them, so that they would fit in a straight line from the furnace to the register. To do this it was necessary to go back to the turn on the edge, and rivet in the extra strip. This required considerable waste of time, and as the price of labor is the one important factor in the furnace construction, it is now policy to cut the casing collar on the same angle and if necessary use an extra elbow or angle.

TO ATTACH COLLARS TO BONNETS.

Hold the completed collar to the bonnet, and scribe on the inside of same, cut out this opening, and insert the projected edges, bend them over on the inside, drawing them up tightly. This will leave the formed edge on the outside, and another flange on the inside will make the casing collar absolutely tight.

Continue with all of the collars in the same order, spreading them around the casing as much as possible, and as near as can be on a straight line to the register.

ELBOWS.

All right angle elbows should be 4 p.c. To prevent the necessity of carrying different angles, these should be made adjustable, and can then be turned to any point that may be required. The size of sheets that these elbows are to be cut from, is the same as round pipe. Very seldom an elbow is used next to the casing collar, but in nearly every instance, it requires one at the register or connection on pipe leading to the rooms to be heated. Pipe and elbows should be put together properly, to prevent any dust or dirt getting into the joints, and attached to the collar at one end and to the register box or boot at the other.

These cellar pipes usually are covered with asbestos paper, which insulates them and at the same time, covers any opening that may otherwise be left at the joints.

REGISTER BOXES.

When floor registers are used, a register box should be made to fit the register or border. These boxes can either be made with a flat bottom and collar of proper size, attached, or can be made funnel shaped, from a square top to the round collar at bottom.

SIDE WALL REGISTERS.

Side wall registers are more generally used for first floor work than they were formerly, and many different styles and sizes of same are being made. The use of the side wall register is, without doubt, a success. They are made to fit the ordinary studdings, and to project from the wall enough to make the bottom of the opening of proper size and capacity to admit for the pipe necessary to heat the room. These boxes or heads, must be made to fit the register. This can be of single material, either tin or galvanized iron or of double construction. The latter is now more generally used, and proper fittings are made by different manufacturers for this purpose, which can be bought at less cost than they can be made in the ordinary tin shop.

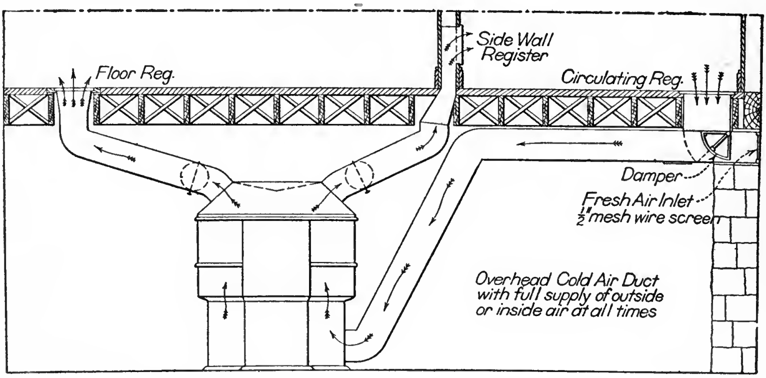


Fig. 13*a*.—General Arrangement of Ducts and Registers.

The connection to these boxes or heads, is by means of a boot, which can be made either straight, with a round collar at the bottom, as shown in Fig. 20, or, if an offset is used, as shown in Fig. 21.

COLD AIR CONNECTIONS.

In Fig. 13*a* is shown the method, of a leading furnace manufacturing company, of making the connections for the cold air when the overhead scheme is adopted, which would be so in the majority of cases. If the re-circulating system is not used the circulating register is omitted and a damper attached so that cellar air can be taken into the cold air box.

MAKING PIPE.

We will now consider briefly the making of warm air pipes. Where any large amount of round furnace pipe is to be made I think it economy to use the standard sizes of pipe stock found in the general market. The sizes are as follows: For 8-inch, 20x26½; for 9-inch, 20 x 29½; for 10-inch, 20 x 32½; for 12-inch, 20 x 38½. These sizes make a joint of pipe of the respective sizes 20 inches long without waste and may be had in IC or IX gauge. They are also very convenient sizes for general use in the shop. However, if a small dealer does not wish to carry such a variety of stock then the most economical method of making all sizes of pipe from one size of stock is to groove together a number of sheets, say 25, and roll up in a roll. Set the gauge on the squaring shears for the required size and have the roll on the floor in front of the shears. Let the man take the end of the roll and put through the shears and the helper hold it against the gauge, repeating the operation until the roll is cut up. As one end of the joint must be cut a trifle smaller than the other for the small end it will be necessary from time to time to cut off a small piece to square the sheet, but this waste will be but a mere trifle and will include all the waste there is. Having cut the sheet turn the locks, form up groove and solder together in lengths of four joints each.

Almost every man has a way of his own for soldering pipe. Some solder it on the bench and some use a trough, either answering the purpose for small quantities. But if a large amount of pipe is made it will pay to construct a device by which it can be neatly and quickly done, and such a device can be made by any furnacemen as follows: Construct two frustums of cones of galvanized iron with base 13 inches in diameter and top 6 inches in diameter and 7 or 8 inches high, as shown at A and **A, Fig.** 13*b*. Fasten a head on each end of these cones. Before putting on punch a hole in the center of each that will admit a piece of 1-inch gas pipe. After the heads are in place fasten in a piece of 1-inch gas pipe long enough to be soldered to both heads of the cone and extend from the bottom 3 or 4 inches. Now from 1-inch lumber construct two brackets, as shown at B and B. Let the uprights be, say, 10 inches high and the bottom of one of them 4 inches long and the other equal to the upright and 5 or 6 inches wide. In the center of the uprights and 7 inches from the bottom bore a hole just large enough to admit the pipe in the cones. In the one with the short arm bore hole for ½-inch bolt, as shown, with which to fasten to the bench. In the other cut a slot in the center of the bottom ½ inch wide and, say, 4 inches long. Provide a bolt with a lever nut with which to fasten this one to the bench. Now fasten the one with the short arm firmly to the bench and the other at a distance from it that will allow a length of pipe between after the cones are inserted in the ends, holding them just snug enough to turn and not slip, and fasten with the lever nut. It may be found necessary to put a boss or washer around the pipe where it extends through the bottom of the cone to avoid too much friction against the bracket in turning.

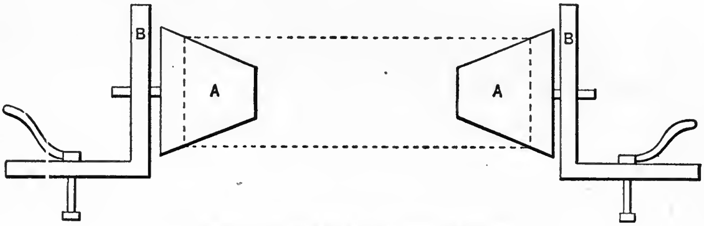


Fig. 13*b*.—Device for Soldering Pipe.

I have given the outlines of a crude device of this kind, knowing that many improvements will suggest themselves to any one who attempts to make one and also knowing that whoever succeeds in perfecting one will be well repaid for his trouble when he comes to use it. It will be observed that the sizes of these cones are such that all sizes of pipe from 8 to 12 inch may be soldered on the device. The slot in the one bracket is to allow the bracket to move back and forth to allow the length of pipe to be put on and taken off.

It is hoped that the suggestions contained in these pages will stimulate the reader to devise ways and means to facilitate the installation of furnace heating plants.

ELBOWS.

As furnace pipe after it is made cannot be put up without elbows, we will consider them next. All right angle elbows for furnace work should be four-piece elbows, to provide for an easy flow of air. They should be made strong and neat and at the same time by methods permitting rapid work. The first requisite in making elbows is a perfect pattern, and to procure such a pattern for a four-piece elbow proceed as follows: Upon any horizontal line set off the diameter of the elbow required, as *a b*, Fig. 13*c*. Upon line *a b* extended establish point *c* at a distance from *b* equal to one-half the diameter of the elbow. With *c* as center and *c a* as radius describe arc *a d*. At right angles with line *a b* draw line *c d*. Now divide arc *a d* into six equal spaces, as 1, 2, 3, 4, 5, *d*. Draw lines from 1, 3, 5 to *c*. With *c* as center describe arc *b e*. Then *a d e b* will represent the elevation of the elbow required. As a four-piece elbow is composed of two half sections and two whole sections, *a* 1 8 *b* will be the first half section; 1 3 7 8 the first whole section; 3 5 6 7 the second whole section, and 5 *d e* 6 second half section.

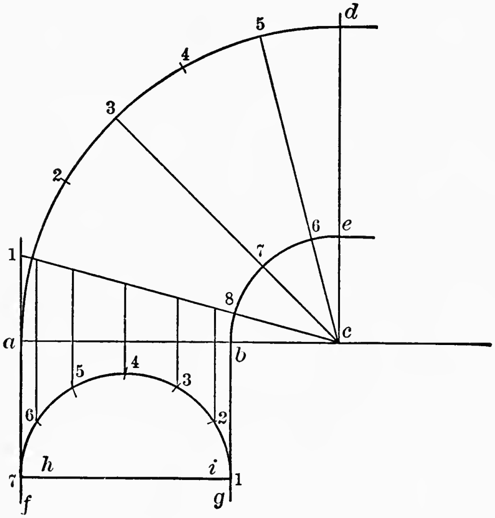


Fig. 13*c*.—Elevation of Four-Piece Elbow.

As we shall have no use for any of the lines in developing the pattern except those composing the first half section, we shall give no further attention to the others. To develop the pattern proceed as follows: At right angles to *a b* drop lines *a f* and *b g* indefinitely. At a convenient distance from *a b* describe half circle of diameter of elbow, and draw line *h i* at right angles with *a f*, cutting the center of circle. Divide this half circle into any number of equal spaces, as 1, 2, 3, 4, etc. Then draw lines parallel with *b g* and *a f* from points 2, 3, 4, 5, 6, cutting line 1 *c*, as shown. Now draw any horizontal line, as A B, Fig. 14, equal in length to the circumference of the elbow. At right angles to this line erect center line C. Divide the spaces on each side of the center line C into as many spaces as there are spaces in the half circle, numbering them from 1 to 7, and draw lines indefinitely from these points at right angles with A B. Now with dividers transfer the distances from the points on line *a b* Fig. 13*c*, where lines 1, 2, 3, 4, etc., cross to points where same lines cut 1 *c* to corresponding lines and numbers in Fig. 14, as shown. Then a line drawn with free hand through these points will be the pattern for first piece or half section of elbow. It is well in developing that part of the pattern as represented in Fig. 14 to use a sheet of iron or tin. Then when this first section is obtained it may be cut out and all the others marked from it by simply turning it over and allowing for the distance required in the throat (which should not exceed 1¼ inches) and mark around. For tin elbows it is necessary to use only one section of the pattern.

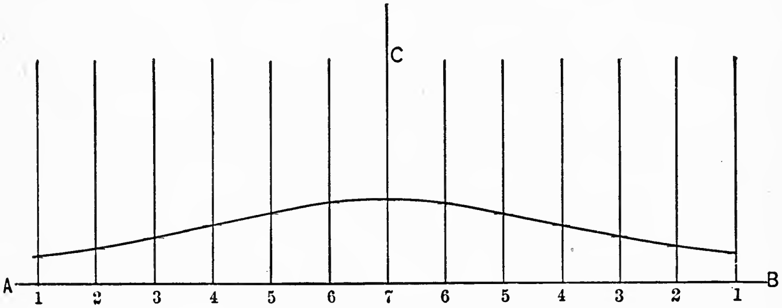


Fig. 14.—Pattern for Elbow.

If there is but a small number to be made use the first section, as follows: Get out the sheet of tin of the required length and width and cut with small and large end. Let the pattern represent the first section of the large end. Lay the pattern on the sheet, allowing for the length of the large end. Then turn the pattern over, allowing for the width of the throat, and mark around the upper side, repeating the operation until the last piece, leaving the length required for small end. If a large number of elbows is to be made it will pay to construct a device for marking them more rapidly, which may be made at very little expense, as follows: From a sheet of galvanized iron cut a third section of the elbow, allowing the ends to extend ½ inch longer than the regular pattern. For convenience in handling this pattern should be stiffened in the following manner: Cut a piece of galvanized iron of the same shape as the pattern, but about ¼ inch smaller all around. This is bumped up with the raising hammer until it assumes an arched form. It is then fitted to the flat surface of the pattern and soldered all around the edges. Before the raised part is soldered to the pattern an opening is cut in it oval in shape, so that the fingers of one hand may be inserted for holding the pattern firmly to the sheet to be marked.

In connection with this pattern a board with pins is made for marking the different sizes, as shown in Fig. 15, and may be constructed as follows: Provide a board 36 inches long, 18 inches wide and 1 inch thick. Across the board at the proper distances from the ends let in flush with the top three strips of iron 1 inch wide and ⅛ inch thick, as shown by A A, B B, C. C. The distance between the two strips A A, measuring from center to center, should be about ½ inch more than the circumference of an 8-inch elbow, locks included; strips B B, the distance equal to the circumference of a 9-inch elbow, and strips C C, the same for 10-inch elbow. Before strips are fastened in their place drill holes in them into which No. 8 wire nails will fit snug. The first row of holes, D D D, should be drilled so that the distance from the edge of the board to the under side of the hole will equal the length required at the throat of the first section and large end of the elbow. The second row of holes, E E E, should be at a distance from holes D D D equal to the length required for the large end of the second section, including the length required at the throat F, and including also the thickness of pins. Drill holes in like manner in strips B B for 9-inch elbows and stops C C for 10-inch elbows.

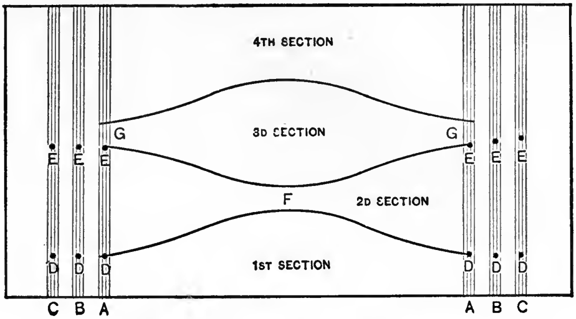


Fig. 15.—Board for Marking Patterns.

In marking out elbows cut the sheet the required length and width. Supposing it to be for an 8-inch elbow it will lie between the pins D D and E E in strips A A. Bring the sheet down to the edge of the board. Lay the pattern on the sheet and against the lower side of pins D D and mark around upper edge of pattern. Then move pattern to the upper side and against pins E E and mark around both edges of the pattern, and the elbow is completely marked out.

It will be observed that I have not taken into consideration the 12-inch size of elbow, for the reason that a board for a 12-inch size would be so large that it would be cumbersome, and as there are comparatively few 12-inch elbows used they can better be marked out the other way. After they are marked out they should be notched and the locks turned before they are cut out. When grooved together the seam of the third section should be soldered, as it is so short it is liable to slip out in turning the edges. It is well also to tack the small end to prevent it slipping apart when being crowded into a piece of pipe.

If the above instructions in regard to obtaining an elbow pattern are closely followed it will be found to be a comparatively short method and will produce a correct pattern for a right angle elbow.

Tin elbows at the furnace, however, should not be at right angles, for every pipe should have some elevation. It is best,

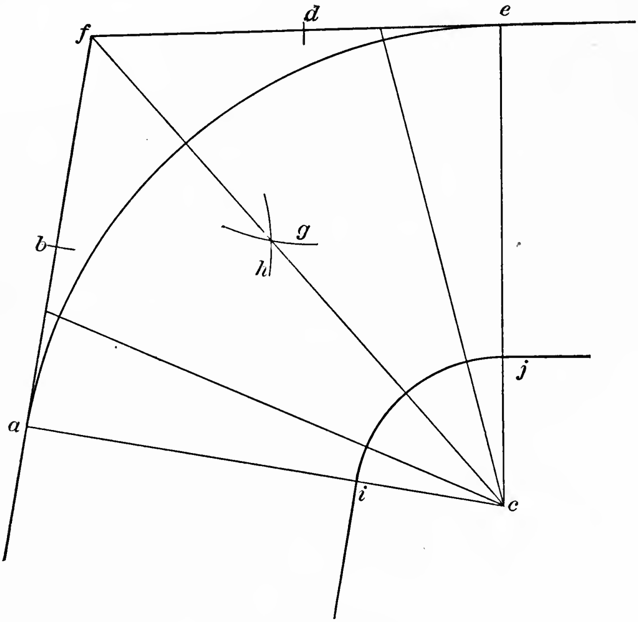


Fig. 16*a*.—Bevel Elbow.

therefore, to make the elbows at an angle of about 80 degrees. Hence it will require a pattern made accordingly.

To cut a pattern for a four-piece elbow other than a right angle will require a little different process, as follows: In Fig. 16*a* let *afe* be the required angle. Bisect the angle by the line *f c*, which may be done in the following manner: On lines *a f* and *f e* establish points *b* and *d* at any equal distance from *f*. From these points as centers strike arcs *g* and *h*. Then draw line *f c* through the intersection of these arcs. Now draw line *a c*, whose length will equal one and one-half the diameter of the elbow, and at right angles to *a f;* also draw line *e c* at right angles to *e f*. Now with *c* as center strike arcs *a e* and *i j*, and then proceed to develop the pattern in the same manner as described for right angle elbow. This will give us a pattern for the regular four-piece elbow for general use. But in practice it is often found necessary to have elbows with more bevel than this. For this purpose it will be found that taking the first and fourth sections and putting the two together will make a very convenient bevel, and using the first, third and fourth pieces will make a three-piece elbow of another very convenient bevel, and the two will meet almost any demand that will be made for bevels.

In regard to the stock used for elbows I would say that I think it poor practice to use the full width of the sheet (20 inches) for any elbow up to and including 12 inches, for the following reasons: If a flat top is used the elbow should be set as close to the top as possible, hence the large end must be short. The elbow that connects to the register box should come up close to the timber and in order to do so the small end must be short. Of course they can be cut off to fit, but that takes time and stock is wasted. Hence the large end of the elbow should not be over 2 inches long at the throat and the small end not over 4 inches long at the throat. When elbows are made this way 14 inches will make an 8-inch elbow, 15 inches a 9-inch elbow, 16 inches a 10-inch elbow and 17½ inches will make a 12-inch elbow. Then we have saved a 6-inch strip from the 8-inch elbow, a 5-inch strip from the 9-inch elbow, a 4-inch strip from the 10-inch and a 2½-inch strip from the 12-inch. Further along we will explain how these strips can be used to advantage.

In making galvanized iron elbows I think it well to use separate patterns for each section. These should be riveted together and the rivet holes punched in the patterns so they can be marked at the same time the elbow is marked out. The taper for the small end may be all in the last section and may be made as follows: After the patterns are cut out and before the holes are punched in the last section draw in the holes toward the outer end of the section enough to have it fit into the large end nicely; then form it up and fasten it lightly and trim it until it is true across the bevel end; then take it apart and use it for the pattern. The object of having the taper all in one section is that in making it there is no danger of getting the sections mixed, and also in cutting out the pieces for the elbow it can be done in the square sheet without regard to large and small end.

In closing these remarks on elbows I would like to make this observation: That I think it will pay any dealer who intends to do any furnace work at all to take the time when not busy and cut out a set of patterns for tin elbows from 8 to 14 inches inclusive (above that size they should be made of galvanized iron) and patterns for smoke pipe elbows from 6 to 8 inches inclusive, and have them hung up in their place in the shop ready for use when wanted. Considerable time will be saved if this is done.

REGISTER BOXES.

