WATER & AIR CIRCULATION xxxxx

1892

WATER AND AIR CIRCULATION IN HEATING AND VENTILATING

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ABRAM COX
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WATER AND AIR

CIRCULATION

IN

HEATING AND VENTILATING.

PHILADELPHIA:
ABRAM COX STOVE CO.
1892.

SALUTATORY.

THIS treatise is addressed to all who are in any way interested in the subject of house-heating. We offer it to heating engineers who through this means will learn of the new apparatus we have brought out; they will likewise find in it much of value in their professional work. We also commend it to architects to whom the proper heating of buildings is a very important matter; to plumbers who are more and more entering into the work of house-warming, and finally we address our friends and customers in the furnace trade, many of whom are supplementing their business in hot-air furnaces with the sale and erection of heating apparatus of other kinds.

This book, which has been prepared with the greatest care and at much expense of time, labor, and money, contains, we believe, more practical, more reliable, and more complete information than can be found anywhere else. We have endeavored to present the subject of water and air circulation in heating and ventilating in such simple language as to make it equally plain to journeymen, engineers, and architects. It will be noticed in the selection of buildings for illustration, that we have chosen examples to represent the various constructions to which the hot-water system is ordinarily applied. In each case floor plans and elevations are presented, while in the text accompanying the drawings are given all measurements and other information required to install a successful plant in the building illustrated. Rules and formulas are also given by which any intelligent mechanic can determine the number of the circulator to be employed, the square feet of radiation necessary, size and quantity of pipes, etc., required in buildings of similar design and construction.

The data made use of have been largely compiled from experiments and tests made on our own premises, and under conditions commonly met in daily practice. They are therefore much more reliable than figures ordinarily given in trade publications, and which are often taken from foreign authors who are unfamiliar with American practice and whose instructions are not suited to the American climate and conditions.

We make no mention of the Novelty Circulator in this place further than to say that while it is new in design it is not an untried apparatus. During the past two years it has been in continuous operation under all possible conditions which have given it the severest test, and as now placed before the public it is a perfect apparatus for house-heating.

ABRAM COX STOVE CO.

Philadelphia, April, 1892.

CIRCULATION.*

BY JOHN J. HOGAN.

THE arrangement of fire and flue surfaces, so as to present the greatest area of each in the most advantageous position to receive heat, is generally thought to be of first importance in designing boilers, but the extent of these surfaces and their arrangement with respect to the fire is really of little account if their form be not such as to promote circulation. The amount of heat transferred from fire to water is controlled almost absolutely by the velocity of circulation of water within the boiler.

THE TRANSFERENCE OF HEAT.

As circulation is effected by heat, it is necessary, in examining the subject of circulation, to remember that heat is transferred from one body to another in one of three ways, and in no other way. It is transferred either by radiation, convection, or by conduction.

By radiation heat passes from the radiant body to the absorbent body through the intervening medium, as, for example, air, without raising its temperature. The sun gives heat by radiation, and it will be noticed that the rays pass through window-glass, for illustration, warming objects beyond the glass, as, for instance, the furniture in the room, or the floor, without raising the temperature of the glass. The rays of the sun may be passed through a lens in a way to set on fire the object upon which they are focused without raising the temperature of the lens itself. A slab of ice may be substituted for window-glass, and the rays of the sun, passing through the ice without melting it, will still be perceptibly warm to the person or will add heat to other objects upon which they may fall.

Radiant heat reaches the absorbent in radial lines, *i.e.*, straight lines, and its intensity is inversely as the square of the distance traveled. This is an important fact, because it bears upon the location of the fire with reference to the heat-absorbing surfaces upon which the fire is to act. This principle is illustrated in the accompanying diagram, Fig. 1. Point 2 in this sketch is twice the distance from the candle A of point 1. A unit of surface, say one square foot, placed at the point indicated by 2 in the sketch, receives only one-fourth the quantity of heat that it would if it were placed at 1. At three times the distance, or at point 3, the unit receives only one-ninth the quantity that it would at 1, and so on.

The convection of heat is the process of carrying it from one body to another, and is performed by fluids, such as water, gas, or air. It is through convection that heat is carried by steam or water from a boiler to the radiators, and also from indirect radiators or a furnace by means of air to the bodies of lower temperature with which the air comes in contact. To transfer heat by convection the fluid which conveys the heat must have motion. It must move from the body of higher temperature to the body of lower temperature. This is an important fact, and should be borne in mind in planning all sorts of heating systems. If in the use of indirect radiators the air-passage is stopped, the useful work at once ceases, and in the same way in steam and hot-water circulation if the flow of the fluid through the pipes is stopped the work of heating is also interrupted. Again, if motion to the fluid in a heater or boiler is stopped, the useful action of the fire is interfered with.

Conduction is the transference of heat by direct contact. If a bar of iron be put into a blacksmith's forge and heated at one end to a red heat, it will be found that gradually the temperature of the opposite end will rise. The heat is transferred from the hot end toward the cold end by direct contact of particles in the bar. To still further illustrate conduction, it may be stated that the heat that is given to the fire side of the heating surface of a boiler by radiation from the fire, and by the convection of the gases of combustion, is transferred by conduction to the opposite side of the surfaces, and is there given to the water in contact with them, and in turn is carried off by convection-currents as already explained.

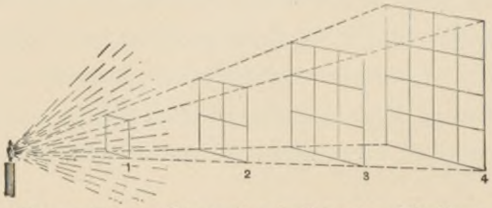


Fig. 1.—Diagram Illustrating the Intensity of Radiant Heat as Influenced by Distance.

THE CAUSE OF CIRCULATION.

Natural circulation is the operation of the law of gravity exerted upon two columns of fluid, as, for example, air or water, when the two columns are of unequal density and are joined at their extremities. The columns may be in separate passages or flues, or they may exist side by side in the same vessel in any number of pairs. The inequality of density is caused by the application of heat to the body of the fluid in one of the columns at some point below its top, or the abstraction of heat from the other. That part of the body which is immediately exposed to the heat is expanded in volume, and is thereby made lighter than the parts which are unexposed to the heat. The expanded and lightened particles are displaced by the colder and denser particles falling by gravity. The latter take the places of the warmed particles, and when they have become warmed are driven forward by still other colder particles falling into their places.

This exchange of places of particles, or circulation of air or water, is continuous so long as the two columns are prevented from establishing an equilibrium through an equality of temperature. In other words, circulation goes on as long as heat is communicated to one column or lost by the other. Circulation is the most rapid when the difference in temperature or of density of the two columns is the greatest. This condition is best secured when the column of high temperature and the one of low temperature are confined in separate passages or flues. This is because the temperatures of the two columns are more easily maintained at the maximum difference, when the opposing columns are prevented from mingling. A mixture of the particles of the two columns tends to an equalization of temperature. A common example of the equalization of temperature due to the mingling of currents of the two columns is afforded by a kettle of water upon an ordinary cook-stove where the entire bottom of the kettle is equally exposed to the action of the heat, as shown in Fig. 2. As heat is imparted to the water a circulation is established by the expanding water rising to make place for the colder and denser water which descends, but as the opposing currents are unconfined they come into more and more intimate contact until the entire body of water approaches a uniform temperature. With the continuous application of heat to the bottom of the kettle, steam globules form there which, instead of being displaced by the water as they would be with circulation promoted by separate ways, are held back by the mass above them. The result of the conflict of currents is an upheaval of water, so that if the kettle has been filled anywhere nearly full in the first place it soon boils over.

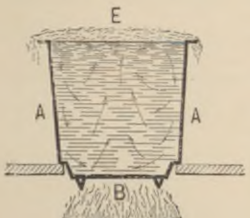


Fig. 2.—Mingling Currents in Boiling Water in a Common Kettle with Fire Applied at Bottom.

A familiar illustration of circulation promoted by separate passages, tubes being provided for the ascending column, is afforded by a kind of wash-boiler attachment, which is sold in many parts of the country, a diagram illustrating which is given in Fig. 3. In this A A indicates the boiler, B the fire against the bottom of the boiler, C the base of the attachment which is open at the bottom and perforated along the edge so as to allow the free passage of water within, D D are two spouts or tubes that extend upward from the base and are provided with curved necks. The water as it becomes heated is forced up these tubes, as shown by the direction of the arrows, by the weight of the descending column which rushes into the holes in the rim of the base already referred to. Particles of steam which are generated after the heat has been maintained for some time co-operating with the weight of the descending column force the water up the tubes D with such power as to carry it above the level E of the water in the boiler. This is an example of assisted circulation. The apparatus here sketched is something that is frequently sold in the trade for laundry purposes. The accelerated circulation of water which is secured in it is depended upon to do part of the washing. If the tube were to be carried up straight instead of being bent, as shown in outline at the right, the result would be a spouting into the air.

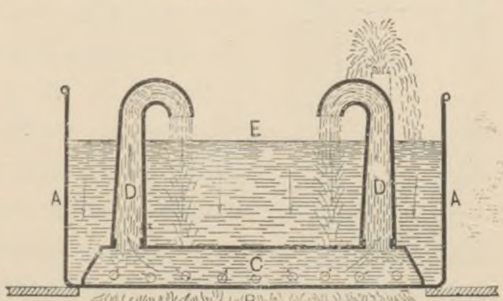


Fig. 3.—Circulation Promoted by Separate Passages, Illustrated by a Common Wash-boiler Attachment.

Referring again to the kettle illustration, Fig. 2: If the vessel is so set into the fire-space as to be exposed on the sides as well as on the bottom to the action of the heat, as indicated in Fig. 4, the results described in connection with Fig. 2 are more quickly reached. Again, if instead of a kettle we take a horizontal vessel closed at the top but with ends open and extended upwardly, as shown in Fig. 5, the conflict of currents will be still further illustrated. When steam forms, as it will by continued application of heat along the bottom and sides, the tendency is to drive the water within the vessel through the upturned ends, and it will thus empty itself if the heat is continued long enough. If in our experiments we employ a vessel of the shape shown in Fig. 6, which has a hollow center, leaving two water columns or legs with the fire applied under each column, the conflict will be the same as in the last instance. If the heat is applied evenly to the two legs, as shown, and is of sufficient intensity and maintained long enough, it will blow the water all out.