The next fitting in order is the register box for the floor register in Fig. 16*b*. This box should be about 4½″ deep when finished, with a collar 3½″ or 4″ long, for all sizes up to and including 10 x 14 inches. For 12 x 15 box they should be 6 inches deep, with collar 4 inches long. The body of all register boxes should be as shallow as possible and allow a free circulation of air from the box through the register, in order that the elbow connecting the box may come up as close to the timber as possible. A register border should be used with all floor registers, and the box should fit the border snugly. In order to have the box fit the border it is necessary to make the box a little flaring. They can be made quicker that way and make a much better box. Of course they cannot flare much or there will not be room in the bottom for the collar. To make such a box proceed as follows: First get out patterns for one side and one end of the box, of the required depth,

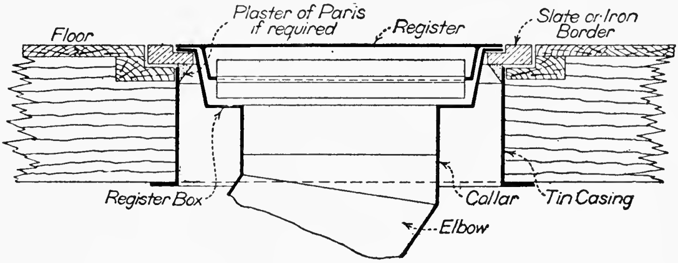


Fig. 16*b*.—Floor Register, Showing Construction and Setting.

allowing for a ½-inch flange on the top and an edge on the bottom to double seam. Allow for double lock on each end of the long piece and single lock on each end of the short piece for double seaming the pieces together on the corners. Cut both the long and short piece flaring ⅛ inch on each side, so that when the box is finished it will be ¼ inch each way smaller at the bottom than the top. Now take the 5-inch strips cut from the 9-inch elbows, as mentioned above, and groove them together in a strip. From this strip cut the bodies for the boxes, reversing the pattern each time to avoid waste. After the pieces are cut out and notched they can be taken to the folder and the locks on the ends, the edge for the bottom and the flange can all be turned with the folder before leaving the machine. Then double seam them together at the corners and it is ready for the bottom. But before putting on the bottom the collar must be double seamed in. I say " double seamed in " because a collar should never be put in any other way. As there are several ways of double seaming in the collar I have thought it best to describe briefly three different methods.

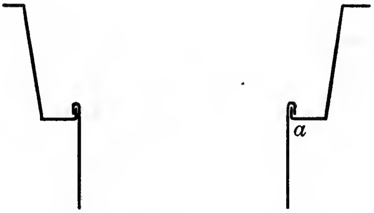


Fig. 17.—Register Box with Collar Passed Through.

The first is as follows: Prepare the bottom and turn the locks ready for double seaming on the body, then cut the hole the required size that will allow the collar to pass through snugly after an edge has been turned up square in the same direction as the locks for double seaming. Before passing the collar through the hole thus prepared turn an edge on one end way over, as far as possible, with the burring machine. Now pass the collar through the hole until the edge turned on the collar will hook over the edge turned on the bottom, as shown in Fig. 17, then close the locks together with pliers, and holding on beakhorn at *a*, double the seam over on the bottom. Then double seam the bottom on and the box is completed.

The second method is to prepare the bottom as before, cutting the hole, allowing for an edge to be turned way over and in the opposite direction from the one shown in Fig. 17. Now turn an edge over square on the inside of one end of the collar so that it will hook over the edge on the bottom snugly, as shown in Fig. 18, and holding on the stake peen down the edges on the inside of the collar. Then, holding on the stake at *a,* drive the seam over on the side of the collar with the side of the mallet. This is a very good method, as the seam on the inside of the collar prevents the elbow or pipe from being forced up into the box above the bottom.

For the third method prepare the bottom as before, cutting the hole and turning the edge the same as in Fig. 18. Now, on one end of the collar, with the small turner, lay off a double edge or flange, then with the burring machine turn an edge back so it will hook over the edge on the bottom, as shown in Fig. 19. Now, holding on the stake at *a,* with a mallet drive the seam down flat and smooth and you have made a connection that is solid, smooth and quickly done. I think this much the best method of the three, and when the workman gets accustomed to doing it that way he will be much pleased with it.

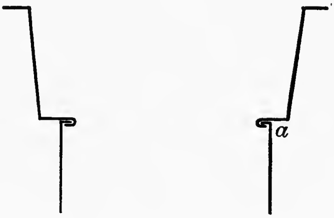


Fig. 18.—Collar with Seam on Inside.

Occasions arise at times when it is necessary to use a larger than 12-inch pipe and 12 x 15 register, such as 14 or 16 inch pipe. As a rule it is difficult to use the larger sizes on account of the hight of cellar. I have found that two 9-inch pipes run to a 14 x 18 inch register answer the purpose and work nicely. If a larger amount of air is required use two 10-inch pipes and 14 x 22 inch register. Another difficulty that is met at times is that owing to conditions that cannot be overcome the furnace, of necessity, must be so located that most if not all of the pipes run off from one side of the furnace, and where there are a number of pipes it may be difficult to get them out of the top. In such cases I have sometimes found it necessary to connect two registers to one pipe, and have had success in doing so by the following method: I will suppose a stack leading to room on second floor, at a long distance from the furnace. About on a line with this pipe is, say, a 9 x 12 floor register, at a shorter distance from the furnace. I would run a 10-inch pipe from the furnace to a point just beyond the 9 x 12 box. From the top of the pipe take a 9-inch tee direct into the 9 x 12 box, having the end of the 10-inch pipe close to the tee. Then put a reducer in the 10-inch pipe at this point to 8 inches, and connect with 8-inch pipe to the stack beyond. The proportions of pipes and registers can be changed to suit circumstances, but I would not suggest putting two floor registers on the same pipe. These and many other ways out of difficulties will suggest themselves to the workman if he will use his head as well as his hands and keep his eyes open.

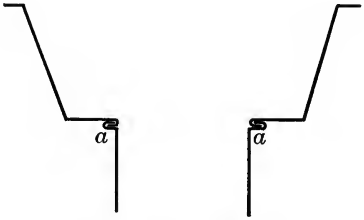


Fig. 19.—Third Method

We now come to the partition pipes or stacks for conducting the air through the partitions to the rooms above. There are several different styles of pipe in use and almost every shop has its peculiar methods of manufacture. Experience has convinced me, however, that the style of pipe best adapted to the requirements of the work—the most readily made and the most economical in construction—is the rectangular pipe, commonly known as square pipe. The sizes must vary more or less according to the conditions met. The partitions usually set in private houses are 4 inches, but as the studding is cut more or less "scant," it is seldom that a pipe larger than 3½ inches the one way can be used. Hence these conditions virtually establish the size one way. As the studding is usually set 16 inches from center to center we have about 14 inches of space that regulates the size of pipe the other way. There are other things, however, to be taken into consideration, and a very important one is the size of stock from which the pipe is to be made. The sizes of tin plate that is adapted to this work are comparatively limited. Hence the size of pipe must conform somewhat to stock at hand. As the 20 x 28 inch size of tin plate is a regular stock size and is usually on hand with all dealers, the sizes of pipes that I would suggest are nearly all those that can be made from this size stock without waste. There is no necessity of more than two sizes of pipes for 4-inch partitions and one size for 6-inch partitions. For the 4-inch partitions 3½ x 10 and 3½ x 11½. For 6-inch partitions 5½ x 13, and these sizes can all be made from 20 x 28 inch stock.

SHOES.

The first fitting to be taken into consideration in connection with stacks is the one connecting the round cellar pipe from the furnace to the stack and known as bottom collars, shoes, heads or boots. For convenience we will designate these fittings as shoes, of which there are two regular styles—namely, the straight shoe, as shown in Fig. 20, and the offset shoe, as shown in Fig. 21. The straight shoe is a fitting rectangular at the top and round at the bottom and straight at the back, as shown in elevation, Fig. 22.

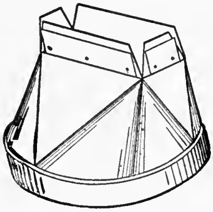


Fig. 20.—Straight Shoe.

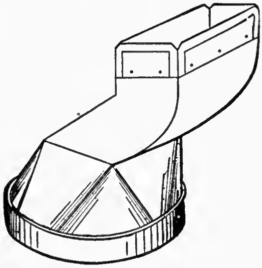


Fig. 21.—Offset Shoe.

As shown in the elevation this shoe is composed of two pieces—namely, the transition piece or body and the collar, the body and extension being made of one piece. To make this body in one piece it is necessary to have a pattern cut expressly for it, and being of an irregular shape I will give a brief description of how to lay it out, as follows: Desired, a straight shoe for 3 x 10 stack, with 8-inch collar. Referring to Fig. 23, let A B C D represent the rectangle 3 x 10. Draw line E F through center indefinitely, as shown. With center on this line strike an 8-inch circle tangent to line B C at E. Divide one-half of this circle from E to F into any number of equal parts, as 1, 2, 3, etc., having the spaces not larger than 1 inch. From the points 1 to 6 draw lines to corner at C and from points 6 to 11 draw lines to corner at D. To develop the pattern draw any horizontal line, as G H, Fig. 24. Erect lines G I and J K at right angles to G H, in length equal to G F, Fig. 22. Now with dividers transfer the several distances from C to points 1 to 6, Fig. 23, to line G H, Fig. 24, as shown at G, 1, 2, 3, etc., being sure to mark corresponding numbers to avoid confusion. (As it will be noticed that the distance C 5, Fig. 23, has the same position on line from G, Fig. 24, as C 3, and C 6 as C 2, care and accuracy will be required at this point to avoid mistake.) From these points draw lines to I. In like manner transfer distances from D, 6, 7, 8, etc., Fig. 23, to line G H from J, as shown, and draw lines from these points to K.

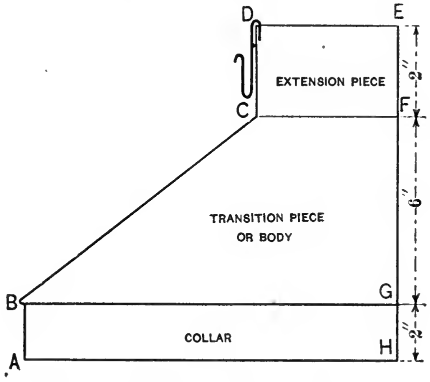


Fig. 22.—Elevation of Straight Shoe.

For the pattern proceed as follows, assuming that the seam is to be in the center at back of shoe, as shown at E, Fig. 23: Draw any vertical line, as L M, Fig. 25, equal in length to B C, Fig. 22. At right angles to L M, Fig. 25, draw line L N equal in length to E C, Fig. 23. Draw line from N to M, which should be equal in length to K 11, Fig. 24. Now with N as center and K 10 to 6 inclusive, Fig. 24, as radius strike arcs 10, 9, 8, 7, 6, as shown in Fig. 25. Then with dividers set same as equal spaces in half circle, Fig. 23, step from point 11, Fig. 25, to arc 10, and from 10 to 9, and so on to arc 6. Draw line from point 6 to N. Now with N as center and C D, Fig. 23, as radius strike arc O, Fig. 25. Draw line from this point to point 6, which should be equal to I 6, Fig. 24. Then with

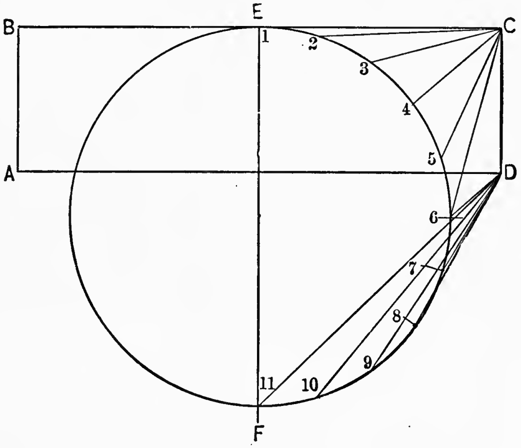


Fig. 23.—Plan of Straight Shoe.

O as center and I 5 to 1 inclusive, Fig. 24, as radius strike arcs 5, 4, 3, 2, 1, Fig. 25. Then with dividers set as before step from point 6 to arc 5, and from 5 to 4, and so on to 1. Draw line from 1 to O. Now with O as center and E C, Fig. 23, as radius strike arc P, Fig. 25. Then with 1 as center and G F, Fig. 22, as radius strike arc that will intersect with arc P, Fig. 25. Draw line from 1 to P and from P to O. Then with free hand draw line through points 1, 2, 3, etc., to 11. Then will 1 M L N O P be one-half the pattern for the body of shoe, less the extension piece.

For the extension piece proceed as follows: Extend lines 1 P and M L, Fig. 25, 2 inches to Q and T. With dividers set at 2 inches and with O as center strike arc R, and with N as center strike arc S. Draw line from Q to intersect arc R and line from arc R to arc S and from S to T. Draw line from point where lines cross at R to O and from S to N. Then will 1 Q R S T M be one-half the pattern for the body and extension piece for the required shoe. The other half of the pattern can be duplicated from this or the body can be made in two pieces, which is desirable for large size shoes. Allow for all locks on this pattern.

In making up this shoe proceed as follows: When the body has been marked and cut out cut the extension piece, Fig. 25, from point R to O, and from point S to N, and the same on other half of body, and turn the locks. Then on the beakhorn stake break from O to 1 and from O to 6 and from N to 6 and from N to M, breaking square at points O and N, but very slightly at points 1, 6 and M, and the same with the other half; then on a round stake form the lower end round. After it is formed up and grooved together make the 8-inch collar about 2 inches wide and peen on the bottom, and the shoe is complete. It will be noticed that the corners of the extension piece will be open. But as the stack will set over this piece the open corners will be no objection. If it is desired to have the corners solid it may be done by making the extension piece separate and double seaming it on the body after it is formed up. But this way of making will require much more time in making without adding much to the value of the fitting, and I think will not be found advisable. Made in one piece it can be done rapidly and with little stock.

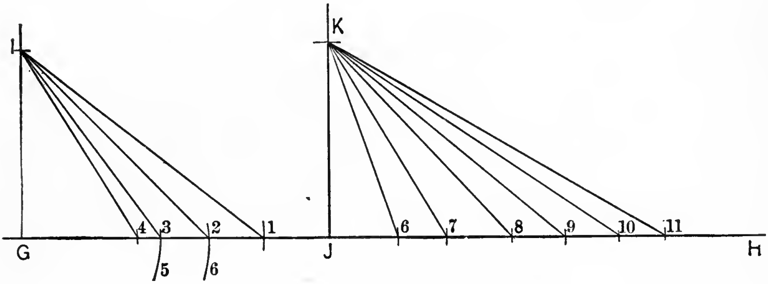


Fig. 24.—Drawings for Straight Shoe Pattern.

There are several styles of cleats used in making the connections with the stacks, any of which may be used according to custom or desire. In Fig. 26 is shown a very convenient cleat that is used as shown in Fig. 22. In Fig. 20 is shown another style that is much used and is riveted on as shown.

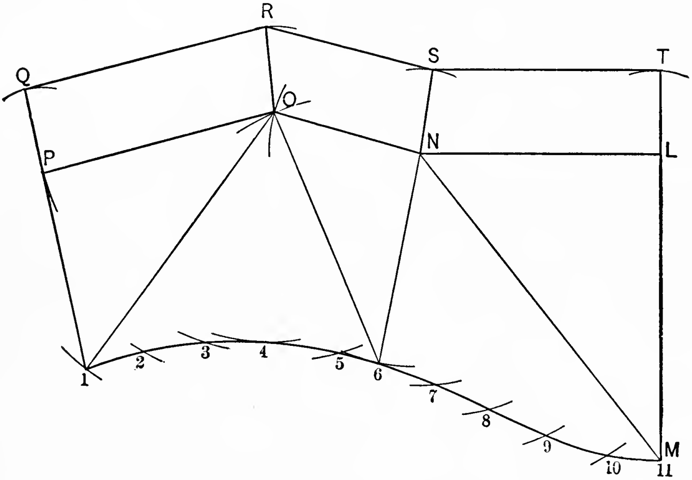


Fig. 25.—Pattern for Straight Shoe.

We come next to the offset shoe, as shown in Fig. 21. This shoe will be found to be a little more difficult of construction, as well as requiring a little more skill in developing the patterns. But the value and usefulness of the fitting will repay the labor in obtaining it. In order to give a better explanation for constructing a shoe of this style, we will suppose a shoe to be required to fit a 3 x 10 inch stack, with 4-inch offset and 8-inch collar. Let A B C D E F G H I, Fig. 27, represent the elevation of the desired fitting, as shown in perspective in Fig. 21. It will be observed that this fitting is composed of three sections—namely, the collar, the body or transition piece, and the offset piece. A G H I repre-

Fig. 26.—Cleat for Connecting with Stack.

sents the collar, A B F G the body and B C D E F the offset piece. These sections are made separate and joined together after they are made. The only difficult part of the fitting is the body or transition from round to rectangular. It will be found in constructing fittings of this design that it is just as necessary to know how to draw an elevation of the fitting required as to be able to develop the pattern for it, hence we will take up the elevation first. Draw any horizontal line, as A G, equal in length to the diameter of the collar required, and at right angles with A G draw line G F 2 inches long. Parallel with and 4 inches from G F erect line E J indefinitely. Parallel with and 3 inches from E J draw line D C. It will be observed by a glance at the elevation that when this fitting is placed in the position for which it is designed the point C will be at the floor line. Hence the distance between the point C and the bottom of the body at G should be as short as possible to prevent the shoe from extending below the floor timbers. It will be seen, therefore, that the line G F must be as short as possible, and as 2 inches is about as short as can be worked that length becomes arbitrary for all sizes. To establish point C on line D C set the dividers equal to D E and place them on line D C at such a point that they will strike arc K F, and this will be point C, as

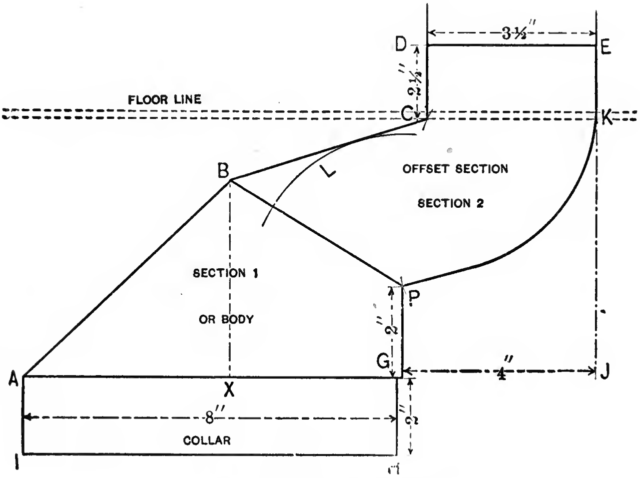


Fig. 27.—Elevation of Offset Shoe.

shown. Now with dividers set same as before, with F as center strike arc L. Now draw line indefinitely from C touching arc L. Draw line from A at an angle of 45 degrees with A G, intersecting line C at B. Draw line from B to F. Then will A B F G be the body or transition piece. It will be noticed that the line B F is longer than D E, hence the rectangular end of the body will be larger than the stack. This must of necessity be so in order not to contract the fitting between F and C. The angle of the line A B is not arbitrary, but can be changed to meet requirements, as, for instance, if this same fitting require a 9-inch collar the angle of the line A B would have to be changed in order to avoid having B F too long. But a little practice will make all these points clear.

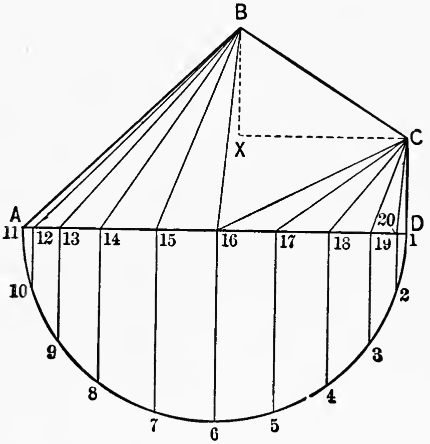


Fig. 28.—Elevation of Body.

As this section of the fitting is the only part requiring the development of the pattern we will proceed to give an explanation of the manner of doing it. To avoid confusion we have drawn a separate elevation of the body, as shown by A B C D of Fig. 28. With center of line A D as center strike arc A D; divide this arc into any number of equal spaces, as 1, 2, 3, 4, etc. From these points erect lines at right angles with and touching line A D, as 12, 13, 14, etc. From points 12 to 16 inclusive draw lines to B. From points 16 to 1 inclusive draw lines to C. Then will these lines represent the bases of sections to be used in the development of the pattern. To produce the sections proceed as follows: Draw any horizontal line, as A B, Fig. 29. At right angles with this line at points A and B erect lines A C and B D, equal in length to one-half the length of the long side of the rectangle end of this section. It being in this case 10 inches one-half would be 5 inches. Now with dividers transfer the distances from B 11 to 16 inclusive, Fig. 28, to A 11 to 16 inclusive, Fig. 29, as shown. In like manner transfer the distances C 16 to 1, Fig. 28, to B 16 to 1, Fig. 29, as shown. From these points on line A B, Fig. 29, erect lines 12, 10, 11, 9, etc., equal in length to corresponding lines in Fig. 28; also lines 16 6, 17 5, etc., to correspond with lines in Fig. 28. It will be noticed that points 1 and 11 have no hight. Now draw lines from points 6, 7, 8, etc., to C and from points 6, 5, 4, etc., to D.

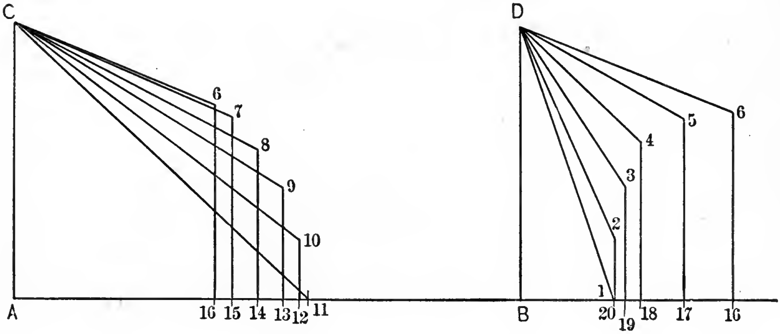


Fig. 29.—Drawings for Pattern.

To develop the pattern draw any perpendicular line, as A B, Fig. 30, equal in length to A B, Fig. 28. At right angles to A B, Fig. 30, draw line A C, equal in length to A C, Fig. 29. Draw line from C to B, which should equal C 11, Fig. 29. Now with C, Fig. 30, as center and C 10, Fig. 29, as radius strike short arc 10, Fig. 30; in like manner strike arcs 9, 8, 7, 6, Fig. 30, as shown. Now with dividers set at the distance used in stepping the circle, Fig. 28, step from point 11, Fig. 30, to 10, from 10 to 9 and so on to 6. Draw line from 6 to C. Now with C as center and B C, Fig. 28, as radius strike arc D. Then with 6 as center and 6 D, Fig. 29, as radius strike arc that will intersect with arc D, Fig. 30. Draw line from point of intersection to C and 6, as shown. Now with

D as center and D 5, Fig. 29, as radius strike arc 5, Fig. 30. In like manner strike arcs 4, 3, 2, 1, Fig. 30. Then with dividers set the same as before step from 6 to arc 5 and from 5 to 4 and so on to 1. Draw line from 1 to D. Then with 1 as center and C D, Fig. 28, as radius strike arc E, Fig. 30. Then with D as center and A C, Fig. 29, as radius strike arc that will intersect with arc E. Draw line from D to point of intersection at E and from E to 1. Now with free hand draw line through points 1, 2, 3, etc., to 11. Then will 1 11 A C D E 1 be one-half the naked pattern for section 1 of Fig. 27. The other half may be obtained by duplication. Notice that if the pattern is made in one piece the seam should be at the back at C D, Fig. 28, or if desired the body may be made in two pieces.

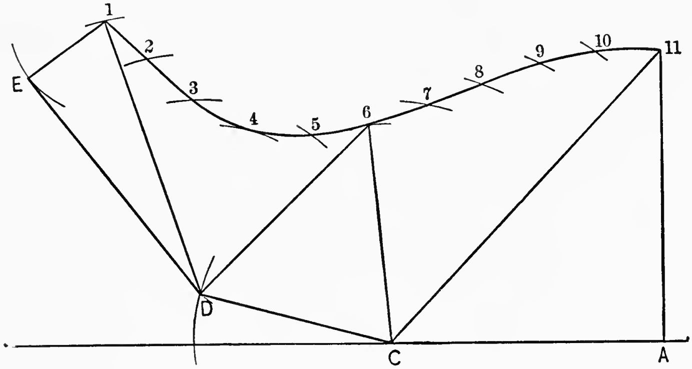


Fig. 30.—Pattern for Body of Offset Shoe.

After the pattern is obtained and the body is cut from it it is necessary to form it properly in order to have it assume the desired shape. To form it break over beakhorn on lines 1 D, D 6, 6 C, C 11 and the other half the same. Break sharp at points D and C and lightly at points 1, 6 and 11, forming the rectangle at D and C and allowing the other end to be formed round. A little practice will overcome any difficulty at this point. The offset section is made in four pieces similar to the regular stack elbow.

There may be found a little difficulty in getting the angle B F, hence we will describe the manner of getting the end piece B C D E F. Draw any right angle, as *a b c*, Fig. 31. Establish point *d* on line *a b* at a distance from *b* equal to the difference between B and G D and C and A D, Fig. 28, as shown by dotted line B X, Fig. 28. With this point as center and with dividers set equal to B C, Fig. 28, or B F, Fig. 27, strike arc cutting line *b c* at *e*. Draw line from *d* to *e*. At right angles with *b c* and at a distance from *e* equal to the required offset (in this case 4 inches) draw line *f g* indefinitely. Parallel with *f g* and at a distance equal to D E, Fig. 27, draw line *h i*. Now with *e* as center and F C, Fig. 27, as radius strike arc cutting line *h i* at *i*. Draw line from *i* to *d*. Let *i j* equal C D, Fig. 27. Draw line from *j* to *k*. Then with *i* as center and *j k* as radius strike arc *l m*. Draw line from *e* tangent to arc *l m*, as shown. Then will *d i j k l e* be the naked pattern for the end pieces for offset section. Allow for all locks.

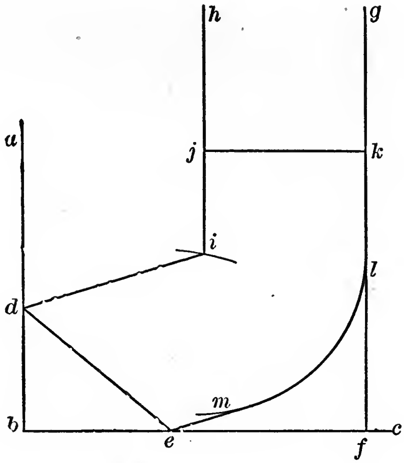


Fig. 31.—Method of Getting Angle.

The front and back of this section is double seamed in and then the section is double seamed to the body at B F, Fig. 27. Before the body is double seamed to the offset section the collar is peened onto the body, thus completing what we have termed an offset shoe, shown in perspective, Fig. 21.

It may be found necessary to have two special stakes to make this shoe to advantage, as shown in Figs. 32 and 33. Both of these stakes are very simple and can be made of wood and cast in any foundry. Fig. 32 is a round head stake, the standard about 1½ inches square. The head is half circle about 5 x 1½ inches and is used in double seaming the back on the offset section, and will be found useful for many other fittings. Fig. 33 is a special stake for double seaming the offset section to the body, with dimensions about as shown.

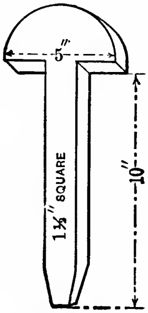


Fig. 32.—Round Head Stake.

It may seem from the length of the description of this fitting that it will be an expensive fitting to make. But it will not be found so by any one who will take time to work it out and get accustomed to making it, as a dozen of them can be made in seven hours. The shoe when done is the best fitting of the kind in the market, and this style, together with the straight shoe, will be found to meet all requirements for stack connections.

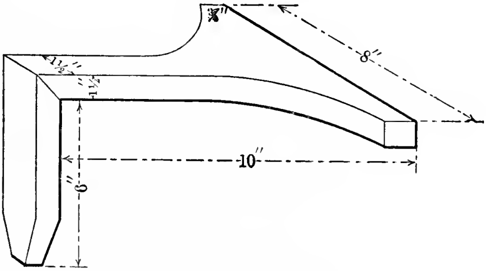


Fig. 33.—Special Stake.

STACK OFFSETS, ELBOWS AND TEES.

The next fitting in order will be the stack offset, as shown in perspective, Fig. 34. This fitting, which is used, as its name indicates, to make an offset in the stack, which is frequently desirable, can be cut from the sheet without waste. But before anything can be done toward obtaining an idea of the sizes and shape to be cut out it is necessary to know what we want, which can only be found by drawing an elevation of the desired article. And as it is sometimes as difficult to draw an elevation as it is to obtain the pattern, we will give an idea of drawing the elevation first. Required, an offset 3 x 10 inches to offset 4 inches at an angle of 45 degrees. Draw any right angle, as A B C, Fig. 35.

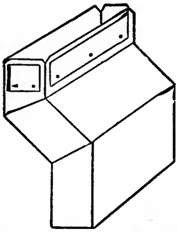


Fig. 34.—Stack Offset·

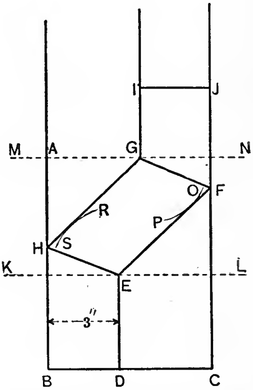


Fig. 35.—Elevation of Stack Offset.

Draw line D E, in length equal to the length required for one end of the offset and at a distance from B A equal to the narrow side of the stack, 3 inches. Draw line C J indefinitely at a distance from D E equal to amount of offset required, 4 inches. As the point F on the line C J establishes the angle of the offset, and as that angle is required to be 45 degrees, it will be seen that it must be at a hight from dotted line K L equal to the amount of offset, 4 inches. Draw line from F to E. Draw line G H parallel with F E at distance equal to B D. Draw line G I parallel with F J and at a distance equal to B D and of a length equal to the required length of the upper end of the fitting. Draw lines I J, G F and H E. Then will B H G I J F E D be an elevation or outline of the required offset. It will be readily seen how the angle and amount of offset for this fitting may be changed to suit requirements.

To lay out the pattern for this fitting proceed as follows: As a sheet of 20 x 28 tin is ample for this fitting complete, let A B C D, Fig. 36, represent said sheet. It is desired that the seam shall be in one of the wide sides of the fitting. Parallel with and at a distance from A B to half the width of the wide side of the stack for which it is to be used draw line E F; at a distance from E F equal to the narrow side of the stack draw line G H; at distance from G H equal to the wide side of the stack draw line I J; at a distance from I J equal to narrow side of the stack draw line K L; at a distance from K L equal to one-half the wide side of the stack draw line M N. Draw lines O P and T U at a distance from B C equal to D E, Fig. 35. Draw line R S at a distance from B C equal to B H, Fig. 35. Draw lines P R and S T as shown. Then will O P R S T U M B be the first section of the required fitting. At a distance from irregular line O to U equal

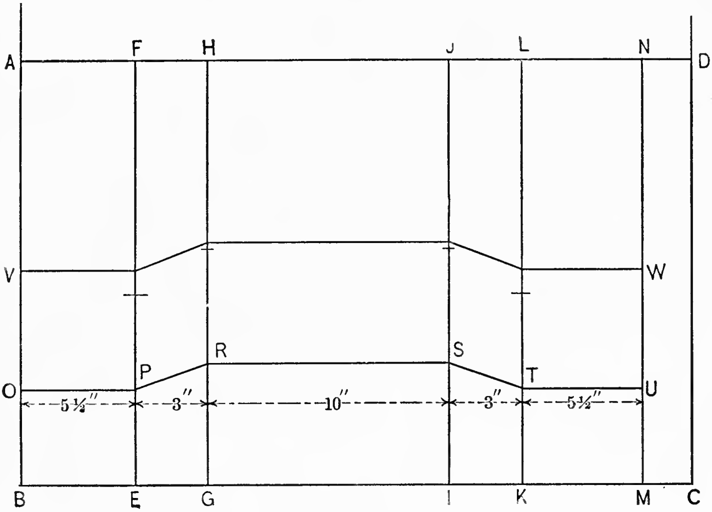


Fig. 36.—Pattern for Stack Offset.

to line E F, Fig. 35, draw parallel line V W. The piece between these irregular lines will form middle section H G F E of Fig. 35, and the remainder of the sheet will form the third section. Allow for locks and cut on line M N. Allow ½ inch for locks on middle section. Before cutting out sections notch at O V and U W and turn the locks. Now cut out the sections and form square at lines E F, G H, I J and K L. Double seam the sections together, as shown at H E and G F, Fig. 35, and you have the required fitting. This fitting, it will be seen, is designed to offset a stack the narrow way of the pipe. It not infrequently happens that it is desired to offset the stack the wide or flat way, and this offset can be laid out and made by the same process as the other by simply producing elevation, as Fig. 35, with the distance B D equal to the wide side of the stack, and the distance B E, Fig. 36, equal to one-half the narrow side of the stack and E G equal to the wide side, and so on to the end.

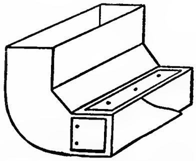


Fig. 37.—Stack Elbow.

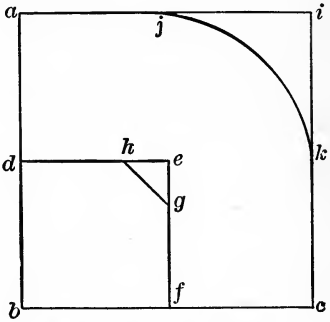


Fig 38.—Pattern for Elbow.

The next fitting is the elbow, as shown in perspective, Fig. 37. This fitting is very useful and simple in construction. It is made in four pieces, double seamed at the corners. The only parts requiring a pattern are the two end pieces. To mark these out proceed as follows: Draw any right angle, as *a b c,* Fig. 38. Then draw right angle *d e f,* equal in length to the required length of the elbow at the throat (usually 4 inches). Parallel with and at a distance from line *d e* equal to the width of the narrow side of the pipe draw line *a i.* Parallel with and at a distance from *e f* equal to the narrow side of the pipe draw line *c i.* At points 1 inch each way from *e* draw line *g h*. With center of this line as center strike arc *j k*, touching lines *a i* and *i c*, as shown. Then will *d h g f c k j a* represent the pattern for end piece. The object of cutting off the corner *g h* is to provide a more easy flow around the corner. Allow for locks and turn in opposite directions. Double seam in a piece fitting the circle from *a* to *c* of a width equal to the width of the wide side of the pipe when finished, then seam in a similar piece formed to the shape of the throat, and the elbow is completed. In a similar manner an elbow for the wide way of the pipe may be constructed.

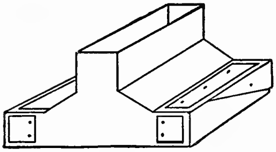


Fig. 39.—Stack Tee.

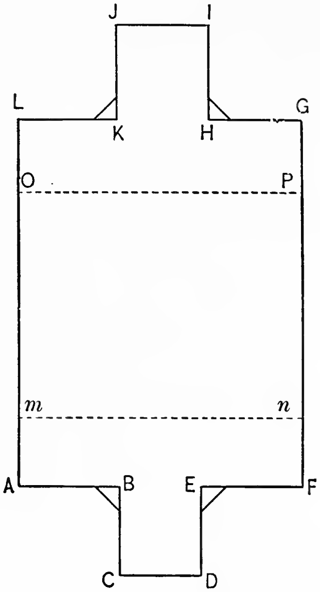


Fig. 40.—Pattern for Tee.

The next fitting will be the tee or branch, as shown in perspective at Fig. 39. It is best to have a pattern for the body of this tee, which may be drawn as follows: Draw right angle equal in length to the required length of the branches of the tee (usually about 4 inches), as A B C, Fig. 40. Opposite and at a distance from B C equal to the narrow side of the pipe draw right angle D E F. Parallel with and at a distance from lines A B and E F equal to the narrow side of the pipe draw dotted line M N. Parallel with line M N and at a distance from the same equal to the wide side of the pipe draw dotted line O P. Parallel with and at a distance from line O P equal to the narrow side of the pipe draw right angles G H I, J K L, with distance between the points H and K equal to the narrow side of the pipe. Draw lines A L and G F and C D and J I. Then will A B C D E F G H I J K L be the pattern for the three sides or body of the required tee. Cut out and brake square at lines M N and O P. Double seam in the two pieces to fit the angles and of a length equal to the wide side of the pipe, and the fitting is completed.

It is best in cutting out to cut at bevel lines at corners B, E, K and H. These lines are found by marking back from the corner 1 inch each way and drawing line from these points. The object is to provide an easy flow for the air around these corners. A tee for the flat way of the pipe can be constructed in the same way, changing the distance between C D and J I to the wide side of the pipe and the distance between dotted lines M N and O P to the narrow side of the pipe.

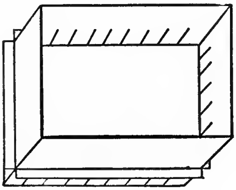


Fig. 41.—Square Register Collar.

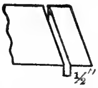


Fig. 42.—Groove in Strip.

REGISTER COLLARS.

Fig. 41 in perspective represents a square register collar to dovetail into a stack. To make this collar of a plain strip of tin and then notch it, and in putting in the stack turn one notch in and one out, is a very unworkmanlike manner of doing it. To rivet a flange on all around takes too much time and is not very neat. The best way of making these collars is as follows: Get out strips of the required width and in length equal to one side and one end. With the folder (which should be a 30-inch folder) turn an edge lengthwise of the strip ¾ inch wide and press down flat. At this point it is necessary to describe a tool that is required to make this collar. Take a piece of cast or wrought iron 3 or 4 inches wide, and if cast iron 3 or 4 inches thick (less will do if wrought iron), and at least 30 inches long, to a machine shop and have a groove cut through the center of one side the entire length, 1/8 inch wide and 3/8 inch deep. When this has been provided, set the double edge of the strip in this groove and bend back each way and flatten down to the stake with mallet, making a strip as shown in Fig. 42, the flange and strip being in one piece. Brake square to the required size and double seam two pieces together at the corner. Then notch to the flange and it is ready to dovetail in the stack, making a strong and neat job and one that is quickly done.

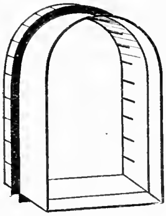


Fig. 43.—Circle Top Collar.