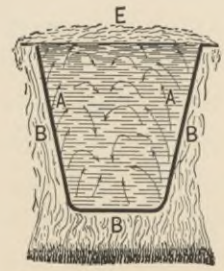


Fig. 4.—Mingling Currents in a Vessel Exposed to the Fire at Both Bottom and Sides.

If, on the other hand, the same shape is employed and the heat is applied to one leg only, as shown in Fig. 7, circulation will be promoted. The column directly over the fire will be the ascending column, while the opposite, containing the relatively colder fluid, will be the descending column. The hotter the fire, providing the descending column is giving off heat, the more rapid will be the circulation. In this case there is no intermingling of currents of different temperatures, and the maximum difference of temperature between the two columns is realized. It is under such conditions that the utmost rapidity of circulation is secured.

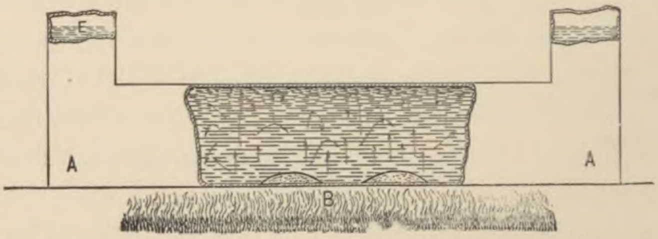


Fig. 5.—Conflict of Currents in a Vessel with Closed Top and Open Upturned Ends.

In Fig. 8 there is shown a vessel composed of three columns, with the fire applied directly under the central column. The conditions here shown are favorable to circulation. The central column will be the ascending column because the water contained in it receives the heat of the fire, while the outside columns will be the descending columns because they contain what is relatively colder fluid. If, however, heat be equally applied under the three columns, as shown in Fig. 9, the result will be impeded circulation, because the currents of the respective columns mingle in each of the divisions of the vessel. This is indicated by the broken and twisted arrows shown in the diagram. Fig. 10 shows a vessel with two columns or water-legs with fire applied above the lowest point and to the sides of the legs equally. In this case circulation is impaired by reason of the intermingling currents and because the two columns are of equal density. Extending water-legs downwardly from such a vessel, as is shown in Fig. 9, and applying the heat equally between the legs, as shown in Fig. 11, does not affect the results as last described, but produces mixed and conflicting currents, as indicated by the arrows in Fig. 11.

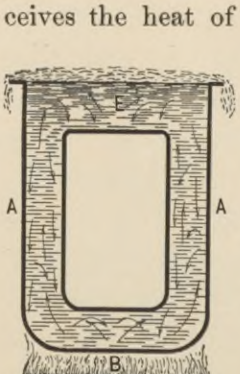


Fig. 6.—Currents in a Vessel with Hollow Center, with Heat Applied under Both Columns.

To go back to the original proposition, namely, that the circulation in a vessel is most rapid when the difference in temperature of the two columns is the greatest, and when the two columns of high and low temperatures are confined in separate passages so as to preserve the difference, it follows that the form illustrated in Fig. 19, which affords separate ways for ascending and descending columns and at the same time transfers heat only to the ascending column, must give the most rapid and positive circulation.

VALUE OF CIRCULATION IN HEATING WATER.

Water is a good absorbent, but a bad conductor of heat. A given particle of water very slowly yields the heat that it possesses to the colder surrounding particles. This has been expressed by an eminent writer in the following words:

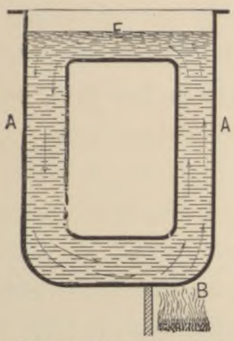


Fig. 7.—Vessel with Two Columns, with Heat under One Column only.

"Water is so bad a conductor that it is only when there exists perfect freedom of motion among its particles that it acts at all as a conductor of heat, so far at least as regards any practical and useful effect."

Another authority says,—

"The quantity of heat which can be transmitted to water in a given time is only limited by the rate at which it can be carried away from the heating surfaces by the convection-currents."

Still another quotation from the same authority may be offered in this connection:

"Heat can only be effectively abstracted by liquids from heated surfaces by circulation of the liquid, and rapid circulation is essential to rapid abstraction of heat."

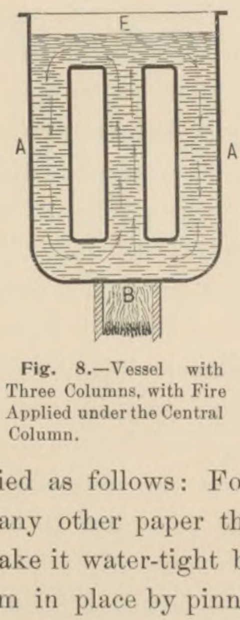


Fig. 8.—Vessel with Three Columns, with Fire Applied under the Central Column.

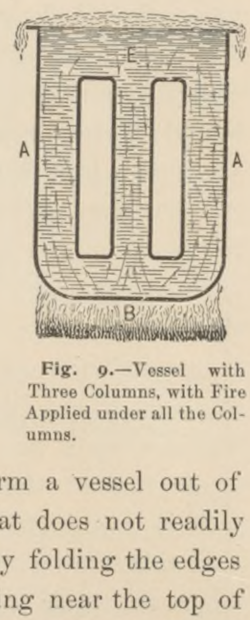


Fig. 9.—Vessel with Three Columns, with Fire Applied under all the Columns.

These peculiarities of water, so far as heat is concerned, may be emphasized by some easily performed experiments. An illustration of its absorbent capacity may be supplied as follows: Form a vessel out of writing-paper or any other paper that does not readily absorb water. Make it water-tight by folding the edges and fastening them in place by pinning near the top of the corners. Partly fill this vessel with water and hold over a flame. This is very readily done by setting the paper vessel on the open work of a gas stove. The gas should be lighted after the paper has been placed in position. Under these circumstances the heat is so rapidly absorbed by the water that the paper is not injured by the flame. Water may be even boiled in a paper vessel in the way described without scorching the paper.

Fig. 10.—Vessel with Two Columns or Water-legs, with Fire Applied above the Lowest Point and to Sides of Legs Equally.

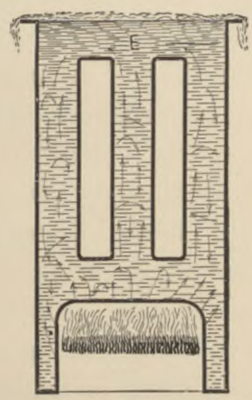


Fig. 11.—Modification of Fig. 9. Water-legs carried down and fire evenly distributed showing same results.

The inability of water to conduct heat may also be shown by an experiment. Let a combustible fluid like alcohol be floated on the surface of water in a vessel. Light the alcohol. It will be found that the latter will be consumed without raising the temperature of the water appreciably, even though the quantity of alcohol so burned is sufficient to evaporate the entire body of water if applied underneath. If applied underneath, the particles of water would take up the heat by convection, resulting in phenomena already given in this chapter.

Still another experiment illustrating the inability of water to conduct heat may be described. If into a vessel containing cold water hot water be carefully poured the latter will spread out over the top of the colder water and will give off more of its heat to the air above than to the cold water below. This experiment may be tried in a bath-tub when in the act of bathing. If the water surrounding the person is comparatively cold and a small stream of hot water be allowed to flow into the bath-tub, it will be found that the hot water will spread out over the surface of the colder water in a way to produce a stinging sensation where it comes in contact with the person. Agitation of the water, producing currents, will, on the other hand, distribute the heat through the entire body of water.

Since motionless water is comparatively incapable of transferring heat, it follows that the temperature of a body of water cannot be raised except by bringing each particle into contact with heating surfaces or by mixing together particles of high and low temperature. We have seen in Fig. 2 that with a mingling of particles irregularly performed less advantageous results follow than when separate passages are provided, as illustrated in Figs. 3, 7, 8, and 19. There are, then, two ideas presented: first, of irregular indefinite currents in the body of water in which the hotter particles slowly share their heat with the colder particles with which they mingle, and second, the idea of directed movement by which every particle of water is brought into contact with heating surface and allowed to take up all the heat it is capable of absorbing. When water is warmed chiefly by the mingling of currents the process is accompanied by much friction and consequent loss of energy, or, what is the same thing, waste of heat. Further, as has already been shown, the result of heating water in this manner is the gradual stoppage of circulation with the ultimate effect of forming steam and raising pressure at points where it is not only not desired to have pressure, but where pressure is decidedly harmful. Surfaces which do not promote the direct contact of water with them by reason of the globules of steam formed thereon are relatively feeble transmitters of heat. Under these circumstances heat is transferred to the water by convection, or more correctly speaking, by mingling currents. For this reason the area of surfaces heated in this manner must be necessarily greater than where the water to be heated is brought in direct contact with the heating surface by the proper disposition of the ascending and descending columns. A recent writer on boiler construction discussing this point says,—

"The heating surfaces should be arranged to facilitate the movement of the convection-currents and promote free circulation. This is effected in the best manner when the heat is applied underneath the water to be heated, and when the shape and position of the heating surfaces facilitate the free escape of the heated water in its upward current and the return of the cooler water in its downward current."

It may be accepted as a fact, then, that water is heated most economically by the contact of each particle with heating surface rather than by mingling currents of high and low temperature.

Circulation which brings the particles of water into direct contact with the heating surfaces is accomplished by a separation of the ascending column of heated water from the descending column of colder water. This arrangement brings only the particles of lowest temperature into contact with the heating surface, which, by reason of their low temperature, are most capable of absorbing heat. It is well known that the capacity of water for absorbing heat is in proportion to the difference in temperature between the water and the heating surface. Thus, with fire surfaces at 800° and water in contact with them at 100°, the rate of heat transmission may be expressed as $8 - 1 = 7$. Again, with water at 200° and with fire surfaces as already given, the rate of transmission would be expressed as $8 - 2 = 6$, or equivalent to one-seventh less. It is apparent from this, that any construction which tends to keep water of high temperature against the fire surfaces is a relatively poor heater, because of the comparative inability of water of high temperature to absorb heat. Again, if the heat is sufficient to form steam globules upon the water side of the surface, the absorbtive efficiency is still further diminished.