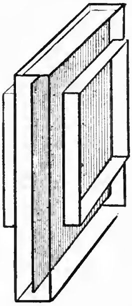


Fig. 44.—Double Stack Head.

For making circle top collars, as shown in perspective, Fig. 43, another device is required and may be made as follows: Take the lower front roll of the stove pipe formers to the machine shop and have a groove cut in it similar to the one mentioned above at about 6 inches from the end nearest the handle. Then get out two strips for the circle top collar of a length that will bring the seam at the top of the circle and in the center of the square end. Mark how far on each piece it will be necessary to form it to have the two pieces make the required circle; then form in the rollers, allowing the flange to run in the groove. If a round collar is required it can be made and formed in the rollers in the same way, either of tin or galvanized iron. This is an excellent way of making furnace collars for flat tops.

In the perspective, Fig. 44, is shown what is known as a double stack head or side wall box. This is simply a piece of the stack with two collars of the required size dovetailed in with partition between and top end closed. The proper way to make these is to get out a strip 20 inches wide and long enough to make the body for the required size. Before forming up, cut out the holes and dovetail in the collars, then form up and put in partition. The collars should be set about 3 inches from the top, and the partition should come up to the top of the collar, leaving a space between the partition and the top of the head. Then when one register is closed and the other open the air can pass over the top of the partition and out the other register. To close the end of this stack head it is not necessary to solder the end piece on or double seam it on, as is generally done, but proceed as follows: Cut out a piece of tin 1 inch larger each way than the size of the head. For instance, if the head is 3 x 10 inches, cut the piece 4 x 11. Cut the corners so they will measure about 1½ inches across the cut. Now with folder turn an ordinary lock on all four sides and all one way. Then turn it over with locks down and turn up an edge about ⅜ inch wide on the four sides, and we have a square countersunk end piece. Next cut each corner of the end of the head that is to be closed straight down about ½ inch. Drop the end piece into the end of the head, allowing the small locks on the end piece to hook over the end of the head. Then with the sharp end of the hammer drive the corners over onto the end piece and close down tight with pliers. Finally, with pliers or mallet flatten the edges that hook over the end of the head down tight all around, and you have a neat, light and solid job without solder or double seam, and one that can be done very quickly. This manner of putting in an end piece will apply to any square pipe or box that requires one or both ends closed.

SIDE WALL REGISTERS.

While discussing registers and register boxes, it is well to consider baseboard registers. These are set partly in the wall and partly on the floor, and possess the advantages of the floor register and common wall register without having their disadvantages. The deflector plates throw the air away from the walls, thereby avoiding discoloring them. The deflector is of considerable importance in securing the discharge of the required amount of air. See Figs. 45 and 46.

In Fig. 45 a cellar pipe is shown connected by the usual elbow to a transition piece fitted to a collar in the register box; the box has also a collar inserted in its top for the wall pipe leading to an upper story. Fig. 46, however, illustrates the manner in which two registers of this kind, set in one register box, are utilized to heat adjoining rooms on the same floor.

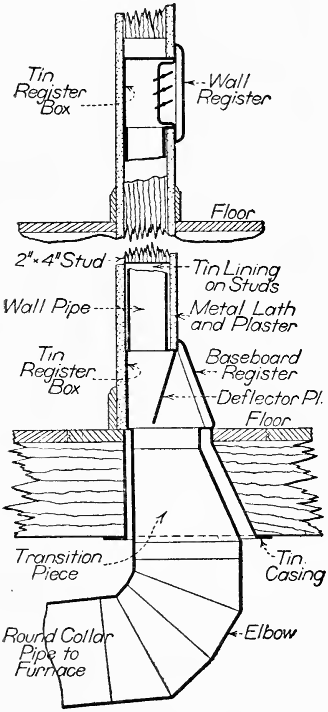


Fig. 45.

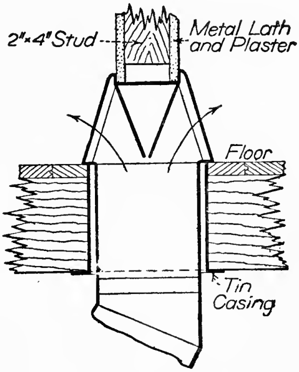


Fig. 46.

Circumstances and general conditions govern the methods of making the boxes and fittings for these registers. Manufacturers as a rule, give detailed instructions in their catalogs.

FITTINGS FOR OVAL PIPES.

As oval, or strictly speaking, flat pipe with semi-circular ends, is a shape popular with many furnace men, it would seem advisable to discuss the making of fittings for this shape.

Naturally the shape of the riser does not govern the shape of the cellar pipe which should be round in any case. whether for individual piping from furnace to risers or for a trunk line system. Of course, trunk lines of square piping as installed by many advocates of this system, is a different proposition and calls for special treatment of all fittings. About the first fitting, therefore, to be affected by the shape of the riser is the starter or boot, and in Fig. 47 is shown a boot transforming from a round cellar pipe, to the shape of the riser and having an offset to pass over a girder or wall.

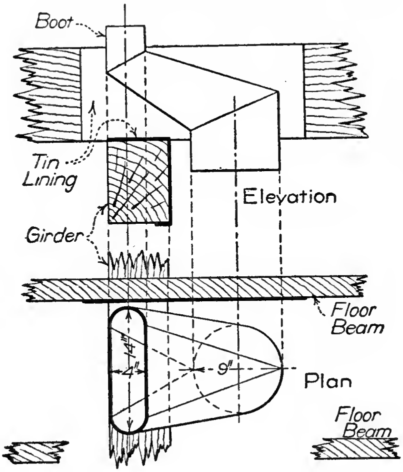


Fig. 47.

At this point of the discussion it is seemingly advisable to state that it is not the intention of the publisher to burden a book of this scope with lengthy expositions of pattern drafting when the same is more adequately presented in special books on the science of the development of the patterns for sheet metal work. Therefore, the readers are referred to the problem on page 124 of volume 9 of "Practical Sheet Metal Work and Demonstrated

Patterns," and problem 209 on page 393 of "The New Metal Worker Pattern Book," for a complete demonstration of the method of obtaining the pattern for the fitting shown in Fig. 47.

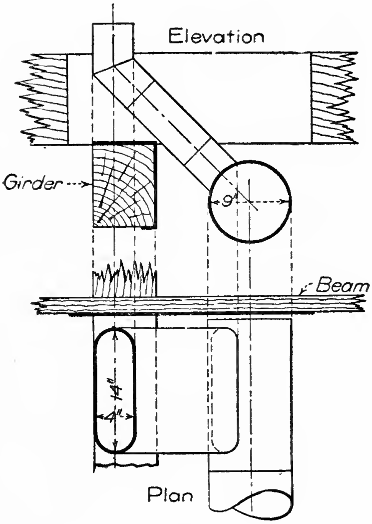


Fig. 48.

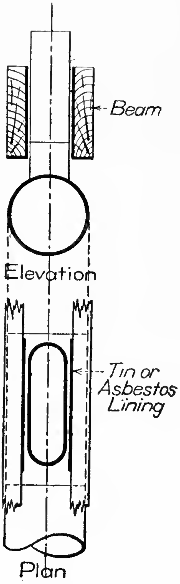


Fig. 49.

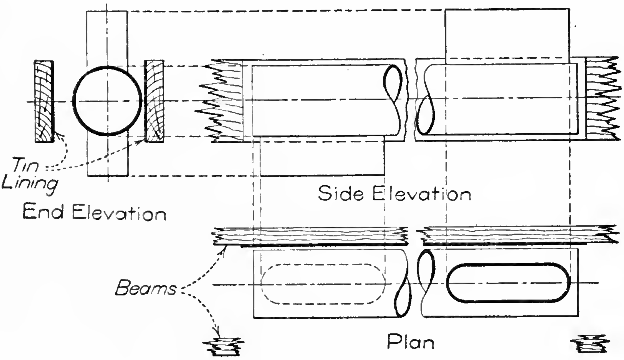


Fig. 50.

Many tinsmiths prefer to make a fitting like that shown in Fig. 48, probably because of the ease in laying out the patterns and making it, although, as can be readily seen, it is not so scientific a fitting as that shown in Fig. 47. The fitting shown in Fig. 48 is simply a joint of round pipe with one of its ends stopped with a head, which can be double-seamed like the bottom of a can and a joint of flat pipe inserted in this. Various applications of this fitting are shown in Figs. 49 and 50.

In laying out the fitting in Fig. 51, draw the end view of the tee, to the top of the flat pipe part, attach half of its profile as shown. Divide the semi-circular part of the profile into equal parts as from 1 to 9. Drop parallel lines down to the circular profile. Continue the line 10–0 to the right and stop off on it the space on the flat profile as 0 to 10 and drop parallel lines as shown. Intersect these with lines drawn from the intersection

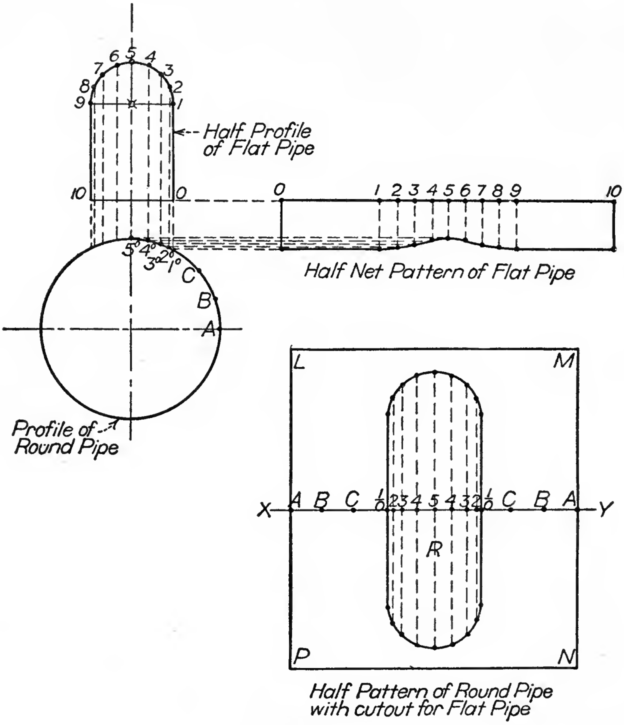


Fig. 51.

on the circular profile as shown and the usual method of tracing a line through the points of intersection will give the net half-pattern of the flat pipe part of the tee. To develop the pattern of the round pipe, draw the line XY and place on it the girth of the round pipe as A to 5, and repeat, as shown. At A and A draw lines of a length to suit the length of pipe required, these lines to be at right angles to the stretchout line X–Y, draw lines to connect these and then the rectangle LMNP is half the pattern of the joint or length of round pipe part of the tee. For the outline of the part to cut out proceed in this fashion, at right angles to XY and through the points 1–0 to 1–0 on this line, draw lines which are to be of a length, each side of XY, as similar lines are in the half profile of the flat pipe. A line drawn through these points is the cut out as shown by R.

EASY-FLOW FITTING FOR BOOT.

Many readers would prefer a true transformation fitting in lieu of the one shown in Fig. 48, and so Fig. 52 has been prepared to convey an idea for a fitting that meets the requirement. The fitting is really a three-piece elbow with the first piece being the regulation first piece of a three-piece square elbow for a round pipe. Similarly, the third piece is the first piece (or the third piece) of a three-piece square elbow for a flat or oval pipe, having the miter along the wide side of the piece. The second piece is the transition from the shape and position of the first piece to that of the third.

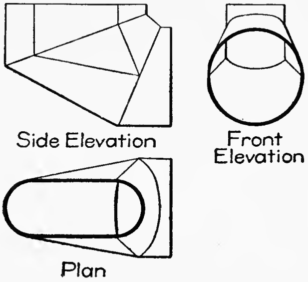


Fig. 52.

When designing this elbow it is well to bear in mind that it is usually placed in a clamped position and hence should be as compact as possible while preserving the full capacity throughout the fitting. The throat therefore should be as small as practicable, and when drawing the elevation, prior to developing the patterns, the customary quarter circle is described as at B in Fig. 53. This quarter circle is divided into four equal spaces, as per the rule for obtaining the rise of the miter line of elbows. From the center draw lines through the first, second, fourth and fifth division points (skipping the third) on the quarter circle, as for instance B 7–0.

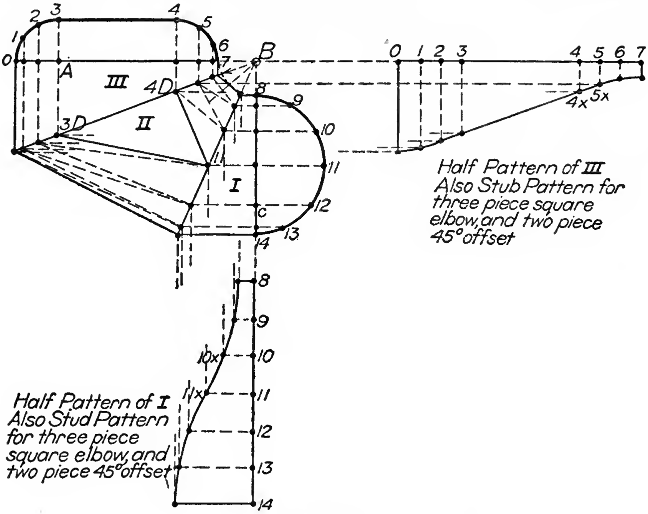


Fig. 53.

Half Pattern of III Also Stub Pattern for three piece square elbow, and two piece 45° offset

Half Pattern of I Also Stud Pattern for three piece square elbow, and two piece 45° offset

On line 7–0 draw the half profile of the flat pipe as shown, continuing the line from 7 and 0 until they meet the miter line. Do likewise on line B 8–14 with the half profile of the round pipe. Connect the points of intersection on the miter lines which gives the elevation of the elbow with attached half profiles.

Diligent search through many books on pattern cutting reveals but one elucidation of the development of the patterns for this object. It is on page 137 of Vol. 9 of "Practical Sheet Metal Work and Demonstrated Patterns," and arbitrarily shows miter lines, whereas binding the rise of the miter lines as here explained is more practical and economical. This exposition will be the basis for the development of similar problems. So to develop the patterns, divide the half circular profile into say six equal spaces and the semi-circular ends of the flat profile into three equal spaces, to correspond with the round profile by having a total of six spaces in both semi-circles. Number these spaces. From these division points in the profile draw the lines to the miter lines as shown and connect by solid and dotted lines.

For the pattern of the flat profile piece number three, one proceeds like this: To the right continue line 0–7 B and place thereon the spaces of the flat profile and drop the usual parallel lines which in turn are intersected by parallel lines, projected from the miter line, all as shown; which, after tracing a line through the intersection points, gives one-half the net pattern of piece number three. Do likewise and as shown for the pattern of piece number one. As was mentioned, these patterns will do for three piece square elbows, that of the flat profile, of course, is for an elbow when the turn is along the wide side. Also, two pieces of number one joined together will make a 45 deg. offset for round pipe and similarly, two pieces of number three will make an offset of 45 deg. for a flat pipe along its wide side.

Before the pattern for piece number two can be developed it is necessary to determine the true lengths of the solid and dotted lines of the elevation. Therefore, as in Fig. 54, draw a horizontal line and place thereon the distances of the solid lines in the elevation, as for instance, 3 to 11 is 3 to 11 on the elevation of piece number two in Fig. 53. Erect verticals from these points as shown. On the first vertical the spaces of the flat profile are set, as for example, 3 A of Fig. 53 is 3 A of Fig. 54, and so on. On the other verticals the spaces of the round profile are set as 12 C in Fig. 53 is 12 C in Fig. 54. The same procedure is followed for the dotted lines in Fig. 55, exercising due care to have the dotted lines join the correct points, as shown.

The pattern may be started to suit one's fancy, still it is a good idea to always first make the triangle representing the flat part of the transition which gives a substantial basis for triangulating the more complex portions of the pattern. So then, as in Fig. 56, draw a line of a length coincident with the length of 3/D to 4/D of Fig. 53, From 4 in Fig. 56 describe a short arc of a radius equal to the length of the line in Fig. 54 marked A B. And from 3 in Fig. 56 describe an arc intersecting the one previously drawn from 4, the radius of this arc to be equal to the length of the line in Fig. 54 designated A/D. Connecting this point of intersection (marked 11) with lines to 3 and 4 realizes the triangle aforementioned. Now, from 4 in Fig. 56 swing an arc the radius of which is equal to the length of the dotted line in Fig. 55 labelled A/B. On this arc step the distance 11x/10x of the miter cut of the pattern of piece number one in Fig. 53 and mark it 10 in Fig. 56. From point 10 in Fig. 56 as a center describe a short arc of the radius equal to the line on verticals 5 and 10 in Fig. 54. From 4 to this arc in Fig. 56 step the distance 4x to 5x on the miter cut of pattern piece number three in Fig. 53. Continue like this until the pattern is completed on both sides of the triangle 3, 11, 4 in Fig. 56 for one-half the net pattern of piece number two; remembering to take the spaces on the miter cuts in Fig. 53 for like space in Fig. 56 and also that the lines 7, 8, 0, 14 of Fig. 56 are shown in their true lengths in the elevation of Fig. 53.

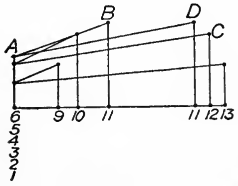


Fig. 54.

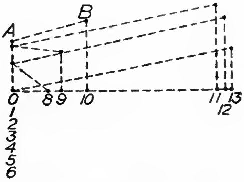


Fig. 55.

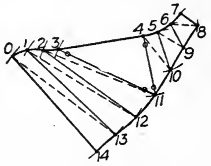


Fig. 56.

In conclusion it is to be said that it can be employed instead of the fitting depicted by Fig. 48 in the situations presented by Figs. 49 and 50 as well as in Fig. 48. In both fittings when used as an offset boot as in Fig. 48 a 45 deg. elbow or offset is required for the flat pipe as can be seen. This elbow has the turn on its narrow side, and in consequence the pattern of Fig. 53 for an offset will not do. By simply turning a quarter around the profile of the flat pipe in Fig. 53 so that the long axis 0–7 instead of being horizontal is vertical as in Fig. 57; the same procedure would then be followed and a three piece square elbow obtained, also a 45 deg. offset, when the turn of the elbow is along the narrow side of the flat pipe. It is an excellent idea to always have the rise of the miter lines for the first and last pieces of a fitting of this kind, so that it coincides with the rise of miter line of some number of pieced elbow; for example, the miter lines in Fig. 47 were for a four piece elbow, and having the patterns already developed for those elbows that much labor is saved, for then those patterns would do for these parts of the fitting.

ANOTHER TYPE OF TRANSFORMATION ELBOW.

In Fig. 57 is shown the different views of an elbow transforming the same as that of Fig. 52 except that the flat pipe is in a different position, that is to say the turn or miter line is on the short side of the flat pipe. The patterns for this fitting are obtained in essentially the same manner as was done for that of Fig. 52. However, Fig. 58 was prepared to show the way the elevation is drawn so that the reader would not be confused in the placing of the half profiles in their correct position. Pieces one and three are parts of elbows and offsets. The patterns for all fittings of a like nature, for example the boot Fig. 47, are developed by exactly the same procedure as outlined for Fig. 53, the elbow shown in Fig. 57 like that in Fig. 52 can be employed as a

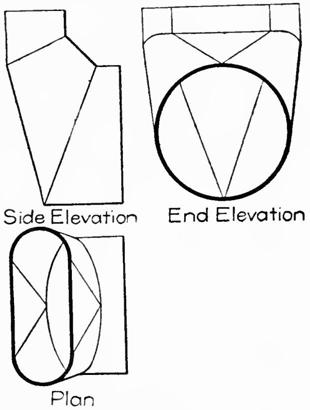


Fig. 57.

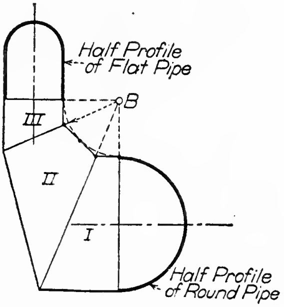


Fig. 58.

starter or boot, providing though that no girder or wall requires an offset, which by the way applies to Fig. 52 also. Fig. 57 can also be used under the floor and between beams to connect different risers as in Fig. 50 and in many other positions which no doubt will come to the mind of the reader.

Another important fitting which is in the same category as these is a reducing elbow for round pipes of different diameters as is illustrated in Fig. 59. Although this fitting has no flat triangular sections as in an oval pipe, it nevertheless has its patterns developed by precisely the same process as the others.

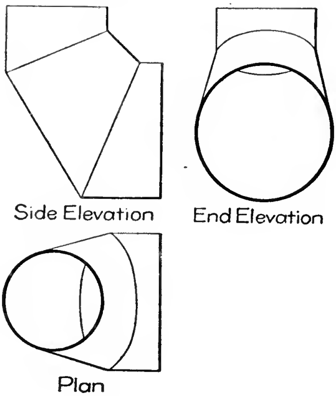


Fig. 59.

FITTINGS HAVING PROFILES IN PARALLEL PLANES.

One of the most common fittings is that termed a straight starter or boot as shown in Fig. 60. This fitting, as with the others discussed, transform from a round shape to an oval with however this difference, it has no turn; that is to say both pipes would be in line or speaking geometrically, the profiles are in parallel planes and a few fittings in this class will now be discussed.

The development of the patterns in Fig. 60 are clearly explained in Problem 188 of "The New Metal Worker Pattern Book."

In Fig. 61 is shown a boot that has the profile of the flat pipe placed centrally to the profile of the round pipe, or in other words the long axis of the flat profile is in the same vertical plane as the axis or diameter line of the round profile. A demonstration of the pattern cutting for this problem can be found in "The New Metal Worker Pattern Book" and also is very ably discussed on page 107 of Vol. 9 of "Practical Sheet Metal Work and Demonstrated Patterns."

Still another fitting of similar nature to these is a reducer for round pipe. That shown in Fig. 62 is when the profiles in plan are not concentric so that the fitting has a straight back similar to Fig. 60. The pattern problem is for a scalene cone and is demonstrated by many problems in "The New Metal Worker Pattern Book." If the profiles be concentric in plan, presenting then a fitting like that of Fig. 61 the pattern problem is then simply a cone development. Should, however, the profiles be eccentric in plan and so that one is outside, or partly so, of the other the problem then becomes identical to Fig. 58 and would be similarly developed. On page 92 of Vol. 10 of "Demonstrated Patterns and Practical Sheet Metal Work" is presented a solution of this problem, but it is not recommended because the intersecting lines of the collars are parallel. This restricts the area of the transition piece of the fitting. These miter lines should be as in

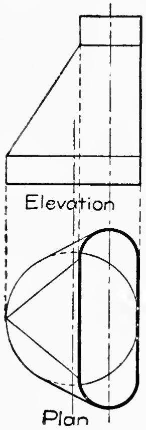


Fig. 60.

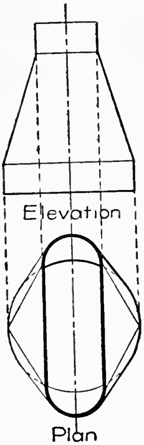


Fig. 61.

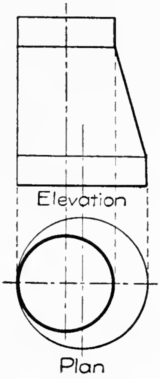


Fig. 62.

Fig. 58, hence, as was said, the problem is similar and should have its patterns developed in the same manner.

Two other fittings that come under the same classification as the immediately foregoing are those shown by Figs. 63 and 64. Fig. 63 makes a quarter turn in a line of flat piping for cross partitions and directly in the corner, while Fig. 64 also makes a quarter turn of a line of flat piping it does so centrally as can be seen. This fitting is decidedly more scientific and practical than the square box with attached collar which is so often used, and an interesting exposition of these problems is presented on page 108 of Vol. 9 of "Practical Sheet Metal Work and Demonstrated Patterns," it to be remembered that both fittings would be developed by the same process.

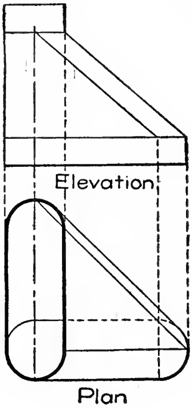


Fig. 63.

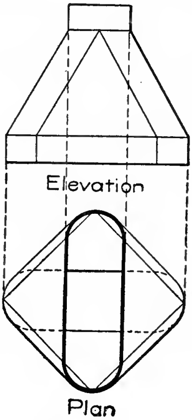


Fig. 64.

In concluding this discussion of fittings and the like it is to be said that numerous other fittings would be presented and discussed would space allow. Those chosen are representative ones, and in the books referred to herein the reader may find a large number of other interesting problems pertaining to furnace work. The reader is also reminded that the publishers are always anxious to assist and that they maintain a large consulting staff of experts and will gladly help and advise readers who have problems to solve and cannot find the solutions in books already published.

CHAPTER XII.

MISCELLANEOUS NOTES AND DATA FROM VARIOUS SOURCES ON FURNACE HEATING.

The principle of heating a room with warm air was introduced by Benjamin Franklin in 1742. His stove of that date contained a chamber surrounded by iron plates and fed by a cold air box, the openings for the escape of the warm air being in the sides or jambs at the top of the chamber. The warm air furnace of the present day is identical in principle, but more elaborated.

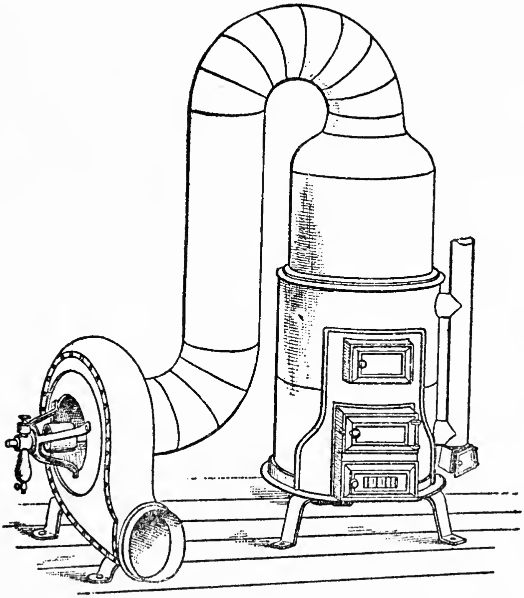


Fig. 65.—Embryo Idea of a Fan Furnace Apparatus, 1870.

In the B. F. Sturtevant catalogue of 1870 what appears to have been the embryo idea of a fan furnace apparatus is shown.

Fig. 65, reproduced from a cut therein shown, serves very clearly to give an idea of the arrangement whereby the heated air from the hot air furnace was to be drawn through a connecting pipe to the fan and thence discharged to any desired point. There appears, however, to have been no general application of this style of apparatus.—*The Metal Worker.*

In an article entitled "Early Hot Air Furnaces" in *The Metal Worker* the writer stated that "it is probable that the modern hot air furnace is the development of a large cast iron stove placed in a brick chamber, having one or more registers directly above it. Just who was the first man to improvise this heating apparatus, or when it was done, is difficult to learn, although a great many people would be willing to thank him for the excellent heating system which has been developed from his experiment. The date, while it cannot be fixed with certainty, was in all probability prior to 1836. There is an impression among many of the older hot air furnacemen that experiments in this line were numerous in the vicinity of Hartford, Conn., and along about 1840 a number of different hot air furnaces are known to have come into existence. The construction of the early furnaces shows that the principle of heating with hot air had received considerable study, and that some of the experimenters had a keen appreciation of the principles involved and also the necessity of making economy and efficiency go hand in hand."

In this article a cut of the Culver furnace, made in 1845, is shown with a firebrick firepot. The products of combustion were carried from the top of the radiator to a series of pipes at the back, so arranged that an indirect draft could be effected by forcing them to pass down one pipe and up another, until the final outlet was reached; or, by opening a damper a direct draft could be secured. The furnace was used with brick setting. Another pattern of the furnace was put on the market in 1846 with a cast iron firepot. This furnace had a cast iron radiator at the back of the furnace, through which the products of combustion were forced to pass, the durability of cast iron as compared with wrought iron for withstanding the moist air of the summer season having been noticed.

Another illustration shows a furnace in which the products of combustion pass up through tubes. A cut of a furnace popular in 1860 is shown, having vertical wings or flanges cast on the firepot to give extended surface. The products of combustion pass to a large radiator, then called the Globe crosshead radiator, above the combustion chamber and to a supplementary radiator with diving flue.

CAUSES OF FAILURE IN FURNACE HEATING SYSTEMS.

C. E. Oldacre, in an article in *The Metal Worker*, writes as follows:

After investigation of hundreds of heating plants, running well up into the thousands, I assign the following as the principal causes of many failures in hot air heating that have occurred in the past—but not occurring so frequently as we more closely study and clearly understand our various undertakings:

Furnace too small.
Furnace improperly located.
Draft not sufficient.
Cellar pipes not properly arranged.
Cellar pipes not properly proportioned.
Cellar pipes too small.
Some cellar pipes too large.
Insufficient pitch to cellar pipes.
Friction from the use of two-piece elbows.
Too much friction in various fittings used.
Failure to use fittings that provide easy turns.
Too much friction at bottom of stack or flue.
Lack of protection to cellar pipes when subject to currents of cold air.
Lack of fresh air duct.
Insufficient size of fresh air duct.
Lack of means for adjusting fresh air duct.
Fresh air duct taken from wrong side of house.
Fresh air duct taken from a point affected by adverse air currents.

Fresh air ducts closed entirely by slides.

Fresh air ducts wrongly connected to furnace.

Improper arrangement of return duct, where used in connection with fresh air duct.

Screen of too small mesh used over fresh air inlet.

Heat flues too small.

Heat flues improperly located.

Heat flues not proportioned to their work.

Heat flues not protected in outside walls.

Heat flues not protected at other cold points.

Heat flues diminished in size at various joints of stack.

Heat flues diminished in size in changing shape of same.

Heat flues diminished in size by register body projecting too far into flue.

Heat flues diminished by too small dampers.

Too many heat outlets on one stack.

Registers too small.

Register not of proper shape.

Register of too close pattern.

Lack of ventilation.

Too much cold air entering through loose fitting doors and windows.

DIRECTIONS FOR SETTING AND PIPING FURNACES.

The following directions are reprinted by permission from the catalogue of the L. J. Mueller Furnace Company:

Determining the proper size and location of furnace and registers, also size of air conducting pipes, is a matter of judgment in each special instance, the successful operation of the plant depending on these important requisites. The construction and exposure of the building, prevailing winds and climatic conditions, also favorable or unfavorable location of the furnace and registers must all be considered. In all instances a furnace a size larger than absolutely necessary will be more economical, more durable and in every way more satisfactory than one just large enough to do the work required.

The furnace should be placed as nearly central to the rooms to be heated as possible, favoring that direction from which the prevailing winds blow. In setting the castings see that they are perfectly level on the foundation, and that the faces of the mouthpieces of ashpit and feed section, dome, or that of radiator, as the case may be, are plumb, so that the door shield will properly fit against them. Mix dry cement with water to the thickness of mortar. Thoroughly cement all joints with this, excepting the flanges on the door shields; on these use asbestos cement. Spread this carefully around the shield flanges and also in the cup joint where the shields join; then place the shields in position and draw them up tightly and evenly with bolts. See that the smokepipe fits tightly over the smokepipe collar, and do not allow it to project into the chimney flue. Before connecting the smokepipe with the chimney see that there is a good draft and that the flue is clear of obstructions, such as brick, mortar or soot. Carefully line with tin all woodwork in close proximity to the smokepipe, leaving space for circulation of air around it.

Registers without valves must always be used where but one is installed for each furnace, or where several registers are placed in the same room, taking the entire capacity of the heater.

Collars attached to the side of the hood in case of portable furnaces, or connected to the inner brick wall in case of brick set furnaces, must be placed close to the top, and have their upper sides on a level with each other, irrespective of their size.

The warm air pipes in the basement should be straight and have all the elevation possible (not less than 1 inch to 1 foot). If necessary to make turns, avoid all sharp angles. The only power that moves air through the pipes is that caused by the tendency of heated air to rise; avoid horizontal and crooked pipes. Protect all warm air pipes from cold air currents, because these will chill the pipes and stop the circulation of air within. Pipes exposed to cold currents, or where they pass through cold rooms in the basement, should be made double or wrapped with air cell asbestos paper. Provide all warm air pipes with dampers close to the furnace.

The partition pipes or stacks must be made double, or, if single, covered with asbestos paper to protect the woodwork, and also prevent the loss of heat. We recommend double pipes. The stacks should be connected to the basement pipes by means of shoes or boots. In case a chimney flue is used for a warm air duct, a single tin pipe should be placed inside of it. Warm air pipes should not be placed in outside walls. Stacks leading to the second floor can be about 25 per cent. smaller in capacity than the warm air pipes connecting them to the furnace, on account of the increased velocity of air in vertical pipes.

The cold air supply, if taken from the outside, should enter preferably that side toward which the prevailing winds blow during the winter, which is usually from the west and north. The capacity of the cold air duct should be equal to three-fourths of that of all warm air pipes. The cold air duct must be provided with a suitable slide or damper to regulate the supply, and the outside opening should be protected with a wire guard of not smaller than ½-inch mesh. If it can be conveniently arranged, we recommend the building of a cold air room. This can be built of brick or wood, but care must be taken to have it tight.

If the air supply is taken from the inside it should be of the full capacity of all warm air pipes.

We recommend the use of both outside and inside air, enabling the user in severe weather and during the night to use inside air. Where the same air duct is used for outside and inside air, it must be provided with a damper or slide, so that the air can be taken from either source.

For stores, churches, halls and other buildings where the space to be heated is all one large room, the best and cheapest manner of installation is to place directly over the furnace one large register face with border, having a capacity equal to that of the furnace, connecting the casing hood to the register border with a discharge pipe of the same size as the register face, thus saving the cost of a register box. When so installed the whole capacity of the furnace is discharged through the register face, and there being no heat lost through radiation from warm air pipes, and but little friction to overcome, this gives the furnace a greater capacity than it would have for dwellings. When set in this manner a cold air register face or faces equal in capacity to the warm air register face should be used for conducting the cold air from the room to be heated back to the furnace.

Remember that the successful working of the furnace depends largely on the chimney. The furnace smoke flue should be a separate one, with no other openings or connections, as straight as possible, of the same area from top to bottom, extending several feet above the highest point of the roof, and provided with an ashpit door below the smokepipe opening. We recommend that the furnace smoke flue be not less than 8 x 12 inches inside measurement. However, an 8 x 8 inch flue with a good draft may answer for heaters with an 8-inch or smaller smokepipe. No smoke flue should be less than 8 inches in depth. Long, narrow flues, such as 4 x 12 or 4 x 16 inches, are no good.

LOCATION OF HOT AIR REGISTERS.

A writer in *The Metal Worker*, has this to say regarding the location of hot air registers:

When registers are located near inside walls less pipe is necessary and a sharper pitch may be obtained than when they are placed near outer walls. On the other hand, the loss of heat through the ceiling will be greater. This is of little consequence except on top floors. When possible registers should be located about midway of partition to permit the warm air to reach all points along the exposed walls with nearly equal ease. The rapid circulation caused by the downward currents along the cool outside walls, coupled with the upward current of inflowing air from the register near inner wall, gives an even temperature throughout the room. The current of hot air is flattened on striking the ceiling and passes without perceptible draft over the heads of the occupants to the outer walls. In effect this is similar to that produced by the overhead system of heating mills, where coils of steam pipes are hung from the ceiling a few feet from the exposed walls. Even when there are no machines or belts to stir up the air this system works well.

Following the same theory of circulation, it is the established custom in school houses to place the warm air inlets on inside walls. Those advocating the placing of registers near outer walls may refer to the practice of so locating them in indirect steam and hot water work. This is done, however, chiefly from considerations of economy in piping, since when the stacks are placed near the exposed walls both cold and warm air pipes may be made very short. With a furnace system having registers similarly placed the hot air pipes would stretch from one side of the house to the other, their excessive length reducing the pitch and increasing the friction and loss of heat.

When registers are placed below windows the upward current of hot air meets a downward current from the glass, which tends to retard the flow through the pipes. Back drafts through such pipes are more likely to occur (in case the cold air box is insufficiently open) than through short pipes having a sharper pitch.

As bearing on this subject the effect of the location of direct radiators may be cited. They are commonly placed under windows: 1. To counteract down drafts. 2. Because they give off the most heat in that position. 3. Because such location seldom interferes with the arrangement of furniture. The objections to a furnace register location near outer walls have no force when applied to radiators. With evenness of temperature and comfort in rooms of moderate size and glass surface the location of the radiator has little to do. Wherever placed the warm air will seek the cold walls and a continuous circulation will be established.

FURNACE AIR SUPPLY.

The Metal Worker published an editorial of interest on the above subject, which is reprinted here:

Laws to compel the change of air, in school buildings in particular, by taking fresh air from out of doors, warming it and then sending it into a building, with provision to exhaust the air previously contained therein, have had a noticeable influence in the East on the method of supplying furnaces with air. It is quite a common custom, and one that is growing, to provide the furnace with a duct connected at the bottom and leading to a point outside of the building, so that the exterior air can readily flow in, to pass over the heated surface of the furnace and be distributed through the building by means of the hot air pipes. The size and location of this air supply duct have remained an unsolved problem to many in the furnace trade, although experienced men favor running it from the most exposed side of the building and providing it with a capacity equal to from two-thirds to three-quarters of the area of the combined hot air outlets from the top of the furnace. Evidently this custom is by no means universally observed, at least in some sections, in the West. The conditions there are somewhat different from those obtaining in the Eastern part of the country. The Western winters are apt to be more severe throughout their entire length, and the period at which the mercury ranges below zero is much longer extended. Consequently the heating of buildings with furnaces is a somewhat more difficult problem in that section. Quite a strong favor is shown to the use of return air ducts in the West. In many instances provision is made to take some air from out of doors, but the damper in this section of the air supply duct is frequently closed as soon as severe weather is experienced and the supply of air for the furnace is taken from the inside of the building. Whatever may be urged against this practice from an advanced sanitary standpoint, the arguments are strongly in its favor from an economic point of view. There is no question but that the building in which the heating is so arranged can not only be more readily warmed and the temperature more evenly maintained, but also with a much smaller consumption of fuel than if the entire air supply was taken from out of doors with the mercury from zero to 20 or 40 degrees below. The fact that this method of using furnaces has been customary for many years also strengthens the position of those who advocate it. When the question of the purity of the atmosphere in such buildings is raised it is pointed out that the buildings are occupied by comparatvely few people to vitiate the atmosphere, and that a sufficient change to maintain a satisfactory purity is effected through the natural leakage around the crevices of the windows and the building generally, in addition to the large amount of air that will naturally be admitted through the opening and closing of doors.

INSTALLING FURNACE PLANTS IN OLD HOUSES.