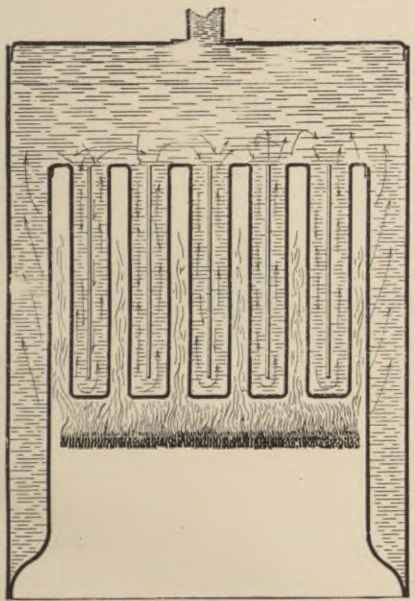


Fig. 12.—Adaptation in Practice of Forms Shown in Figs. 2 and 10.

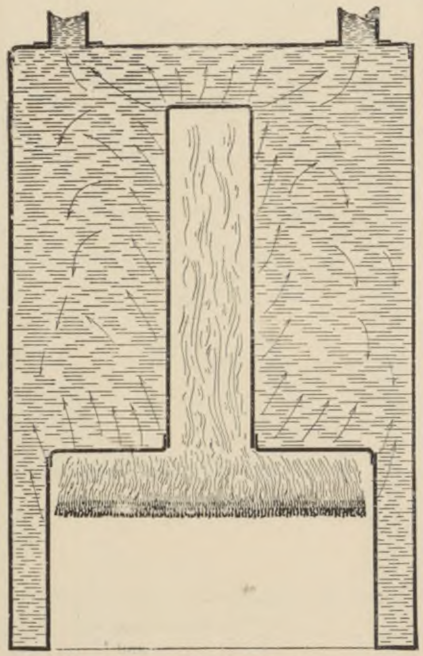


Fig. 14.—Adaptation in Practice of Forms Shown in Figs. 2 and 10.

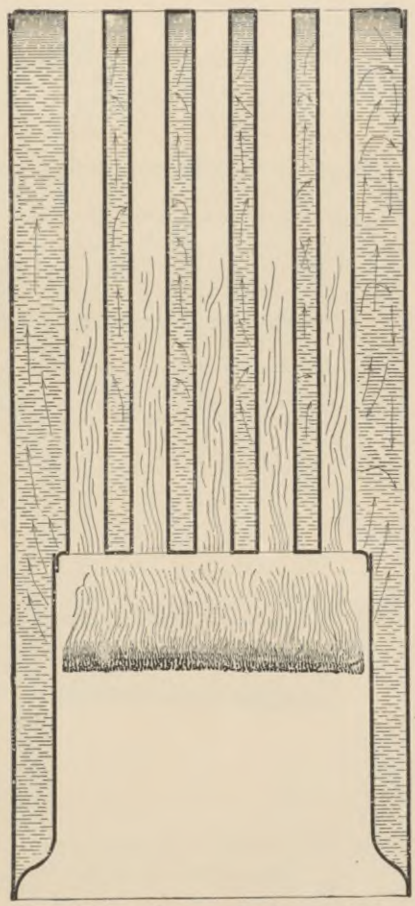


Fig. 13.—Adaptation in Practice of Forms Shown in Figs. 2, 9, and 11.

Another advantage following upon the use of two passages, one for the descending column and the other for the ascending column, so arranged as to cause each particle of water to pass over the heating surfaces, is that there is no loss of heat through friction between ascending and descending currents. In other words, there is no retardation of circulation through conflict of currents. Again, there is no chance for the formation of steam on the inside of the fire surfaces, either to the extent of interfering with the transference of heat to the water or of producing pressure.

ADVANTAGES OF INDEPENDENT CIRCULATION.

The value of independent internal circulation at the heating point, in promoting circulation in a system of pipes and radiators, is next to be considered. In Figs. 2 to 11, inclusive, the effect of heat upon the circulation of a fluid contained in vessels of certain forms has been indicated, so far as circulation is confined to the vessel itself. To make a practical application of the illustrations let us

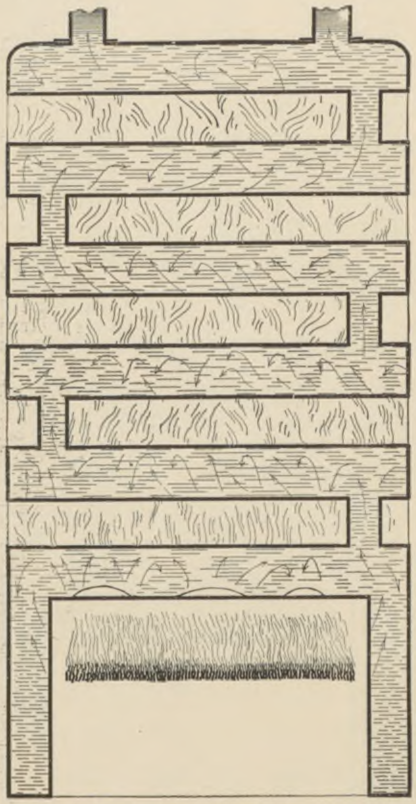


Fig. 15.—Adaptation in Practice of Forms Shown in Figs. 4, 5, and 10.

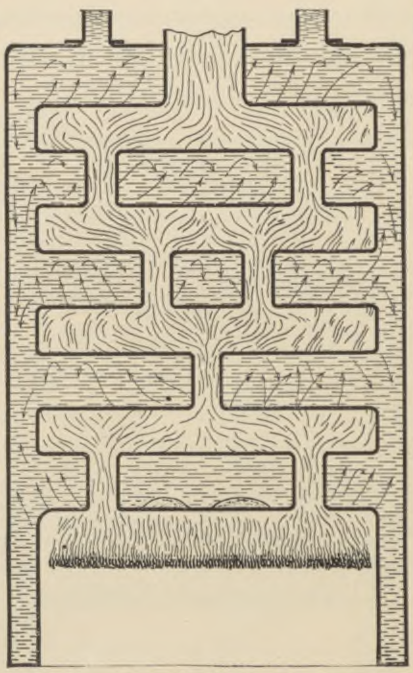


Fig. 16.—Adaptation in Practice of Forms Shown in Figs. 4, 5, and 10.

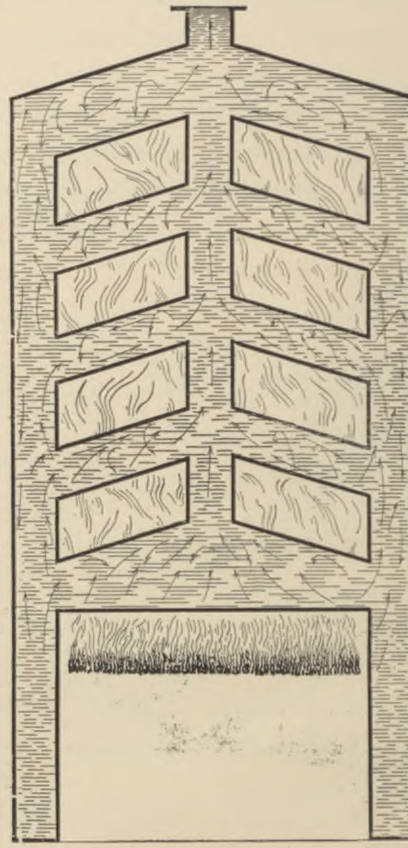


Fig. 17.—Adaptation in Practice of Forms Shown in Figs. 9, 10, and 11.

adapt the forms to the heating of water for warming purposes in connection with a system of pipes and radiators. What is shown in Fig. 12 is adaptation in practice of the forms shown in Figs. 2 and 10, and may be described as a drop-tube boiler. Each drop-tube, it will be noticed, is equivalent to the kettle shown in Fig. 2. The diaphragm or partition which separates the column of water in the drop-tube into two parts does not sufficiently destroy the equilibrium between the two columns to establish vigorous circulation. Whatever circulation takes place in the tube is a local circulation which is entirely nullified when the particles rise to the top of the tube and are compelled to intermingle with those in the body of water around the mouth of the tube. Excessive firing in this form will ultimately stop circulation and blow the water out of the tubes by the formation of steam in their extremities. Whatever heat is given off by the fire to the water-legs at the sides of the boiler results in the same action as was described in connection with Fig. 10. Circulation is impaired by mingling currents.

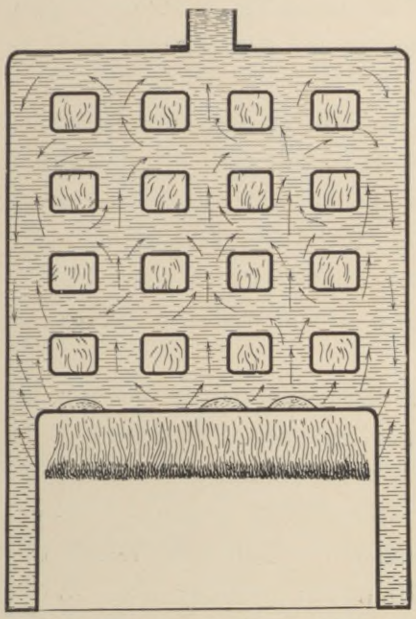


Fig. 18.—Adaptation in Practice of Forms Shown in Figs. 9, 10, and 11.

Fig. 13 exemplifies in boiler construction the features of circulation illustrated in Figs. 2, 9, and 11. The columns of water over the fire in this case receive heat equally, which, as we have shown, is opposed to circulation. This is still further proved by the fact that boilers of this kind, when used for steam purposes, frequently prime and produce very wet steam. Inasmuch as the heat is given equally to the several water-spaces around the fire, the result produced is the same as that illustrated in Fig. 9, and again illustrated, so far as the water-legs and side-passages are concerned, by Fig. 11.

The design of boiler shown in Fig. 14 results from an effort to increase the surfaces within the fire-pot. Fire ascends in the central column, and, striking the crown-sheet, produces the same results as shown in the case of the pot in Fig. 2. Again, whatever heat is given off at the sides has the same action as was explained in connection with Fig. 10. The result is that the entire body of water is heated by mingling currents.