The following extracts are reprinted from an article by M. L. Kaiser in *The Metal Worker:*

Floor Registers.—The better way to provide the requisite area of warm air flues for the first floor is to place the register in the floor. The householder and his wife will sometimes refuse to consider the placing of floor registers, however, on account of the cutting of carpets. The fact remains that by using a floor register the entire area of the leader pipe, whether it be 8 inches or 14 inches in diameter, may be made available, while the maximum available area with a partition flue placed in a house already built is reached at 4¾ x 12 inches for the first floor and 3¾ x 12 inches for the second floor. The objection that the floor register collects dust is also true of the wall register, as any one who has removed a wall register which has been in use can testify. The argument in its favor is that the floor register may be easily removed for cleaning, while the old people of the house will be quick to appreciate the advantage of being able to warm the feet over the floor register.

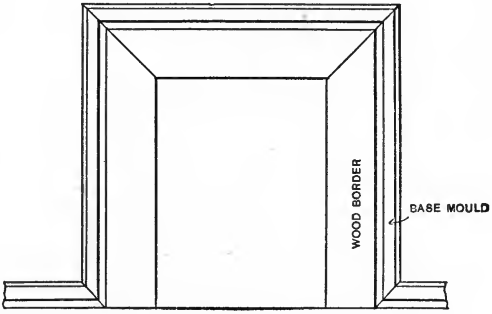


Fig. 66.—Installing Furnace Plants in Old Houses.—Method of Arranging for Side Wall Register.

Arranging Side Wall Registers.—To obtain the maximum area from 4¾ x 12 inches, or 57 square inches, for the first floor partition flues, it is necessary to cut away the lath and plaster back of the basebord, and let the asbestos covered tin pipe rest against the baseboard and flush with the finished wall surface. To make this effective there should be some means of so placing the register that it will not extend into the tin flue, as the flue would thereby be reduced in area just as surely as though the entire flue were the size of the space remaining. One way to accomplish this is to miter a 1 x 3 inch strip around the register opening and nailed to the studding, with the bottom ends resting on the baseboard. The base mold may either be finished against the strip or mitered around it, as shown in Figs. 66 and 67. The face of the strip is flush with the base, and the register flanges rest against the strip at the top and sides and against the baseboard at the bottom. The edges of he strip under the register flanges should be covered with tin and asbestos. A convex register used in connection with this plan entirely obviates the obstruction of the flue by the register body.

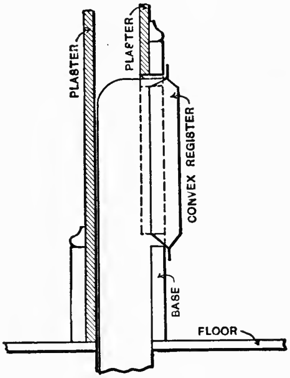


Fig. 67.—Side View of Side Wall Register Connection.

SIZES OF SMALL PIPES BASED ON CUBIC CONTENTS OF ROOMS.

From a perusal of various rules given in manufacturers' catalogues, the subjoined has been prepared as representing a fair average. These rules afford a rough check as to pipe sizes determined on the basis of equivalent glass surface:

For dwellings allow 1 square inch of pipe area in first floor living rooms to each 20 to 25 cubic feet of space. In second floor sleeping rooms allow 1 square inch of pipe area to each 30 to 35 cubic feet. In bathrooms allow 1 square inch of pipe area to each 15 to 20 cubic feet of space.

For churches and halls an allowance of 1 square inch of pipe area to each 40 to 50 cubic feet of space will give a rough approximation as to pipe sizes.

Examples: Living room, 16 × 16 × 10 = 2560 cubic feet. Divide by 25 = 102 square inches. Use 12-inch pipe.

Sleeping room, 14 × 15 × 9 = 1890 cubic feet. Divide by 35 = 54 square inches. Use 8-inch pipe.

Bathroom, 6 × 9 × 9 = 486 cubic feet. Divide by 20 = 25. Use 6-in, if short run.

MEANING OF "EQUIVALENT GLASS SURFACE."

In response to a question as to the meaning of the words "wall surface," "glass surface," and "equivalent glass surface," and their use, this answer was given in *The Metal Worker:*

By measuring the length of the outside walls of the room to be heated and multiplying by the hight of the ceiling, the wall surface in the room is determined, after the glass surface exposed in the windows has been subtracted from it. The glass surface is obtained by taking the number of windows in the room and adding together the total amount of square feet of surface presented in each. The equivalent glass surface is determined by assuming that the cooling effect of 4 square feet of exposed wall surface is equal to that of 1 square foot of glass surface. So, after subtracting the glass surface presented in the windows from the wall surface and dividing this amount by 4 and adding the result to the glass surface in the windows, the equivalent glass surface exposed by the room is found. Dividing this by the cross sectional area of the pipe gives the ratio of pipe area to equivalent glass surface (E.G.S.).

A number of furnace heating systems have been described in *The Metal Worker,* and the proportion of hot air pipe area to the space heated has been given in each case. By a comparison one can satisfy himself as to what is the proper proportion between the area in the hot air pipe and the space to be heated. A definite rule cannot be readily given, but with good heating work it will not vary greatly for first floor rooms from 1 square inch of area in the hot air pipe to from 25 to 30 cubic feet of space. We have given the wall surface and equivalent glass surface in these cases so that the proportion between them and the area in the hot air pipe can be studied, as these are the factors in the work to be done which are most important to be considered. In order to keep a building at a comfortable temperature during the cool season it is necessary to continually supply the heat which is lost through the walls and through the glass, consequently it will be better practice to consider the wall surface and the equivalent glass surface than to consider the cubic space alone.

Those who are looking for a rule for determining the size of hot air pipes required for rooms will find it much safer to reduce the wall surface of a room to equivalent glass surface than to follow some of the rules using cubic feet of space as a basis that have formerly been used.

PROPORTIONS OF FURNACES AND FURNACE HEATING SYSTEMS.

The following extracts are taken from an article by J. J. Blackmore in the *Engineering Magazine*:

Some manufacturers advocate large firepots, others deep firepots. Some use a comparatively small amount of heating surface over the firepot, and claim that highly heated surfaces do not have a detrimental effect on the air, while others claim that large surfaces over the firepot give the best results. A careful comparison will show that the best and most expensive furnaces of all reputable makers have a heating surface definitely proportioned to the size of grate, and that the proportion of heating surface is larger than it is in cheaper grades of heaters. This indicates that large surface areas for the air to impinge upon have been found advantageous. All manufacturers are not agreed on this point, however. It is a somewhat difficult task for the lay mind to determine which of the various kinds is the best.

Without trying to settle the question, I will describe the conditions under which a furnace has to perform its work and how the heat it gives off may be utilized. The first task of the furnace is to burn the fuel properly—*i. e.,* it must have a chamber where the various elements in the fuel and air may be united to produce combustion. This function of the furnace has a much greater importance than is usually ascribed to it, and, as a result, losses from imperfect combustion are frequent. In the burning of fuel rather more than two-thirds, under certain conditions, may be burned to carbonic oxide, an intermediate product of combustion; and, unless this gas can be further converted into carbonic acid, most of the heat which the fuel might have developed goes up the chimney with the smoke. Carbonic oxide is a combination of 1 part oxygen with 1 part carbon, usually written CO. The addition of 1 part of oxygen will complete the combustion and develop all the heat which the fuel can yield.

If the draft of a furnace is poor, or if the firepot, or combustion chamber, is too small, enough oxygen will not be brought into contact with the fuel, or gases, to enable them to give off the heat that is in them; hence it is important that a good chimney flue should be provided, and that the furnace room should be properly supplied with air. The furnace should have a space above the fuel at least three times as large as the firepot, to allow the gases room for combustion. The size of chimney required depends, of course, on the size of the house, but a furnace should not be connected to a flue less than 8 x 12 inches, and houses containing more than 20,000 feet of space should have larger flues.

In a pound of the average grade of anthracite coal there are about 14,000 units of heat (1 unit is the amount of heat necessary to raise 1 pound of water from 60 to 61 degrees F.) In burning to carbonic oxide (CO) from 4000 to 4500 units only are given off; the rest may all be lost through the fault of a poor draft or a badly constructed furnace.

If a furnace is constructed with a large firepot and only a small amount of heating surface above it a large portion of the heat will be wasted (no matter how perfect the combustion may be), for the reason that the air coming into contact with the outer surfaces cannot carry off the heat as rapidly as it is generated, and the surplus escapes up the chimney.

We will now consider how the heat is taken up by the air as it comes into contact with the heated surfaces of the furnace. One thousand cubic feet of air at the temperature of zero weigh 86.4 pounds, and, as the specific heat of air is 0.238 and the temperature of the air delivered through the registers should be 140 degrees, there would be absorbed by 1000 cubic feet 2878.4 units of heat, as follows: $a \times b \times c \times d = x$, in which a represents 1000 cubic feet of air at zero, b the weight of a cubic foot at zero, 0.08641; c the specific heat of air, 0.238; d the number of degrees to which the air is heated, 140; and x the heat units absorbed by 1000 feet of air. To change three times an hour the air contents of a house having a capacity of 20,000 cubic feet absorbs in zero weather 172,704 units of heat, equal to 12.33 pounds of coal per hour, presuming no waste of heat. But even in well constructed furnaces there is a loss of 25 per cent.; hence it would be necessary to burn 16.44 pounds of coal per hour to do this amount of work in zero weather. As a fire burns actively for 16 hours and at one-half its capacity for 8 hours in the 24, we have 20 hours at the rate of 16.44 pounds per hour, or a consumption of 328.8 pounds per day, or, again, very nearly 1 ton of coal in six days.

Taking the average winter temperature in the northern portion of the United States as 40 degrees it would be necessary to heat the air 60 degrees, requiring 6½ pounds of coal per hour, or, for 200 days, 13 tons of coal.

THE INSTALLATION OF FURNACES.

The following is from a paper read by R. S. Thompson, Springfield, Ohio, and Jas. H. Brown, Rochester, N. Y., to the convention of National Association of Master Sheet Metal Workers, Cleveland.

The author, W. G. Snow, recommends that without recirculated air 1 sq. inch of grate (average fire pot area) should be provided for 1½ square feet of E. G. S.

The furnace should have 1 square inch of grate surface to 2 2-10 square feet of equivalent glass surface. Locate the furnace as nearly as possible to the center of the area to be heated. This will usually result in the pipes radiating more uniformly in all directions from the furnace and secure better results than if the greater number are taken from one side. If found necessary to vary this on account of chimney or other obstruction, place it to the side of the center toward the prevailing winds.

If the furnace casing is made with a truncated cone hood, there should be an inverted cone of tin inside the top to divide the current of hot air and assist in distributing it to all the pipes. If a flat top casing is used group the pipes as near the center as possible, where they will get the hottest air.

An inner lining of tin riveted to the casing will lessen the loss of heat in the cellar, but by all means suspend a black sheet lining about an inch from the inside of the casing. This will act as a powerful supplementary radiator. The relative radiating power of tin is given as 27, while that of black sheet iron is 345. As air is heated only by contact with a hot surface, it will be seen that these black sheets very materially increase the heating capacity of the furnace.

The use of asbestos lining is open to objection, and it is a question if it serves any good purpose.

The capacity of each hot air pipe should be proportionate to the size of the room to be warmed, allowance being made for exposure and glass surface. If more than one register is used on a pipe the size should be increased proportionately. Tables are published giving definite information on this point. A good general rule is to allow 1 square inch of cross sectional area of hot air pipe to $2\frac{1}{10}$ square feet of equivalent glass surface. A more conservative rule is given on page 225. Very good results are obtained by the use of deflecting registers where from two to four registers are served by one pipe.

Cellar pipes should in all cases be run straight where conditions permit. Use elbows made with as large a sweep as possible. It is stated that a 12-inch elbow with a 6-inch throat has a resistance equal to 121 feet of straight pipe, while an elbow of the same size with a 60-inch radius has a resistance equal to 8 feet of straight pipe.

The fresh air duct should have a capacity of at least two-thirds the aggregate area of all the hot air pipes. It is good practice to supplement this by the use of a cold air exhaust pipe from the hall on the first floor. If this is done the combined area of the two should be equal to the combined area of all the hot air pipes. The inlet should be on that side of the house which will result in the air traveling with the prevailing winds, not against them.

A damper or slide should be provided, but it should not be made so that the passage of air can be entirely shut off.

If the duct is run overhead care should be taken that the vertical shaft does not drop too near the furnace. There is danger that the air may become rarefied by heat radiated from the furnace and cause a back draft or outflow instead of an inflow.

The draft of the furnace should be controlled by a lift check damper, connected with the smokepipe. An excellent method of attaching it is to extend the smoke tee down vertically for about 2 feet below the smoke collar and attach a 90-degree elbow on the lower end. In this elbow place a lift check damper. In this arrangement there is no danger of escaping gas. The check damper and the direct draft in the ashpit door should be connected by chains with a plate on the first floor, from which point they may be operated.

Mark each hot air pipe near the furnace, designating the room which it serves, so that the dampers may be operated in the cellar without confusion.

Stipulate in the contract that the owner is to furnish a chimney of good and sufficient draft.

To ascertain the wall surface in a house wholly exposed, with no re-entering angles, add extreme length to extreme breadth, multiply by combined hight of ceilings and multiply product by 2.

To ascertain the number of cubic feet of air per minute at a temperature of 140 degrees required to maintain a temperature of 70 degrees, with the outside temperature at zero, divide the number of square feet exposed wall surface by 2. (This approximate rule is fairly close when glass surface is equal to about $\frac{1}{6}$ the total exposure of glass and wall combined.—W. G. Snow.)

To ascertain in square feet the area of air supply divide the exposed wall surface by 600.

To ascertain the grate surface required where all outside air is used divide the exposed wall surface by 900. When all inside air is used divide by 1500. The product is square feet of grate surface.

To ascertain area of leader pipe for a first-floor room where pipe is not over 15 feet long and has no bad bends, divide exposed wall surface of such room (in square feet) by 3. The product gives area in square inches. If pipe is over 15 feet long add 20 per cent.

To ascertain the area in square inches of the leader pipe for a second-floor room divide the number of square feet exposed wall surface of such room by 6, if pipe has no bad bends and is not over 15 feet long. If over 15 feet long add 25 per cent. If over 25 feet long add 50 per cent.

The area of a perpendicular stack should be two-thirds that of the leader pipe feeding it.

A 45-degree horizontal bend in a leader pipe should be compensated for by an increase of 20 per cent. in area. A 90-degree bend should be compensated for by an increase of 30 to 40 per cent. in area.

In *The Metal Worker*, an editorial study of the rules given above by R. S. Thompson and Jas. H. Brown was given as follows:

The rules all refer to the exposed wall surface of a building taken as a whole. In other words, it is not necessary to measure the windows and take the glass surface into account, and the wall surface also into account, and finally get the area of the so-called equivalent glass surface. Incidentally, it may be remarked, such rules must obviously be of a more or less approximate character, but if they can be shown to have a rational evolution, they are far better than no rules at all.

If we let *W S* stand for the wall surface of the building, these rules stated in their simplest terms are as follows:

1. (Extreme length of house + extreme breadth) × combined hight of ceilings × 2 = *W. S.*
2. *W. S.* ÷ 2 = cubic feet air per minute at 140 degrees.
3. *W. S.* ÷ 4 = cubic feet air per minute at 210 degrees.
4. *W. S.* ÷ 600 = square feet of air supply duct.
5. *W. S.* ÷ 900 = square feet grate when outside air is used.*
6. *W. S.* ÷ 1500 = square feet grate when inside air is used.
7. *W. S.* of any first-floor room ÷ 3 = square inches leader pipe.†
8. *W. S.* of any second-floor room ÷ 6 = square inches leader pipe.†
9. Two-thirds of leader pipe = area of perpendicular stack.

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* See discussion on page 233.

† See discussion on page 234.

The correctness of rule No. 1 will be apparent to any one if he will sketch the plan of any house, providing there are no re-entrant angles, like courts, to the building, the authors stating that the rule was for exposed walls without re-entrant angles. Adding the extreme length and the extreme breadth of a house gives one-half of the distance around it, and multiplying this by the ceiling hights gives the area of this exposed wall, while multiplying this product by 2 gives the total wall area.

The correctness or approximation of rule No. 2 can be indicated as follows: In the average type of house one-sixth of the total wall surface is of glass. That leaves five-sixths for the area of the exposed wall proper. As 4 square feet of wall surface in the average building is equivalent to 1 square foot of glass, then one-quarter of 5-6, or 5-24, of the entire wall surface can be regarded as having the same heat transmitting properties regarding it as glass, as the whole of that same 5-6 exposed wall regarded as it actually is. So the actual 1-6 of glass and the 5-24 that are equivalent to glass make it that 1-6 + 5-24 = ⅜ of the wall surface, regarded as glass has the same heat transmitting property as all of the glass and all of the exposed wall combined. It is commonly accepted that 1 square foot of glass with 70 degrees indoors and zero outdoors will lose 85 heat units per square foot per hour. This is equivalent to 1.4 heat units per minute per square foot. As every square foot of wall surface is regarded as ⅜ foot of glass, every square foot of the wall surface will thus lose in a minute ⅜ of 1.4, or 0.525 heat unit per square foot per minute. (The author, W. G. S., recommends ¼ in place of ⅜ as stated). If the air is assumed as being admitted into the room at 140 degrees and cooled to 70 degrees, each cubic foot of air will give up 1.1 heat units in being cooled the 70 degrees. As this heat is transmitted through the walls and by the foregoing calculation is shown to amount of 0.525 heat unit per minute for every square foot of the wall surface, as many cubic feet of air will be needed to provide the heat passed through 1 square foot of wall surface as 1.1 is contained in 0.525, which is about 0.48, or ½. That is, there will be required about ½ cubic foot of air for every square foot of wall surface, which is what the rule stated, dividing the wall surface by 2.

(The author considers 210° too high a temperature at which to supply air.)

Rule 3 may be shown approximately correct also in the following way: If the air is admitted into the room at 210 degrees and leaves it at 70 degrees, it has a range of 140 degrees for giving up the heat necessary to offset the loss through the exposed wall, or twice as much as needed when the air is admitted at 140 degrees. As the air has twice the range in temperature, it needs to be but half as much in quantity, so that instead of dividing by 2 the wall surface can be divided by 4.

Rule 4 has the following basis: By rule 2 it is shown that the quantity of air needed in a minute is obtained by dividing the wall surface by 2. If the velocity of air in the supply passages to the furnace is 300 feet per minute, the necesseary area would be determined by dividing the air volume by 300. Dividing one-half of the wall surface by 300 is the same as dividing all the wall surface by 600.

The derivation of rule 5 does not bring the close results obtained in the case of the rules preceding. As the following will show, grates of the small size given by the rule would require a construction of furnace and method of operation that would allow for getting, say, 10,000 heat units from each pound of fuel burned and of burning the fuel at a rate between 5½ and 6 pounds of coal per square foot of the grate per hour. It is acknowledged that some authorities give the figure 10,000 as the amount of heat that can be absorbed from 1 pound of coal in a house heating apparatus, but it is safer to figure on 8000 or 9000. With regard to the development of the rule, it will be recalled in a preceding paragraph that it was shown that the heat lost through the exposed wall was 0.525 heat unit per square foot of the wall per minute. It is assumed that the air is admitted into the furnace at zero degrees and heated to 140. The heat loss just stated is that compensated by the cooling of the air from 140 degrees to 70 degrees. The rest of the heat, represented in the fact that the air warmed from zero escapes at 70, is equal to the amount of heat offsetting the heat losses through the exposed wall, so that the total heat required of the furnace is twice that represented by the losses through the exposed wall. The total heat required is thus

2 × 0.525, or 1.5 heat units per minute, or 63 heat units per hour per square foot of wall surface. If we allow 5.5 pounds of coal burned per square foot of grate per hour, the total heat delivered into the furnace at 10,000 heat units per pound is 55,000 heat units. As 1 square foot of exposed wall needs only 63 heat units per hour from the furnace, the total amount of heat obtained from 1 square foot of grate is sufficient to heat 55,000 ÷ 63 = 873 square feet of wall surface. If, therefore, 1 square foot of grate will supply enough heat for 873 square feet of exposed wall, 1 square foot of wall will need 1-873 square feet of grate, or the total number of square feet in the grate will be found by dividing the wall surface by 873. This, it will be seen, is nearly equal to 900, the figure given by the authors. If each furnace were credited with the capacity to absorb 8000 heat units from each pound of coal, and the coal were burned at the rate of 5 pounds per square foot per hour, the grate surface would be found by dividing the wall surface by 630, a figure which is considerably different from 900.