In Figs. 15 and 16 are shown adaptations in practice of the forms shown in Figs. 4, 5, and 10. The water passages have fire beneath and around them, as shown in Fig. 4, and are liable to blow out by the formation of steam, as illustrated in Fig. 5, and as described in connection with that figure. There are also water-legs which, although not connected at the bottom, as shown in Fig. 10, contain motionless water which cannot be brought into circulation by the heat as applied. Steam boilers having water-legs of the type shown in Figs. 15 and 16 are noted

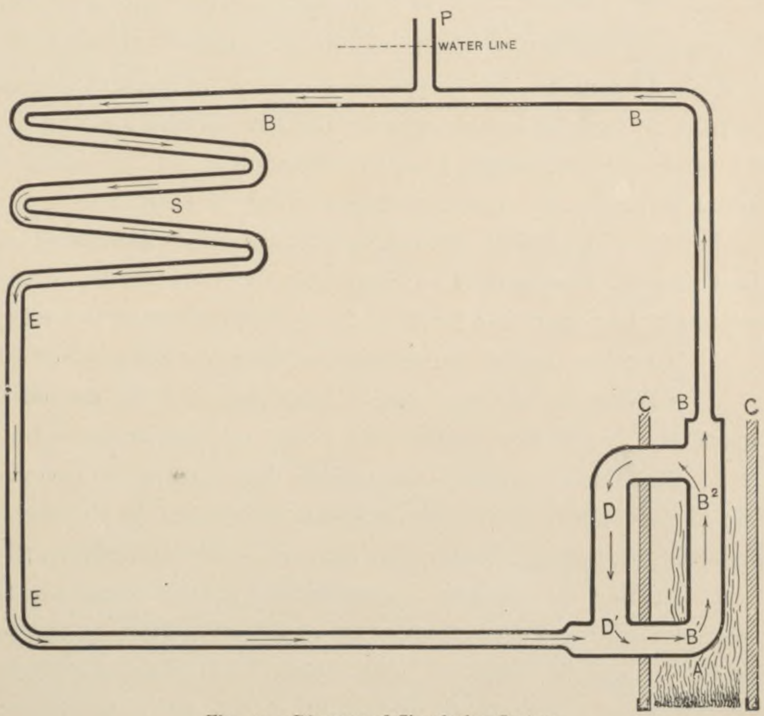


Fig. 19.—Diagram of Circulating System.

for the accumulation of sediment in these parts, which fact is still further proof of the lack of circulation therein. Boilers of this design, with small increase of firing, produce steam in the sections immediately next to the fire, thus maintaining the water in them at temperatures relatively higher than that of the upper sections, producing pressure opposing the inflow of the return water, and impeding the circulation of the entire system.

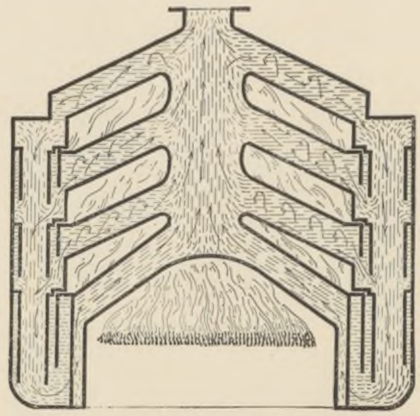


Fig. 20.—Adaptation in Practice of Figs. 3, 7, and 8.

Figs. 17 and 18 exemplify forms of construction illustrated in Figs. 9, 10, and 11. There is the equivalent of the central column shown in Fig. 9 and two outside columns, but free circulation is not possible because the heat is equally applied under the three columns. The water-legs contain motionless water for reasons explained in the last instance, and as shown in Figs. 10 and 11.

With the impaired internal circulation that is shown in all these examples, the warmed water can never rise freely. It follows, then, as in the case of the kettle in which the excess of temperature resulted in boiling over (Fig. 2), pressure is generated at the return opening, the effect of which is to retard the general movement of the water contained in the system. What is variously called the "belt principle," "positive circulation," "continuous circulation," etc., shown in Figs. 15 and 16, being the development of the principles explained in Figs. 4 and 5, in which there is no provision whatever for internal circulation, the general movement of the water is toward the points of discharge into the flow pipe, but it comes into interference continually with the colder water in the upper passages which is endeavoring to find its proper place at the bottom of the boiler. The result, at best, is a feeble and embarrassed advance. In addition to the retarding of the water by the conflict of currents, the narrowness of the passages with which these boilers are ordinarily provided also tends to produce pressure at the return opening.

To quote one of the greatest authorities upon boiler designing:

"When water-spaces are so cramped that the ascending and descending currents cannot flow separately, circulation cannot take place, and the water is put into a state of perturbation."

By this is explained the curious fact that with certain forms of waterways increased application of heat not only does not increase circulation in the system, but actually stops it so that the pipes and radiators are at a lower temperature with a forced fire than with a moderate fire.

In Fig. 19 is shown a diagram of a circulating system. It illustrates the application of the principles of rapid independent internal circulation in the heat source, as exemplified in Figs. 3, 7, and 8. In this the effect of rapid firing is found to be a vastly increased circulation in the entire system instead of the retarded movement which occurs in all other forms. The higher the temperature at B and B, the greater is the velocity of descent in the columns D and E E. It is easier for the water to descend through E E than to ascend and overflow at P, because in absorbing heat at B′ no pressure is produced to resist or impair the descent in E E or D. At D′ the temperature of the water from E is increased by mingling currents from D, but at B′ the heat is taken up by the water directly in contact with the fire surface.

Fig. 20 exemplifies the practical application in a working apparatus of the form shown in Figs. 3, 7, and 8. In this design the heat is applied only to the ascending column of water, and the outside descending columns are comparatively cold. Though separated from the ascending columns they have continuous communication with them at the intersection of the cross passages, thus inviting the easy descent of any particles of water in them or in the cross passages which may be of relatively low temperature. It will be observed that the outside column is provided with a series of downward projecting tubes, so arranged as to deliver descending particles of water from each section at a point somewhat lower than the portions in the same sections which receive the greatest heat from the fire. This construction results in the separation of the ascending and descending columns and is a mechanical means of maintaining a condition of inequilibrium between the two columns. It also results in such a disposition of the two columns of water as to produce a line of greater resistance in the direction of the descending column and of less resistance in the direction of the ascending column so far as would be affected by the generation of steam in the event of hard firing. This arrangement of parts in turn, referring now to the cross passages in combination with the tubes extending downwardly in the outside or cold columns, serves to separate and sort the particles of water in a way to keep the hotter particles in the center or ascending column, and allow free passage of the colder particles in the direction of the descending column. The only conflict from mingling currents that can occur in this type of boiler is in the limited space of the cross passages, and here they result in separating particles of unlike temperature and conducting each class to its own appropriate place in the boiler without impairing or retarding the circulation of the boiler as a whole.

The Novelty Circulator.

TWO views of the Novelty Circulator are presented herewith, one the exterior appearance, and the other a vertical section showing the grate, fire-brick linings, water ways, etc. There are also presented views of the parts of which the circulator is composed. Referring to the latter, it will be seen that there are five in all, namely: the ash-pit, the fire-brick lining, the fire-box, the intermediate section, and the top section. The ash-pit, which is of liberal height, contains the grate and is provided with doors of ample capacity for removing ashes. These doors, in turn, carry

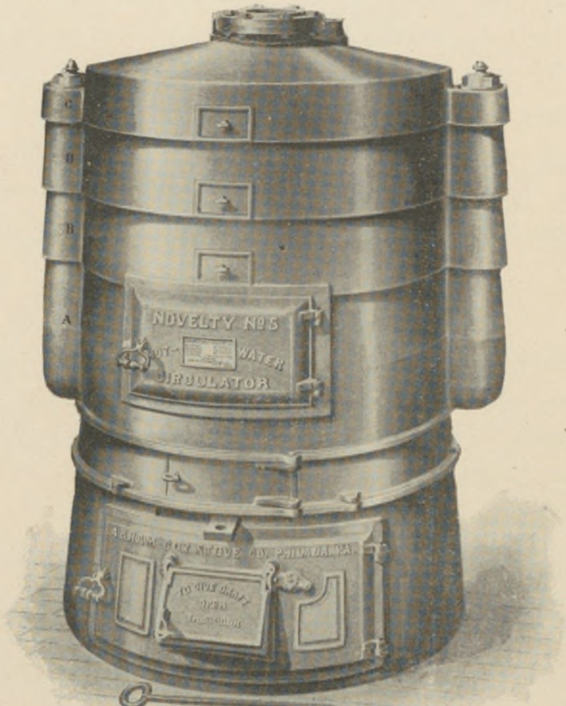


Fig. 21.—Exterior View of the Novelty Circulator.

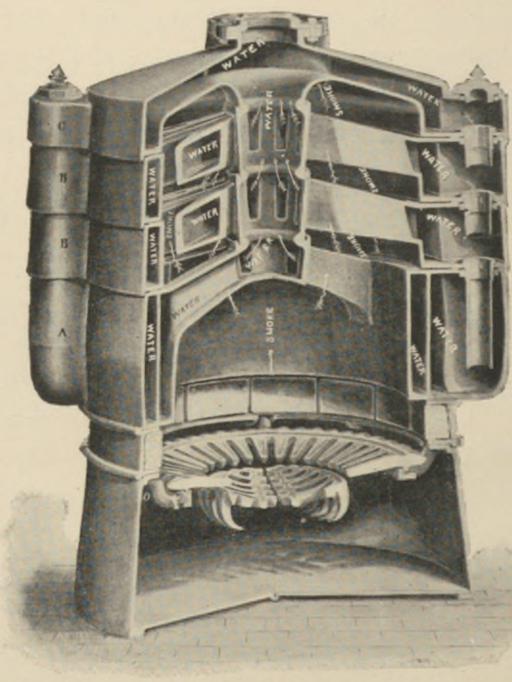


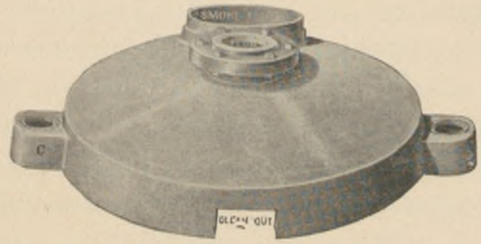
Fig. 22.—Vertical Sectional View of the Novelty Circulator.

the draft-doors, which are fitted with latches and adapted to be set as circumstances require. The center of the grate is of the anti-clinker variety, and is of such a form as to be revolved by a crank in a way to dump ashes, throw down clinkers, and that, too, without danger of dropping the fire. The outside part of the grate is arranged to shake by means of the shaking-arm shown in the cut. All the shaking may be done while the ash-pit and clinker-doors are closed, thus avoiding all dust.