If all the air is to be taken from the inside, as specified by rule 6, it would be expected that theoretically only one-half the grate surface would be required, for the reason that theoretically the air is heated over and over again and there is no loss by ventilation, which was shown to be one-half of the total heat requirements. Instead of that the authors divide by 1500, which indicates that the heat needed when all inside air is used is 60 per cent. of that needed when all outside air is used.

Rule 7 indicates that a velocity of air in the leader pipe is taken at about 200 feet per minute. By rule 2 it was shown that the air required in the system or for a room, for that matter, is half a cubic foot for every square foot of wall surface. At a velocity of 216 feet per minute, the required area of the leader pipe in square feet would be obtained by dividing ½ by 216, which is 1-432 square foot for every square foot of wall surface. As there are 144 square inches in a square foot, the area of the leader pipe is thus equivalent to 144-432, or 1-3 square inch for every square foot of wall surface, as given by the rule. (By wall surface is meant total exposure of wall and glass combined. This rule checks closely with Table IV, page 45, for rooms on first floor.

The author, W. G. S.) It will be remembered that this rule is for cases where the cellar pipe is not over 15 feet long and has no bad bends. If the pipe is over 15 feet long it is advised to add 20 per cent. to the area.

Rule 8 shows that the velocity for second floor rooms is taken at twice that for first floor rooms, in as much as the divisor is twice that used for the first floor rooms. If the cellar pipe is over 15 feet long it is advised to add 25 per cent. to the area and if over 25 feet long to add 50 per cent.

Rule 9 is that the area of the perpendicular stack should be two-thirds that of the leader pipe fitting it. This indicates that the pipes are proportioned for velocities half again as great as that in the cellar pipes—that is, 300 for first floor rooms and 600 for second floor rooms. The first figure is that commonly given for first floor rooms, but the 600 ft. per minute is higher than ordinarily is allowed. The modification of this rule as set down by the authors is that a 45-degree horizontal bend in a leader pipe should be compensated for by increase of 20 per cent. in area and a 90-degree bend by an increase of 30 to 40 per cent. in area.

TRUNK LINE SYSTEM OF FURNACE PIPING.

By F. D. Goddard.

The trunk line system of running furnace pipes is no new idea; it has been used for years, but has usually been done in a careless manner and without much consideration as to maintaining proportions and areas. There are, however, many things that can be said in its favor and little to be said against it. In planning the layout of the cellar pipes for a furnace plant where two or more risers or uptakes are to be taken from one main cellar pipe, care should be taken to maintain the area of the main pipe; it should be equal to the combined area of the branches supplied. This is an important consideration and should never be overlooked.

Another feature to which careful consideration should be given is the importance of having the top of the line straight, avoiding anything that will add friction or prevent a free flow of the air. It is not good practice to combine a first floor pipe with a second or third floor connection; two first floor pipes may be taken from one main with good results. The best method is to take the branches from the end of the main, leaving length enough in the connections to place a damper. When it is desired to take off a branch at some point between the end and the furnace, the connection should be made with a Y-branch and the area of the branch passing beyond should be maintained equal to what it supplies. Under this system, when properly executed, the whole

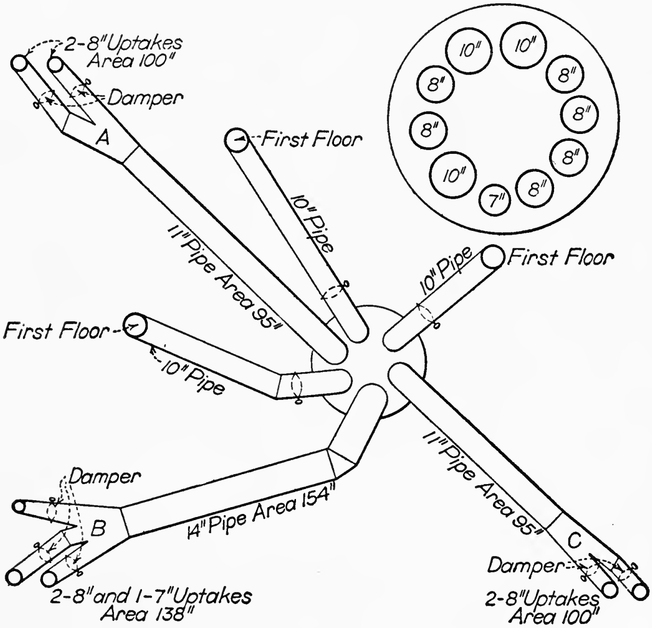

Fig. 69.—Trunk Line System.

job is simple and compact and does away with many features that are an objection in the ordinary single-pipe installation.

Fig. 69 shows the cellar piping for an average ten-register house, with three pipes to the first floor and seven pipes to the rooms above. The same top is also shown having the collars for each separately. It will be seen that the furnace man will have some little maneuvering to do if he gets the collars all in and the pipes satisfactorily run without interfering with the head room about the furnace and getting the collars properly spaced. When collars are placed too near together or too near the outer circumference of the furnace top, there is not so good a distribution of the warm air. It is the practice of some furnace men to cut the furnace collars in near the edge of the top. This is all wrong; the collars should invariably be at least 4 in. from the edge.

In the illustration there are three trunk lines shown, one line supplying three risers and two lines supplying two risers each; this arrangement allows the use of three cellar pipes in place of seven, clears the space above the furnace and allows room enough to properly cut in the collars without decreasing the area capacity. If each one of these risers had a separate pipe to the furnace there would be six 8-in. pipes and one 7-in. pipe. The combined area of these pipes would be 338 sq.in.; as run in the illustration there are two 11-in. pipes and one 14-in. pipe, and the combined area of these three pipes is 344 sq.in. or 6 in. more than the seven smaller pipes.

The outside circumference of these pipes shows a large gain in favor of the trunk line system in less exposed surface. The combined circumference of the seven separate pipes is 172 in., while the circumference of the three main pipes amounts to 113; thus it can be seen that the exposed surface of the three main pipes is about 66 per cent. of that of the seven separate pipes. This is an important gain, a gain that counts in the efficiency of the apparatus. The larger cellar pipe contains a greater volume of air, has less exposed surface and consequently does not cool so quickly.

In cases where two or more branches are taken from one main there is frequently one of the branches that does not convey the air as freely as the others. In such a case the dampers to the more freely working branches can be partly closed, thus forcing the air into the weaker pipe; this would be impossible if the pipes were run separately. The air in a small pipe, if carried a considerable distance, is liable to be cooled before reaching the point of delivery, its volume being so small.

The furnace man who installs a few furnace plants under this system in accordance with correct methods will be suprised at the results, both in satisfaction to his customer and to himself. Someone will advance the argument that the average shop cannot get out the fittings for a job of this description. To such the writer will say that there is hardly a furnace manufacturer but would be pleased to send patterns of such fittings, and there are the pipe and fittings concerns who would be only too glad to supply the manufactured articles. All that is required out of the regular is the Y-branches, two-way, three-way and four-way branches, patterns of which once obtained can be varied to suit conditions.

As to the cost of the trunk line system compared with the regular single pipe job, the writer is not prepared to say. Investigation so far as made would indicate that the trunk line costs less after the furnace man has the patterns and understands the method.

THE CONTROL OF AIR LEAKAGE AROUND WINDOWS.

By Harold M'George.

Air leakage around windows is a matter that, up to a comparatively recent date, has received but little attention. The heating engineer in calculating the amount of radiation required for a house or building has accepted an arbitrary factor for glass loss.

Early in the year 1907, H. W. Whitten, heating engineer, ran into a circumstance that to him was of such importance that he decided thereafter to devote his entire time and attention to window leakage and its prevention. The Mt. Royal Apartment House, Baltimore, Md., had been built and equipped with an efficient heating apparatus. During the first season this apparatus was very satisfactory, supplying the necessary amount of heat with reasonable economy of fuel.

This building is located near the Union Station, where dust and smoke are prevalent. To overcome this nuisance the building after standing one year was equipped with metal weather strips. It was then observed that the temperature of the rooms was too high and could only be reduced to normal by reducing the steam pressure to the lowesr point consistent with circulation. Clearly the radiation, which was barely sufficient originally, was too large for the new condition. Acting on this assumption, the radiating surfaces were reduced nearly 25 per cent. and the difficulty remedied. The result of the joint action of the weather strip and reduction in heating surfaces was to lower the coal consumption 35 per cent. Mr. Whitten came to the conclusion that if the stated reduction in radiation was due to the metal weather strip then there must be some way of securing a definite formula or calculation whereby the saving in radiation could have been figured in the original calculation. To arrive at such a basis a number of interesting tests were made.

The first experiment made by Mr. Whitten, in conjunction with Ralph Collamore of Detroit, was with a double tapered sheet iron cone; to one end was connected a motor driven pressure blower, to the other end an anemometer; in the middle a frame into which sash of varying clearances could be placed. Three styles of sash were tested, one having $\frac{1}{32}$ in. clearance, which is usually termed by builders a tight window; one of $\frac{1}{16}$ in. clearance, a loose window, such as is usually found in average house construction, and one fitted with metal weather strip in accordance with the foregoing specification. The results obtained are shown in the accompanying table:

LEAKAGE AROUND DIFFERENT TYPES OF WINDOWS.

Air pressure in inches.	Corresponding wind velocity in miles per hour.	2 x 4 ft. ordinary window. Cu. ft. of air per minute passing through sash.		Window equipped with metal weather strip.—Cu. ft. of air per min. passing through sash.
		Sash of $\frac{1}{16}$-in. clearance.	Sash of $\frac{1}{32}$-in. clearance.	
0.03	7.75	22	7.4	....
0.05	10.78	31	15.0	....
0.08	13.66	...	.....	1.4
0.1	15.11	43	24.7	2.8
0.2	21.61	57	37.4	5.3
0.3	26.48	71	47.4	8.4
0.4	30.37	83	57.4	9.6
0.5	34.18	99	65.1	10.7
0.6	37.44	103	73.1	11.7
0.7	40.45	112	80.7	12.4
0.8	43.24	121	88.1	14.0
0.9	45.86	130	95.0	15.6
1.0	48.34	137	101.4	16.1
1.3	55.19	160	124.5	20.7

The author (W. G. S.) would state in this connection that when the late A. R. Wolff introduced heat loss values into this country based on German standards his first charts showed a heat loss through glass of 70 B.T.U. per square foot per hour of 70 degrees difference in temperature.

Later he found it advisable to increase this amount to 85.

Now Peclets values and those of other experimenters are not far from 70 B.T.U. per square foot of glass per hour for 70 degrees F. difference in temperature.

Wolff's increase was evidently due, in the opinion of the author, to the necessity of allowing for the air leakage around the windows.

This the author has found to be a matter of extreme importance.

In computing heat losses or computing the size of a furnace or heating apparatus the kind of windows should always be taken into consideration; are they plain double hung, are they casement windows or have they transoms? Have they plain wooden sash or is the sash of steel with steel frames? Are they fitted with metal weather strips or are double windows used in winter?

The author has found steel sash to be very leaky and the leaks very difficult to overcome.

Inside double windows of the casement variety are to be recommended for use in connection with steel sash.

A liberal allowance over the usual heat loss must be allowed for casement windows or for transoms.

When one considers the matter it is evident that the glass area alone is a very poor index of the heat loss through windows; for example two rooms of the same size may have exactly the same glass area, yet one may have twice as many windows as the other, in which case it stands to reason that with windows equally tight the air leakage will be much greater in the second case as in the first due to the greater aggregate length of cracks around the window sash.

While there appears to be no rules which make due allowance for the lineal feet of cracks around windows the question of the number of windows into which the glass area is divided must receive consideration in determining the heat losses for a room.

TESTING A FURNACE PLANT IN WARM WEATHER.

The following answer appeared in *The Metal Worker* in reply to the question whether a test of a warm air plant can be made at a time when the weather is 22 degrees above zero so as to tell if the furnace would heat the rooms to 70 degrees in zero weather:

The subject of equivalent heating powers under different conditions has been discussed in connection with direct steam and hot water heating, but for indirect or furnace heating the problem is more troublesome, owing to the greater number of variable factors. Heating a house to a certain temperature during above zero conditions proves little as to the heating capacity of the furnace in zero weather unless the volume of warm air delivered is known. If this be measured with an anemometer, then the cubic feet per hour at register times the weight of 1 cubic foot of air at that temperature times the excess of temperature over outside air times the specific heat of air (0.238) will equal the heat units per hour delivered to room. Combining the results of similar tests and computations in all the rooms gives the total effective output of heat by the furnace. If this sum total equals or exceeds the estimated heat loss in zero weather the furnace should easily do the work under the latter conditions. The heating surface will then be more effective, since colder air is brought in contact with it, and the chimney draft will be stronger. To compute the heat loss in zero weather see page 45 of this book. Note the percentage corrections for exposure to cold winds.

The statement is sometimes heard that it makes no difference whether a room is heated by a large volume of warm air or a smaller volume of hotter air. Those familiar with hot air heating know, however, that the total quantity of heat that must be supplied to keep the house at the desired temperature is affected to a marked degree by the temperature at which the air is delivered by the furnace. When air enters at 140 degrees, for example, with outside temperature 0 degree, 1 cubic foot at the higher temperature brings in 2.2 heat units, of which 1.1 are available to offset the loss by transmission, the remainder escaping with the air at 70 degrees. With air at, say, 120 degrees, these figures are 1.94 and 0.81, respectively. To compensate for a given transmission loss through walls and windows more air at 120 than at 140 degrees, in the ratio of $\frac{1.1}{0.81} = 1.36$, would be necessary. The total heat would be as $\frac{1.36 \times 1.94}{1 \times 2.2} = \frac{2.64}{2.2} = 1.2$; that is, 20 per cent. more heat would be required at the lower temperature. This shows the importance of noting the inlet temperature when testing a furnace. A register temperature below 120 degrees in zero weather, with the fire in good condition, indicates an oversupply of air and consequent waste of heat, or insufficient heating capacity.

TEST OF A FAN-FURNACE COMBINATION.

Tests of a Kelsey generator, as the hot air furnace manufactured by the Kelsey Heating Company is known, were made under the direction of Prof. Wm. Kent and were reported in *The Metal Worker* in part as follows:

Air was supplied through a 48-inch Sturtevant disk type fan driven by a 5 horse-power electric motor. The arrangement is shown in Fig. 70. The horizontal cold air intake was designed to conduct the forced supply of air to the generator [furnace] casing, but the special arrangement was provided of taking from this intake a supply of air to the ashpit of the generator. It appears that this scheme was chiefly to obtain additional means for regulating the rate of combustion, or, in other words, for maintaining the condition of the fire uniform throughout the trials.

The means for measurement of the air handled were as follows: At a hight of 6 feet above the floor line in the vertical downtake the cross section of the shaft was accurately measured and laid off in 24 sections or rectangles, so that an anemometer could be placed opposite each rectangle, and the average of the 24 readings of the instrument thereby obtained to secure a figure for the average velocity in the downtake. It has been proved that the air in such a passage does not travel in currents of equal velocity over the whole cross section, and this is a common method for eliminating the errors which would arise by taking a few readings

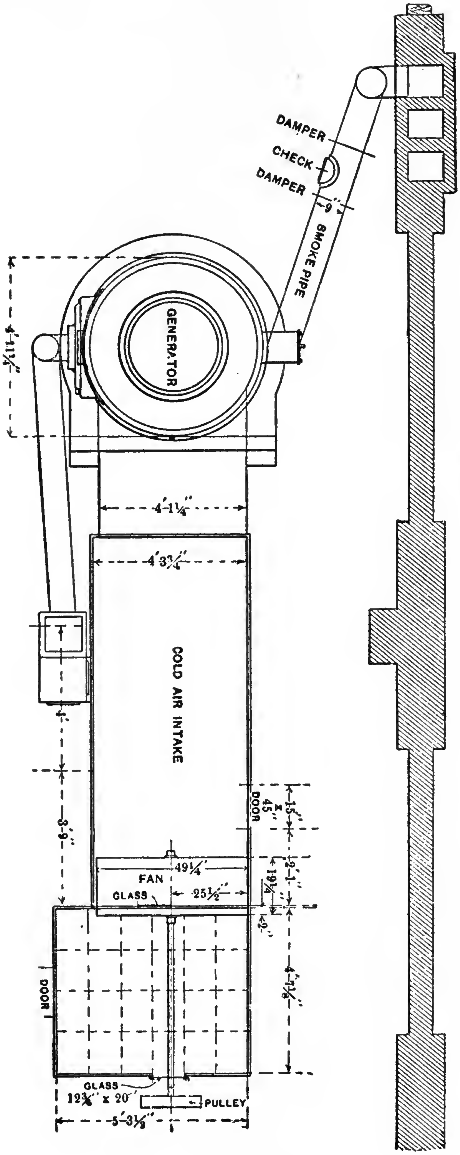

Fig. 70.—Plan of Kelsey Warm Air Generator and Testing Plant.

of the instrument at places selected more or less at random. The cross section of this downtake, according to accurate measurements, was 11.88 square feet.

To determine the variations in the pressure produced by the fan and to see that these were not of an excessive character a U-shape water gauge was connected to the horizontal intake, and its fluctuations were noted every few minutes. The vertical and horizontal air passages were carefully made of tongued and grooved material, and in order to prevent any further leakage of air all joints were carefully covered by strips of building paper on both the inside and outside. The instruments were standardized in order to make the measurements as accurate as possible.

The heater was a No. 30 Kelsey generator with 211 square feet of heating surface and a grate area of 4.91 square feet. The velocity of the air was read in each of the 24 rectangular spaces in the main air supply shaft once an hour, and the whole was carefully averaged to determine the true velocity, as already mentioned. The thermometer was placed centrally in the air intake to record the temperature of the incoming air. Above the dome of the generator and on a level with the top of the bonnet a thermometer was hung in the center, which recorded the temperature of the heated air emerging from the generator. The other apparatus used consisted of a thermometer in the smokepipe, a hygrodeik on the roof and another near the generator to determine the percentage of moisture in the air both before and after passing through the generator. Analyses were taken of chimney gases in the usual manner.

The test was taken by what is called the standard method—that is, having a given thickness of fire in the firepot at the beginning of the test and the same amount of coal in a similar condition at the end of the test, all coal supplied in the meantime being carefully weighed. The temperatures were recorded every 15 minutes. Observations were made for eight hours on two separate days, and the average results are shown in the accompanying table.

This table besides giving the results of the tests on the two days mentioned includes also a supplementary test conducted on March 23, in which the velocity of the air was measured at the outlet of the generator. These results are tabulated under the column marked test C.