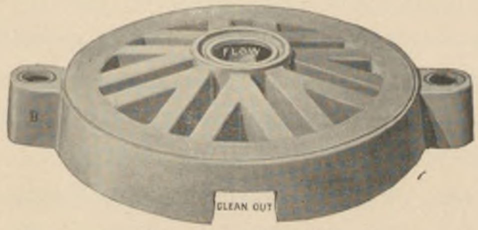
The shell of the fire-brick lining is a circular frame joined at intervals by vertical partitions. The bricks occupy the spaces between these vertical partitions, and are put in place from the outside, an arrangement of parts permitting the exchange of an old brick for a new one without drawing the fire. This feature of construction is peculiar to this apparatus, and is of great advantage. The bricks are held in place by hollow frames of cast-iron. The frame which holds the front brick is hinged, and is so arranged as to form a door, and gives access to the fire for cleaning, stoking, etc. It is provided with a bracketed shelf, which carries the lining-brick when the door is swung.

The fire-box (A) is a casting containing two annular water-spaces around the fire, the inner one of which is connected by radial inclined arms with the central water way immediately over the center of the fire, while the other is connected with two outside water ways in the lugs or projections at the sides. The return water of the system enters the outer annular space at the back of the fire-box and passes around to the front, at which point the division between the two annular spaces is cut away. The central water way and the two outside water ways join corresponding parts in the section above, and thus provide a separate passage for the ascending and descending columns respectively.

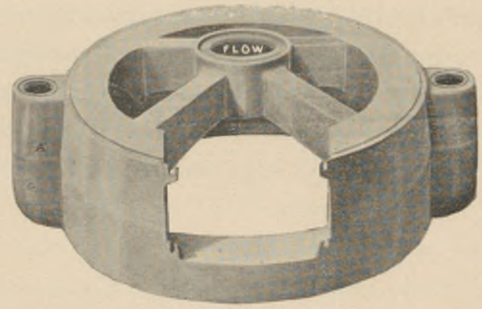
The intermediate section (B) of the Novelty Circulator contains an annular water-space or water-jacket connected with the central column by radial arms, the spaces between the arms forming smoke passages. From the annular water-space lugs are extended at the sides which connect with corresponding lugs on the sections above and below. The radial arms in this section are so disposed as to be staggered over those of the fire-box, thus presenting their surface to the radiant heat of the fire. Further, the opposite sides of this section are unlike; that is, the number of radial arms is odd, not even, and it is adapted to be used either face to the front. Where there is more than one intermediate section used they are reversed, thus continuing the staggered order mentioned. The central water way joins the corre-



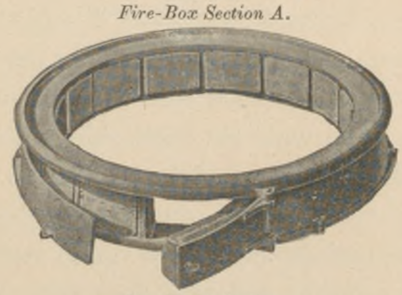
Top Section C.



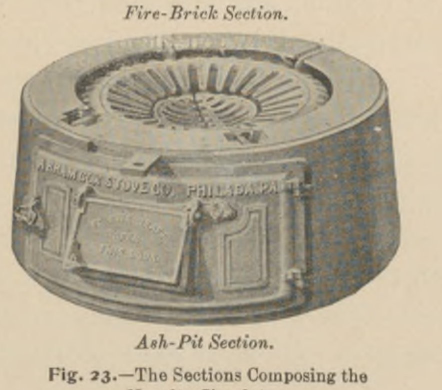
Intermediate Section B.



Fire-Box Section A.



Fire-Brick Section.



Ash-Pit Section.

Fig. 23.—The Sections Composing the Novelty Circulator.

sponding part of the fire-box below and of the section above. The top section (C) of the Novelty Circulator is very much like the intermediate section just described, except that the radial arms are replaced by a continuous water way connected with the central ascending water way and also with the two outside descending water ways in the lugs already referred to. All three of the water-sections, namely, fire-box, intermediate section, and top section, communicate freely through the central ascending water way and through the two outside descending water ways.

The several sections of the Novelty Circulator are joined together by means of nipples in the outside water ways, as clearly shown in the sectional view. No bolts are used. The nipples project downwardly in the water ways, as will be seen by an examination of the view just referred to, in a manner to afford additional safeguard against the mingling of currents of different temperatures.

In the arrangement of water ways it will be seen that the Novelty Circulator completely answers the requirements of perfect circulation. It also meets the demands of good design, such as large direct fire surface, ample flue area, accessibility of flue surfaces for cleaning, easy water ways, and vertical circulation. It goes still further than this, for in the completeness of its adherence to natural laws this apparatus realizes an ideal development. This becomes manifest by an examination of the sectional view, and is thoroughly proven by its performance. In operation the water in the fire-box is always lower in temperature than that in the upper sections. This is due to the rapidity of the internal circulation. The result is the most economical working, because the relatively cooler water is always kept against the fire surface, thus taking up the maximum of heat.

By reason of its rapid and powerful circulation the Novelty Circulator can be depended upon to perform satisfactorily under conditions which render other forms of hot-water heating apparatus entirely inoperative. It circulates water in a system on the same level with the boiler, with an open expansion tank, as low as five feet above the top of the circulator, and with all the radiating surface below the top of the circulator, and much of it below the fire-box. This is a feat quite beyond the power of any other construction now known.

To what do these things point? Not to the discovery of a new principle, but to the proper application of principles that are as old as nature,—principles which all designers of hot-water boilers have recognized in some degree, but to the realization of which none have previously found the key. These principles may be briefly stated as follows: The separation of the ascending from the descending columns and providing each with proper ways, the maintenance of the greatest difference of temperature between them, and prevention of equilibrium by difference in the levels of the columns.

The operation of the Novelty Circulator may be briefly described as follows: With the parts arranged as described, and a fire built upon the grate, circulation begins instantly. Particles of water in the bottom of the central column immediately over the fire become rarified and are driven forward by the weight of the colder columns at the sides of the boiler pressing downwardly and through the passages. As the particles of water which have become warm or rarified leave the fire surface and start in their upward course, their places are filled with particles of colder water advancing through the inclined water ways leading to the central column. In turn particles of water which become heated in the water ways of the several sections are similarly driven toward the central column through the free passages and upward in that direction. At the same time particles of colder water from the exterior columns advance into their places. As the heat of the fire increases, the circulation becomes more rapid.

Connections between sections, both central and at the outside, are such that complete circulation is maintained in each section independent of all others, and also in the whole apparatus as a unit. The downwardly projecting nipples in the exterior columns in combination with the inclined water passages in the sections, and the central column, serve to prevent an equilibrium between the two columns. The water of relatively low temperature is always at a lower level than the warmer water, both in the individual sections and in the apparatus as a whole, and at the same time it is in immediate contact with the fire surfaces. By reason of the descending water ways which contain water relatively cool, being at the exterior of the circulator, combined with the central ascending passage directly over the hottest fire, all crossed or mixed currents of various temperatures are avoided. Hard firing only drives the circulation; in no case can it impede circulation. Steam serves to rarify or lighten the central column, and when produced against the fire surfaces moves forward instantly. It never remains in a way to retard heating, and if pressure should be generated it would exert its force in the direction of the least resistance, which is upward in the central passage, thus still further promoting circulation.

DIMENSIONS, RATINGS, AND PRICES.

THE Novelty Circulator is manufactured under patents granted to the Hogan Engineering Company, and is supplied of the sizes and dimensions shown in the table on the opposite page. The annexed diagram affords a key to the principal dimensions.

Each circulator has one flow and one return pipe only, which are always of like diameters. Ratings are given for each size circulator of both direct and indirect surface.

The Novelty Circulator under all ordinary conditions of piping and distribution of radiation is fully guaranteed to supply the radiating surface given opposite the several sizes in the table on page 21.

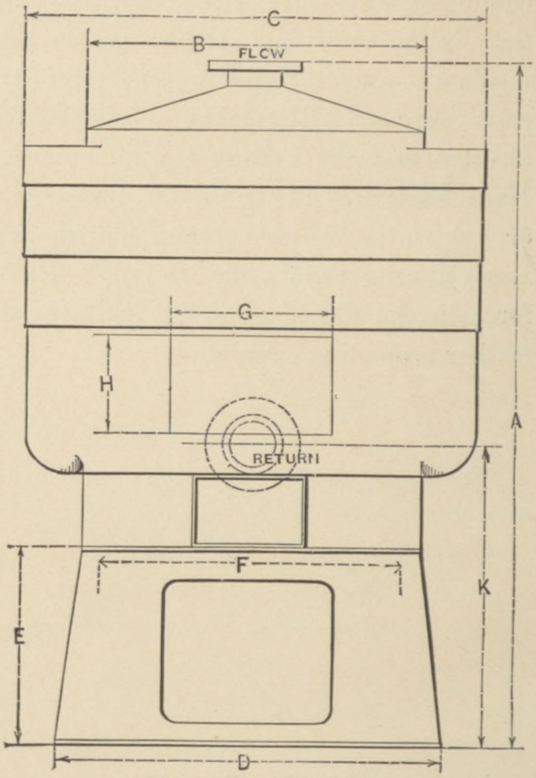


Diagram Key to Dimensions.

TABLE OF DIMENSIONS, RATINGS, AND PRICES OF THE NOVELTY CIRCULATOR.

NUMBER.	Letter in Diagram	1*	2*	3*	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Height in inches	A	43	48¼	53½	44½	50	55½	47	52¾	58½	50	56	62	52¾	59¼	65¾	55½	62½	69½
Diameter in inches	B	22	22	22	24½	24½	24½	27½	27½	27½	31½	31½	31½	36¼	36¼	36¼	40¼	40¼	40¼
Width over all in inches.	C	32½	32½	32½	35	35	35	38	38	38	42	42	42	46½	46½	46½	50½	50½	50½
Diameter of ash-pit at base in inches	D	24	24	24	27	27	27	30½	30½	30½	35	35	35	40	40	40	44½	44½	44½
Height of ash-pit in inches	E	13½	13½	13½	14	14	14	14¾	14¾	14¾	15¼	15¼	15¼	15½	15½	15½	16	16	16
Diameter of fire-box in inches	F	16	16	16	19	19	19	22	22	22	26	26	26	30	30	30	34	34	34
Width of feed-door in inches	G	11	11	11	12	12	12	13½	13½	13½	14	14	14	14½	14½	14½	15	15	15
Height of feed-door in inches	H	8	8	8	8½	8½	8½	9	9	9	9½	9½	9½	9½	9½	9½	10	10	10
Height from floor to center of return in inches..	K	22½	22½	22½	23	23	23	24	24	24	25¼	25¼	25¼	26	26	26	27	27	27
Diameter of flow and return in inches		4	4	4	4	4	4	4	4	4	5	5	5	6	6	6	6	6	6
Diameter of smoke-pipe in inches		7	7	7	7	7	7	8	8	8	9	9	9	9	9	9	10	10	10
Ratings		RATING IN SQUARE FEET OF DIRECT RADIATING SURFACE.																	
		250	300	350	350	425	500	500	625	750	750	950	1150	1150	1400	1650	1650	1950	2250
		RATING IN SQUARE FEET OF INDIRECT RADIATING SURFACE.																	
		185	200	235	235	285	335	335	420	500	500	630	770	770	935	1100	1100	1300	1500
Prices, F.O.B., Phila.		$87.50	100.	112.50	120.	135.	150.	155.	180.	205.	210.	240.	270.	280.	320.	360.			

* In course of construction.

ILLUSTRATIVE EXAMPLES.

FOR the purpose of showing how the Novelty Circulator may be advantageously installed, we present a number of illustrative examples indicating the runs of pipes, quantity of radiating surface, position of radiators, and other features of interest to steam-fitters, builders, house-owners, and architects.

These examples include (1) a cottage residence, (2) a suburban mansion, (3) a city residence, (4) a railway station, (5) a church and school, and (6) a city office. Elevations, floor plans, and sections are given in each instance with enough of constructive details to make every feature of the work easily understood, while the text contains a description with reasons for everything that is done. In the calculations of surfaces frequent references are made to the rules given further on in the book. In thus presenting the examples before propounding the methods of calculation, we bring to the attention of the reader the need of definite and reliable rules and formulæ, now for the first time presented, and at the same time avoid tiring him with pages of tabular work preceding the illustrations. Tables and rules at best find their largest use as references. In each case we have been careful to refer specifically to the rule employed in a way we trust to bring the reader into pleasant acquaintance therewith.

KEY TO THE PLANS AND REFERENCES.

═════════ Double or parallel lines indicate Flow Pipes.

▬▬▬▬▬▬ Single heavy lines indicate Return Pipes.

- - - - - - - - - - - Broken lines indicate Air Pipes from radiators, coils, and flow pipes.

RAD.—" Radiator."

RAD. 44□′—" Radiator with 44 square feet of surface."

RAD. 7 44□′—" Radiator No. 7 with 44 square feet of surface."

RAD. 16 32□′—" Radiator No. 16 with 32 square feet of surface."

(Nos. 7 and 16 in such instances refer to the numbers of the rooms in the tables.)

REG.—" Register."

W. REG. or W. R.—" Warm Air Register."

W. REG. XI 8 x 10.—" Warm Air Register 8 x 10 inches in room No. 11."

W. D. or W. A. D.—" Warm Air Duct."

D. W.—" Duct for Warm Air."

W. D. 5 x 21.—" Warm Air Duct 5 x 21 inches."

C. D. or C. A. D.—" Cold Air Duct."

CIR. REG.—" Circulating Air Register."

E. REG. or E. R.—" Exhaust or Exit Register." (Exhaust Register" refers to the register connected to the ventilating flue and near the floor. " Exit Register" refers to the register connected to ventilating flue and near the ceiling.)

E. D. or E. A. D.—" Exhaust or Exit Air Duct."

V.—" Ventilating Shaft."

F.—" Flow Pipe."

F. M.—" Main Flow Pipe."

R.—" Return Pipe."

R. M.—" Main Return Pipe."

V¾—" ¾-inch Valve on Radiator."

G. V.—" Gate Valve."

G. V. F.—" Gate Valve on Flow Pipe."

A. V.—" Angle Valve."

A. V. R.—" Angle Valve on Return Pipe."

S. P.—" Smoke Pipe."

T.—" Thermometer."

EX. TANK.—" Expansion Tank."

EXP. PIPE.—" Expansion Pipe."

Heating and Ventilating Cottage Residence with the Novelty Circulator, No. 8.

Fig. 24.—Perspective View (Reproduced from *Carpentry and Building* by Permission).

IN Fig. 24 is given the perspective of a typical cottage residence. Fig. 25 is a sectional longitudinal elevation in which the location of the radiators is shown, and in which the relative positions of the warm-air and exhaust or exit registers are indicated. The inclination of the main flow and return pipes in cellar, and the vertical lines of pipes connecting radiators on second floor to main pipes in cellar, are also shown. The height of the expansion-tank above the circulator is indicated, as well as the location of the emptying or blow-off cock. Fig. 26 is a plan of cellar. The double lines denote the flow pipes, and single heavy lines the return pipes. The latter lines are only seen in a few places in this plan, as the return pipes, where not indicated, are the same as the flow pipes and pass under them. A B D D give the location of the air pipes from the indirect radiators. The position of the main cold-air duct is also shown.

Fig. 27 is a plan of the first floor, and Fig. 28 a plan of the second floor. The location of radiators and registers on each floor is shown. The dotted lines indicate the floor-beams and the proper

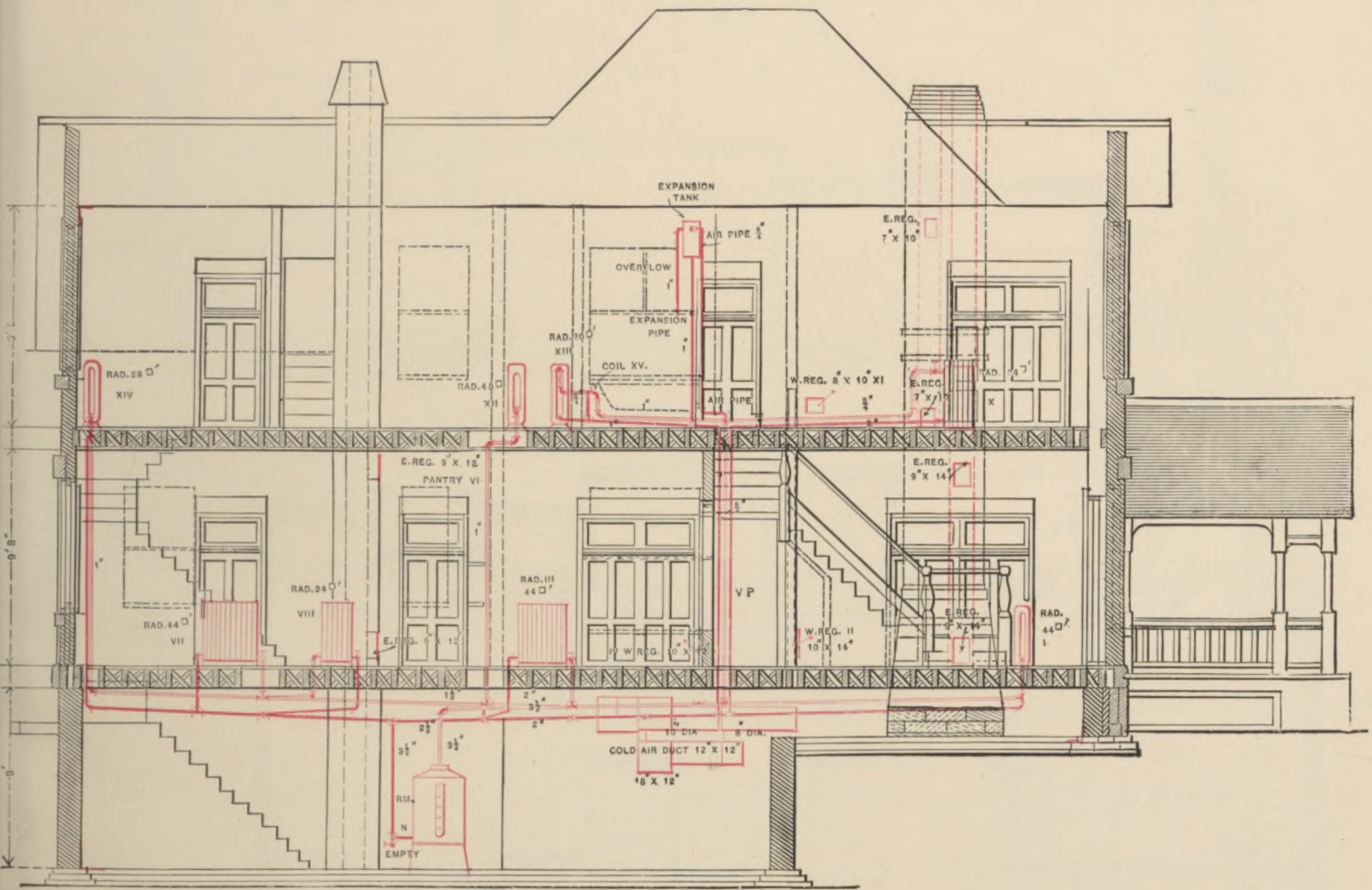


Fig. 25.—Sectional Longitudinal Elevation of Cottage Residence Showing Location of Circulator, Position of Radiators, etc. Scale ⅛ inch to the foot.

location for trimmer-beams so as to provide space for the passage of heating pipes and ducts to radiators and registers respectively. Fig. 29 is a sectional elevation giving an enlarged view of air ducts and air pipes from indirect radiators at A, B, and D, details in bath room, and location and connections of expansion-tank. Fig. 30 shows emptying-valve and discharge to sewer.