In connection with the table the following explanations may be in order: The third line, giving the weight of the vapor in each cubic foot of the air is, of course, determined by multiplying the weight of moisture which air at the temperature given can hold in suspension by the percentage of humidity. The weight of dry air per cubic foot for the given temperature can be obtained directly from tables for the weight of air as varied by the temperature. The fifth line gives the average of the readings of the anemometer in velocity expressed in feet per hour as a matter of convenience in making the further calculations. The loss in leakage, it is understood, includes not only the air delivered to the ashpit, but provides for leakage that inevitably took place through the boards of the intake passages.

The numberof British thermal units absorbed by the dry air per hour is, of course, obtained by multiplying the weight of dry air delivered to the heater per hour as tabulated by the specific heat of the air, and this product by the range of temperature, which, for example, in test A was 96 degrees. The specific heat of air, which is the number of British thermal units which are required to raise 1 pound of air through 1 degree F., is sometimes taken at 0.2375, so that for the 19,821 pounds dry air delivered per hour in the case of test A the number of heat units absorbed in increasing the temperature 96 degrees is equal to 19,821 × 0.2375 × 96 = 451,872.

In calculating the heat units absorbed by the vapor per hour it will be interesting to note that the specific heat in this case was taken at about 0.3, although the specific heat for water in the liquid state is 1. For example, the number of heat units absorbed in the case of test A are 70 × 0.3 × 96 = 2016. The total number of heat units absorbed by the mixture is, of course, the sum of those absorbed by the dry air and those absorbed by the vapor.

In determining the number of heat units given up in combustion, shown in next to the last line of the table, the number of pounds of coal burned per hour was multiplied in each case by 14,700, the coal used being credited with a heat emitting value of 14,700 B. T. U. per pound.

	Test A.	Test B.	Test C
Average temperature of the cold air, degrees F.	39	58¼	52¾
Per cent. saturation or humidity of the cold air.	71	56½	....
Number pounds of vapor in each cubic foot of the air	0.000281	0.000434	....
Number pounds of dry air in each cubic foot of the air	0.079004	0.075754	0.062
Average velocity of air through measuring orifice, feet per hour	26,400	26,220	28,860
Average volume of air through measuring orifice, cubic feet per hour	313,620	311,494	270,660
Average volume of air lost through leakage, cubic feet per hour	62,724	62,299	....
Average volume of air delivered to heater, cubic feet per hour	250,896	249,195	....
Number pounds of dry air delivered to heater per hour	19,821	18,878	16,781
Number of pounds of vapor delivered to heater per hour	70	108	....
Average temperature of the warm air, degrees F.	135	152¼	178
Average difference in temperature between warm and cold air	96	94	125¼
B. T. U. absorbed by the dry air per hour	451,872	421,496	....
B. T. U. absorbed by the vapor per hour	2,016	3,102	....
B. T. U. absorbed by the mixture per hour	453,888	424,598	502,678
Average number pounds of coal burned per hour	36	33½	38³/₇
B. T. U. given up in combustion per hour	529,200	492,450	564,900
Per cent. efficiency of the generator = $\frac{\text{B. T. U. absorbed by mixture}}{\text{B. T. U. given up by coal.}}$ =	85.7	86.2	88.9

The last line or efficiency of the generator is the percentage of the heat supplied by the coal that is absorbed by the air delivered from the generator, and is consequently the quotient of the heat absorbed by the mixture of dry air and vapor divided by the heat given up by the coal.

The Metal Worker stated editorially in regard to the above tests: "It is common knowledge that where, say, three furnaces have been installed for a given building on the basis of the requirements with gravity operation two of the furnaces have sufficed for the severest demands when the air supply has been forced. It will be noted that as much as 450,000 B. T. U. were absorbed per hour from the heating surfaces in the generator in question, which for the 211 square feet of heating surface in the generator is 2135 B. T. U. per square foot per hour—a figure which is remarkably high for the heat delivered by steam pipe coils in forced blast work. The air delivery through the generator was at the rate of over 1300 cubic feet per square foot of the heating surface per hour. How far these figures can yet be applied in calculations of heating systems without reference to the nature or details of the furnace needs further tests of the same praiseworthy character as those discussed."

ADVANTAGE OF AIR AT RELATIVELY LOW TEMPERATURE.

There are advantages in supplying air at, say, 120 degrees in zero weather. There is less tendency for the air to remain at the ceiling than when admitted at a higher temperature, thus promoting a better circulation in the room and a nearer approach to a uniform temperature throughout. On the other hand, the lower the temperature of the air supply the greater must be the quantity to supply the number of heat units necessary to make good the loss through exposed walls and glass, consequently the more frequent the air change and the greater the fuel consumption.

A source of annoyance in furnace heating systems is the control of the air supply, an insufficient supply causing injury to the furnace from overheating and an unwholesome air supply from the same cause.

FAN FURNACE HEATING.

George W. Kramer, an architect with a wide experience in fan furnace heating, advocated in *The Metal Worker* extended surface in the form of vertical ribs or flanges on the furnace, and stated that by providing these the efficiency of the furnace is greatly increased in this class of heating.

E. T. Child states in *The Metal Worker* as to fan motors in connection with the fan furnace system of heating:

" The motive power of a fan may be furnished by a water or electric motor or by a gas engine. For many reasons the electric motor, if current is available, will be the most satisfactory. The running cost is rarely high, the noise is very slight and if directions are followed it may be operated by attendants not at all familiar with the detail of the construction. The motor should be provided with a starting box, or a speed regulator. These are ordinarily provided with what is called an automatic release, which shuts down the motor in case the current is accidentally cut off. This prevents the motor from being damaged by receiving the full current at once. In starting a motor the starter should be moved slowly, one notch at a time, to let the motor gain speed, otherwise there is danger of burning the motor out. In many localities, however, electricity is not available, while gas is very cheap, and gas engines have been used to a very considerable extent for fan propulsion. When a gas engine is used care must be taken to prevent the sound of the exhaust from being transmitted through the building. This may be accomplished by running the exhaust pipe to a cast iron tank or equalizing chamber, from which it may be run into a pit or dry well of large capacity with proper outlet. In gas countries the gas engine furnishes the cheapest power, and for this reason it is to be recommended. Water motors are sometimes used, but the cost for water makes them practically out of the question in large towns and cities. If high pressures and low rates may be obtained the water motor will be found a very satisfactory source of power."

USE OF SMALL ELECTRIC FANS IN CONNECTION WITH FURNACES.

What may be termed fan furnace heating on a small scale is the application of a small office type fan 12 to 16 inches in diameter to accelerate the flow of air in the cold air box. One large concern engaged in furnace heating has suggested that mention be made in revised " Furnace Heating " of this use of such fans, stating that the work it has done in this line has been very satisfactory, especially in cases where return air is used.

PRACTICAL APPLICATION OF A DESK FAN.

From *The Metal Worker* is taken the following description of the use of a small fan in furnace heating by F. N. Jewett of the Wagner Electric Mfg. Company, Chicago:

Having difficulties in heating some of the rooms in his house, he devised the following scheme, which operates satisfactorily: Herewith, Fig. 71, is given a diagrammatic cross section through the basement and lower part of the first floor of the house. The usual fresh air intake or cold air box, B, is equipped with a swinging door weighted so as to be self-closing. Connected to this door is a rope, which passing over pulleys and through the floor, permits opening and closing the fresh air intake from the first floor. At C an opening was made in the cold air box and a round galvanized iron duct 16 inches in diameter was run out and up to a large register, A, placed in the first floor. In this duct a 16-inch desk fan was installed.

With this arrangement it will be seen that should any one room or any part of the house fail to heat properly, the door B may be closed, the register A opened, and the fan operated. Then the cold air on the floor of the house is drawn down through the register A, blown rapidly through the cold air box and mechanically forced up through all the warm air ducts and registers, and the heating not being dependent upon gravity, the air must go where desired. The fan is also found of great value early in the morning in rapidly warming up the house, which usually has cooled off during the night.

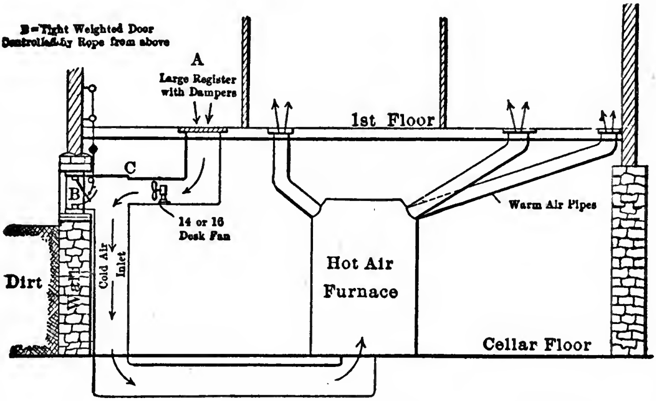

Fig. 71.—Mr. Jewett's Sketch Showing Fan Used with Furnace.

The experience of a neighbor of Mr. Jewett, J. R. Cravath, Western editor of the *Electrical World,* whose heating system includes the use of a furnace, is as follows:

"We find it heats the house much quicker in the morning. It forces the air into rooms that it would be difficult to heat without the fan. The cost of operating the fan is about the same as 16 candle-power incandescent lamp. At Chicago prices it is about ½ cent per hour. An ordinary 16-inch electric fan is used. The fan need not be run more than an hour or so in the morning. Then all of the house will be heated in good shape all over. On extremely cold or windy days it might be necessary to run the fan all day. The cost of installing the fan is from $20 to $25."

THE EFFICIENCY OF A DESK FAN.

From an article in *The Metal Worker* the following practical suggestions are taken:

The capacity of the fan may be greatly reduced if some provision is not made to prevent eddies or back currents. This should be done by installing in the duct a sheet metal cross-partition with circular opening the size of the fan. The illustrations, Figs. 72, 73 and 74, will give some idea of how the fan will act, and will be readily understood by the practical men who are engaged in furnace heating.

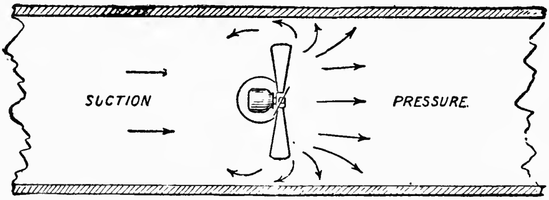

Fig. 72.—Natural Movement of Air from Desk Fan.

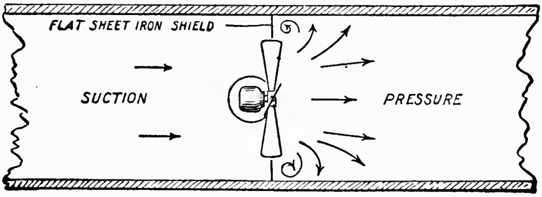

Fig. 73.—Back Flow Prevented by Shield.

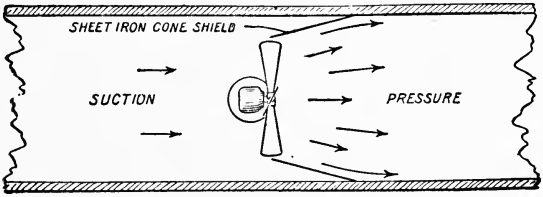

Fig. 74.—Eddies Avoided by Cone Shield.

In the first of these is given the plan showing the side walls of the air duct of sheet iron or wood, and showing the location of the fan and the movement of the air from the suction side to the pressure side. In this illustration it will be noted that the blades of the fan throw the air off in every direction, and that when there is no wind guard or shield there is a tendency for some of the air to be drawn back of the fan to the side where the suction makes it easier for the air to flow than on the pressure side, where some resistance is being encountered.

In order to avoid this a wind guard or shield made of sheet iron or thin board should be placed across the duct with a hole in the center, practically the same size as the fan, and the fan should set close as possible to it. While a perfectly straight shield or guard will serve a good purpose, nevertheless there will still be eddies on the pressure side of the fan at its outer edge. This, in my opinion, however, is not sufficient to warrant any elaborate effort to avoid it, particularly in a square duct. In a round duct it is a less difficult matter to make a cone shield or guard extending just back of the center of the fan blade, as shown in the last diagram. This allows the air to spread, but it directs it forward, overcoming the eddy and possibly contributing sufficient increase to the efficiency of the fan to warrant the employment of the cone guard where the best results are sought or there is no effort to confine the furnaceman in his cost.

It is possible that inasmuch as the fan will not always be in the air supply duct, and the fire may be started up depending on the gravity air supply, a better method of providing a fan and wind guard would be to arrange for it to be on a special slide, which can be slipped into or out of the air duct as may be desired. This will avoid a reduction in the size of the air duct at the point where the fan would be likely to interfere with the proper amount of supply when gravity would be the only force driving the cold air to the furnace, and under such conditions the wind guard might severely interfere with the supply, so that some pipes on the furnace would not work and deliver the hot air expected from them.

Where an inside air supply is used there is advantage in setting the fan under the return air supply register face. Then the face can be lifted and the fan taken out in mild weather, when the furnace will do its work without help or the fan is needed elsewhere in the house for cooling in the summer.

MISCELLANEOUS.

FIRE HAZARDS OF HEATING SYSTEMS.

The great diversity of devices and methods in use for house warming, due to the varying conditions of fuel supply and climatic requirements, says *Insurance Engineering,* presents to the underwriter a range of fire hazards which compels the careful study of all the conditions to enable him to suggest to the user the proper safeguards to prevent disaster.

The surveyor or inspector finds his attention called to problems ranging from the old-fashioned open fireplace, with wood for fuel, such as grace and make cheerful our country homes, to the wood or coal burning stove, and up to the more modern and complicated steam, hot water and hot air furnaces, now so common in the equipment of city and town houses, with a sprinkling of natural gas grates or stoves, and an occasional encounter with the kerosene oil device, each demanding special expert knowledge as to construction and use, and the exercise of good judgment in the suggestions necessary to make safe such defects as may be discovered upon investigation. * * * Considering the record of fires from heating apparatus, the only conclusion to be reached is that carelessness is at the base of each of these accidents, either as a defect in the original installation of the apparatus, or as a result of recklessness and the neglect in its after use and care. With a desire to consider briefly some of the salient points of hazard incident to the methods of house warming, we take up the different devices in the sequence of the statistical record as above noted.

Stoves and Stovepipes.—Where such devices are to be used for heating or cooking, they should be free from cracks or other imperfections which would admit of the escape of coals or sparks; should be set upon solid platforms of brick, or in metal pans with raised sides and legs 3 inches in hight, in either case being large enough to extend well in front of the ashpit and thus protect the floor. Stoves should not be set within 18 inches nor their pipes within 10 inches of any woodwork, lath or plaster partition or other combustible material, except when conditions will not permit otherwise, and then all combustible material should be protected with bright tin sheeting, with a space of not less than ½ inch between it and the combustible.

Stovepipes should be well and frequently supported by wire; each joint should overlap the other toward the stove and be carefully riveted to prevent the escape of sparks. Fires should not be dumped into the ashpit except upon a bed of dead ashes of not less than 2 inches thickness. All pipes should enter the chimney or flue horizontally and in plain sight. Pipes entering flues vertically, or passing through blind or unused attics, where they may not be frequently inspected, are prolific causes of fires, particularly in country houses.

Hot Air and Indirect Steam Heating.—The furnace should be set upon a very solid foundation in order to prevent the sagging or cracking of its walls. The top or dome of the enveloping walls should not be less than 18 inches from the unprotected woodwork or lath and plaster ceilings, and its smokepipe or flue should be a like distance from combustibles. The ashpit should be sunken, or the floor in front of it be of brick, stone or concrete, not less than 36 inches wide. The inclosing walls of the furnace should not be less than 12 inches from all combustible material, and the inlet or cold air duct should be entirely of iron or other metal.

Hot air flues or conduits should be made of heavy, bright tin plates with well soldered lock seams, and be kept at least 10 inches from all woodwork or other combustibles. Where it is necessary to carry them through or into wooden or lath and plaster partitions the flues should be double—*i. e.,* one inside of the other, with an air space of not less than ½ inch between the two, and be properly braced to insure rigid separation throughout. Where register boxes are set in floors or partitions, the woodwork should be framed around them to leave an air space of not less than 2½ inches, and be protected by flashings of bright tin extending from the outer edge of the register opening to and through the floor beams or partition. Each register should be set in a frame of slate or soapstone not less than 2½ inches wide and 1 inch thick, firmly and well set in cement or plaster of paris.

At least one of the registers of the system should be so arranged as to insure its being constantly open, either by the removal of the vanes of the valve or by wiring the same open, so that closing would be impossible. Heater firepots should be carefully examined before use each season, to discover and remedy defects due to the burning out of their walls or the destruction of the luting at the joints of the same, whereby coals might fall into the surrounding air space and ignite dust or other combustibles which are liable to accumulate therein.

Natural Gas.—Heating by this means is restricted to limited areas of the country, and when the supply is sufficient to insure a full supply at constant pressure, the hazards of its use are quite mild, provided the piping has been properly installed and has passed a rigid test for leaks, and the flues for carrying off the products of combustion have been constructed for the purpose. When, however, the supply is weak and restricted and the consequent pressure variable, the hazard of its use is vastly augmented, for with low pressure and small supply the user is inclined to open the valve in the supply pipe to its fullest extent in order to secure a good blaze; and when, later, the pressure is increased from any cause, the small blaze is turned into one of great intensity and power, and is liable to ignite combustibles at a distance.

The only practical means of reducing this hazard lies in the use of an automatic high and low pressure regulating valve in the main supply pipe whereby the flow of gas will be automatically cut off when the pressure either rises above or falls materially below normal, at which it is set to act. Such controlling devices are open to purchase in the districts where natural gas is a factor, and the use of the same should be made obligatory.

RADIATION FROM RED HOT IRON.

In answer to the query how much heat is radiated from an iron casting weighing 1 pound when raised to a red heat, the casting being incased in a sheet metal jacket with a flue to and from so that it is supplied with fresh air, *The Metal Worker* gave this statement:

The specific heat of cast iron is 0.129, water being equal to 1, or 1 heat unit per 1 pound of water raised 1 degree F. One pound of cast iron heated to 1000 degrees F. above the atmospheric temperature will therefore contain 1000 × 0.129 = 129 heat units; which, if transferred to air circulating through a jacket as described, without loss by radiation from the outside of the jacket, should heat 542 pounds of air 1 degree F. The specific heat of air being 0.2377 of a unit per pound, and as about 13 cubic feet weigh 1 pound, the total amount of air heated 1 degree F. would be about 7000 cubic feet. This is the gross theoretical result without loss of heat otherwise. The practical result will be a stream of intensely hot air issuing from the jacket at first and gradually cooling to normal temperature, the total radiation of which will be, as above stated, 129 heat units.

SUITABLE SIZE COAL TO USE.

These hints as to sizes of anthracite coal are given in the catalogue of the Thatcher Furnace Company:

For small furnaces, stove coal; medium furnaces, stove and small egg coal.

For large furnaces, stove and large egg coal.

Do not use what is known as furnace coal. It is too large and not suitable for warm air furnaces.

Use a hard grade of coal in furnaces adapted to this kind of fuel.

INDEX

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One of the best reference and text books ever published. It contains well-written chapters on designing and installing all types of heating apparatus and equipment, with 59 special tables calculated by the author during his extensive practice, and many valuable extracts from the reports of investigations and experiences of other eminent engineers.

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The subject matter has been adapted from lecture courses given by the author before various institutions interested in heating and ventilating, including Y. M. C. A. and other classes. It gets right down to practical heating in the very first chapter, illustrates and describes the detailed use of exactly the same methods that the most proficient engineers use. It tells how to determine the sizes and proportions of equipment for every-day work.

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