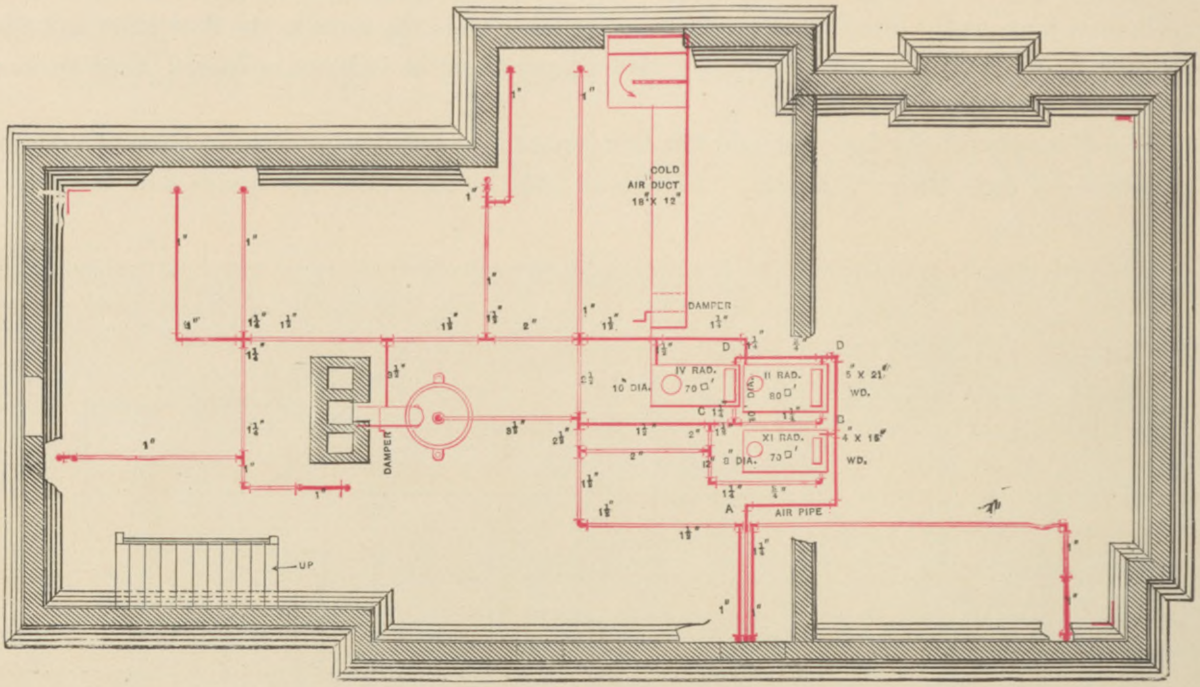


Fig. 26.—Plan of Cellar of Cottage Residence. Scale ⅛ inch to the foot.

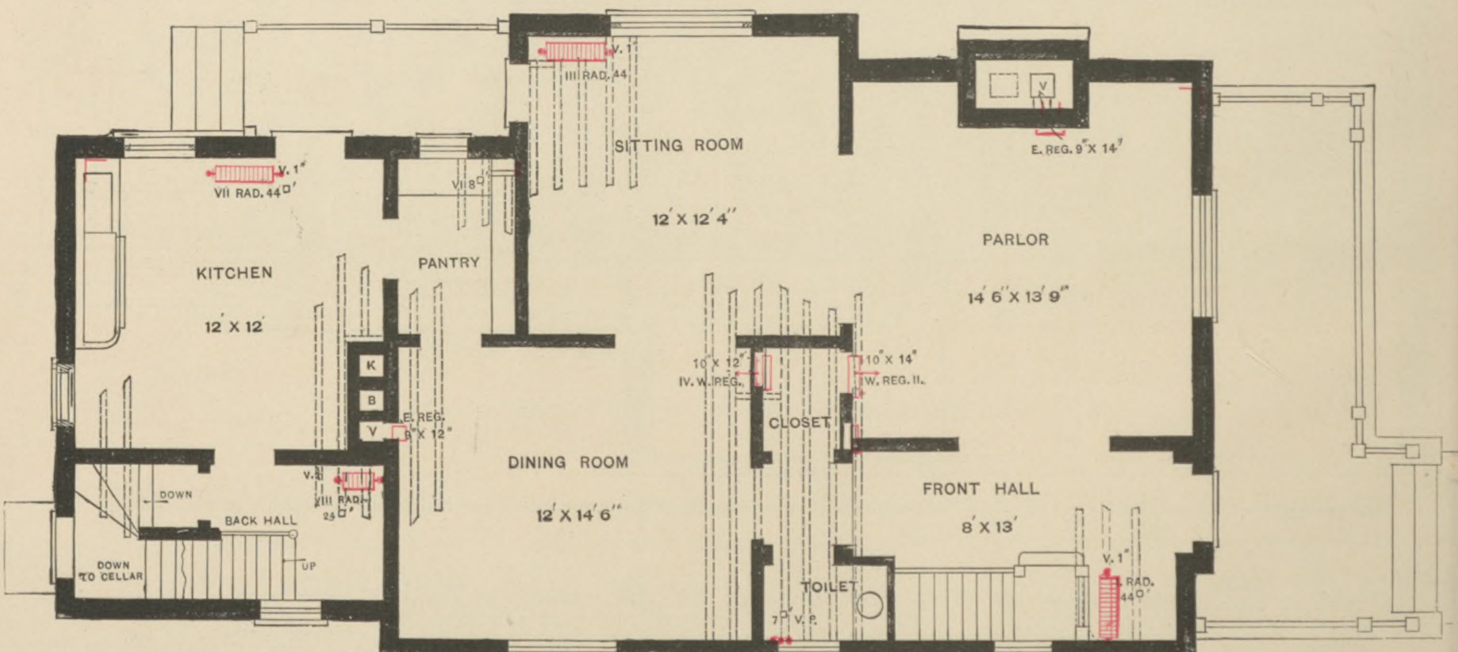


Fig. 27.—Plan of First Floor. Scale ⅛ inch to the foot.

Table I shows the contents, surfaces, and proportions of the apparatus, while Table II gives the surfaces in radiators proportioned.

In proportioning the quantity of surfaces required in radiators by the rule used in Table XIV, the temperature of the water in radiators may be taken at from 160° to 180°. Sufficient surface will be obtained by so doing. The surfaces in the indirect radiators and direct radiators on first floor, except those in pantry and kitchen, are proportioned with the temperature of water at 160°. The radiators in pantry and kitchen, and all on the second floor, are proportioned upon the basis of the water being at a temperature of 180°. The rooms with the latter temperature of water require less heat relatively than the other apartments, and by this change in the calculation less surface in the radiators is given. The surface in the bath room is proportioned with the temperature of the water

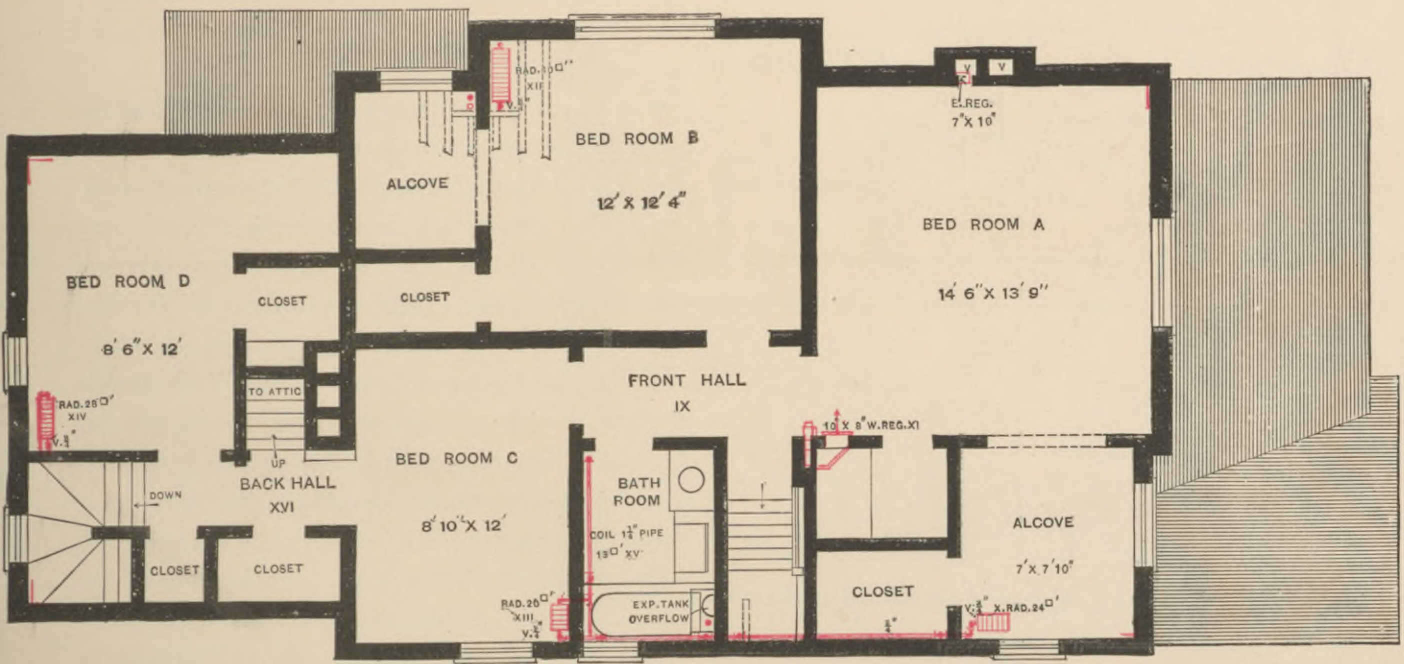


Fig. 28.—Plan of Second Floor of Cottage Residence. Scale ⅛ inch to the foot.

in radiator at 160°, and in order to provide for an increase of temperature, which is sometimes desirable in bath rooms, a special multiplier is given in the foot-note.

The location of radiators and registers is governed by several considerations. Provision for their location in planning the house should be made so that their presence will, as far as possible, remain unobserved. Such locations for them should be obtained in a way to avoid excessive lengths of pipes or ducts, and the introduction of numerous bends or turns. Where direct radiators are used they should be placed so that the most exposed wall will receive as directly as possible the heat given off by radiation. Warm-air registers should be located so as to produce warm-air currents near the exposed walls, and they should be at a higher level than the exhaust registers. Exhaust registers should be placed so as to cause the currents of air to tend toward the exposed walls, and they should be as near the level of the floor as possible. Exit registers should be as near the ceiling as possible, and arranged to cause the currents of heated air to flow toward the exposed walls. These registers are only opened when it is desired to allow the heated air to escape. The location of radiators and registers just suggested cannot always be secured in practice, as is illustrated in the cottage residence.

In the parlor, warm register II is located on the inside wall. As there is no cellar of any depth beneath this room, it is more convenient to locate the indirect radiator in the manner shown. The registers in the dining room and bed room A are also on inside walls on account of convenience of location. The exhaust and exit registers in the parlor and bed room A are near exposed walls, while the register in the dining room is in an inside wall.

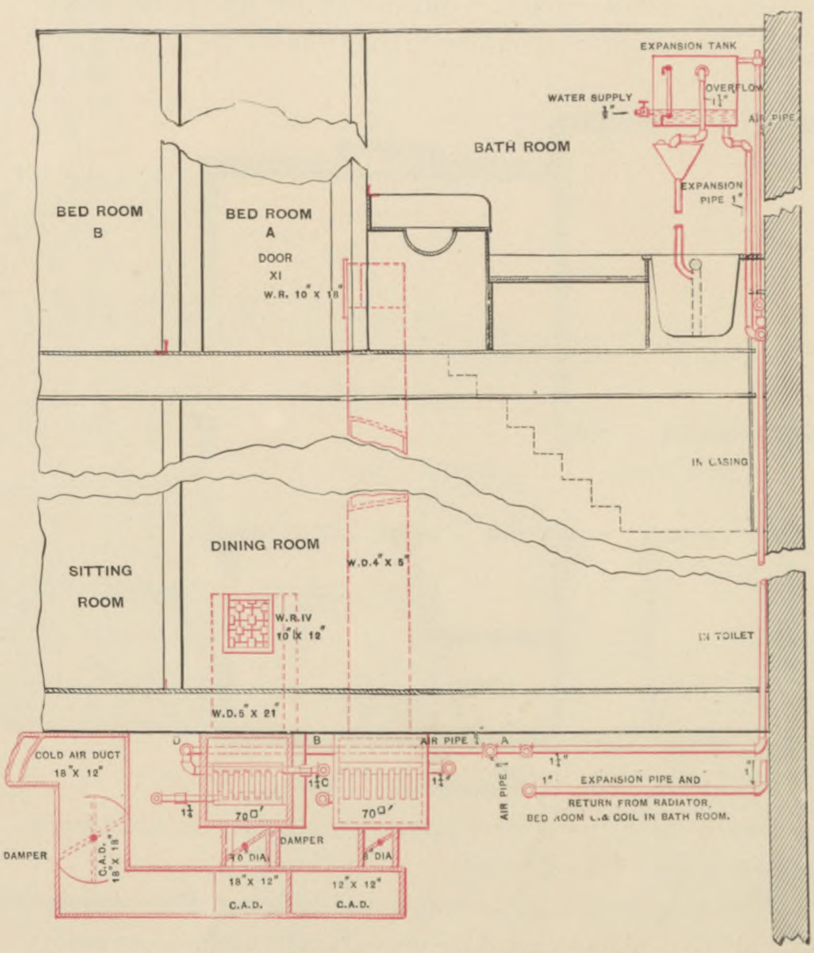


Fig. 29.—Sectional Elevation Showing Air Ducts and Air Pipes, also Details in Bath Room, with Expansion Tank, etc.

The direct radiators are as far as possible located near exposed walls, except the radiator in the back hall, which is placed near the inside walls on account of want of space. The pantry, No. VI, and toilet on first floor are heated by the flow and return pipe connection to the radiators in rooms above on second floor. The area of the warm-air flue is dependent on the velocity of the air, which velocity is due to the difference in temperature of the air in the room, and at the indirect radiator and the relative height of the flue. Under the usual conditions the natural velocity to the first floor is about $1\frac{1}{2}$ to 2 feet per second, and as the height is greater to the second and other floors the velocity increases to $2\frac{1}{2}$, to $3\frac{1}{2}$, and even to 5 feet per second.

The cubic contents of the parlor are 1930 feet, and, as seen in Table II, the air in this room is changed twice each hour, therefore 1930 x .053 (see Table XXVIII) = 102.29 square inches, the area of the warm-air duct. The warm-air duct, 21 x 5 inches, is equal to 105 square inches, which multiplied by 1.33 is 139.6 square inches, the area of the opening for warm-air register; that is, a 10 x 14 inch register. The exhaust and exit registers are found to be 9 x 14 inches by multiplying the area of warm-air flue by 1.2, which is equal to 126 square inches. The warm-air flue to bed room A on second floor is ascertained by multiplying cubic contents in feet, 1800 x .032 (see Table XXVIII) = 57.6 square inches. The warm-air flue therefore is made 4 x 15 inches = 60 square inches. The register openings are found as already explained.

The area of the fresh or cold-air duct is obtained by multiplying the area of the warm-air duct by .8. For the parlor the cold-air duct is equal to 105 x .8 = 84 square inches. Since $10\frac{1}{2}$ inches diameter equals 86.6 square inches, it is therefore used. (See cellar plan, Fig. 26.) The main cold-air duct is equal to the area of all the cold-air ducts.

As shown in Fig. 25, sectional elevation, cottage residence, the main flow and return pipes are inclined from the circulator to the radiator and vertical rising lines. This necessitates air-emission cocks or valves on each direct radiator and air pipes A B D D on indirect radiators, Figs. 25 and 29. The air cocks on direct radiators are opened when filling the system, and the advantage of the air pipes on the indirect radiators is the prevention of all air accumulations without necessity of operating air cocks. These air pipes are connected to vertical rising flow pipe to radiators Nos. X and XIII, second floor (see Fig. 28), which pipe is continued to the top of the expansion tank, Figs. 25 and 29. To the return pipe from radiator No. XIII is connected the expansion pipe shown in Figs. 25 and 29. The overflow pipe from the expansion tank may discharge into a funnel attached to pipe connected to overflow from the bath tub, or this pipe may be continued to the cellar and discharge into some convenient sink. By the arrangement described separate pipes from the expansion tank to the cellar are avoided, and the system is at all times freely open to the atmosphere so as to prevent air accumulations.

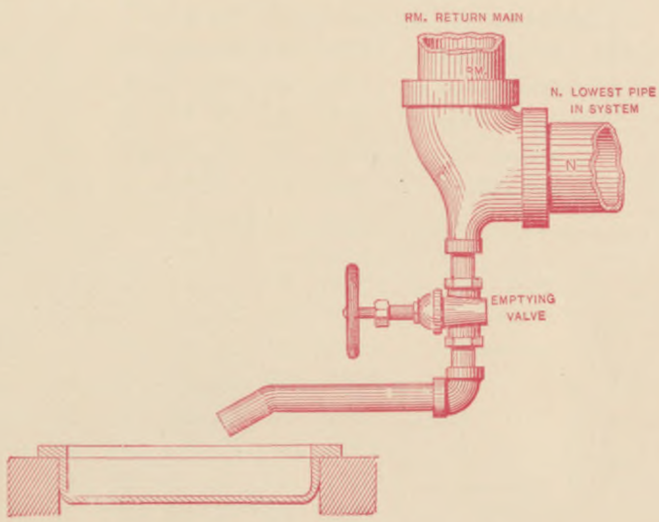


Fig. 30.—Emptying-Valve and Discharge into Sewer.

The area or size of flow and return mains is ascertained by multiplying the total surface in radiators in square feet, 516 x .015 (see "Sizes of Flow and Return Pipes") = 7.74, which is approximate area. Since $3\frac{1}{2}$-inch pipe has an area of 9.88 square inches, and is the nearest to the approximate area, we use it for both flow and return mains. The size of the expansion tank is ascertained in the manner explained under "Expansion Tanks." Square feet of surface in system 516 x .03 = 15.48 gallons capacity of expansion tank, or 516 x 7 = 3612 cubic inches capacity of tank. The entire system, as shown, contains approximately 220 gallons, which at 212° will approximately expand $\frac{1}{23}$ of its volume, or about $9\frac{1}{2}$ gallons or 2194 cubic inches. Therefore the space above the water-line in tank when the apparatus is cold and below the overflow opening should not be less than 2194 cubic inches. The rest of the space obtained by using the multipliers as above is necessary, especially when a ball-cock is attached to the water-supply pipe. By the arrangement of pipes shown, the water, on entering the system through the valve on water-supply connection to the expansion tank, passes down the expansion pipe into the vertical

TABLE I.—COTTAGE RESIDENCE. CONTENTS, SURFACES, PROPORTIONS, ETC., OF HOT-WATER APPARATUS.

	ROOMS.	Contents in cubic feet.	Exposed wall exclusive of glass surface, square feet.	Glass surface, square feet.	Equivalent to glass in square feet.*	Lineal feet of exposed wall.	Heating surface in radiators or coils in square feet.		Diam. flow and return pipes to radiators.	Proportion of contents to surface in radiators.	Dimensions of warm-air pipe in inches.	Area of warm-air pipe in square inches.	Velocity of air per second in feet.	Changes of air per hour.	Dimensions of warm-air registers in inches.	Area of exhaust or exit flue in square inches.	Dimensions of exit registers in inches.	Cold-air duct or fresh-air inlet in inches diam.	Area of cold-air duct or fresh-air inlet in inches.
							Direct.	Indirect.											
First floor.	1. Front hall	1071	133	23	36	16	44		1	25									
	2. Parlor	1930	196	26	46	23		80	1¼	24	5x21	105	1.5	2	10x14	144	9x14	10½	86.5
	3. Sitting room	1449	143	26	40	17	44		1	32									
	4. Dining room	1681	119	26	38	15		70	1¼	24	5x18	90	1.5	2	10x12	144	9x12	10	78.5
	5. Toilet	105	26	4	7	5	7			15									
	6. Pantry	360	46	6	11	5	8			45									
	7. Kitchen	1391	181	50	68	24	44		1	31									
	8. Back hall	438	72	5	12	8	24		¾	30									
	First floor totals	8425	916	166	258	113	171	150		26†		195				288			165
Second floor.	9. Front hall	486	36		4	4													
	10. Alcove	480	111	24	35	15	24		¾	20									
	11. Bedroom A	1800	184	23	41	23		70	1¼	25	4x15	60	2.5	2	8x10	144	7x10	8	50.2
	12. " B	1644	165	34	51	22	40		¾	40									
	13. " C	954	67	15	22	9	20		¾	47									
	14. " D	1005	196	15	35	24	28		¾	35									
	15. Bath room	384	44	5	9	5	13		¾	29									
	16. Back hall	297	84	6	14	10													
	Second floor totals	7050	887	122	211	112	125	70		36†		60				144			50.2
	Grand totals	15470	1803	288	469	225	296	220		30†		255			237	432	203		215
		cubic feet.	square feet.	sq. feet.	sq. feet.	lineal feet.	516 square feet.								square inches area.		square inches area.		square inches area.

* On the basis that 10 square feet of exposed wall equals 1 square foot of glass.
† Average.

return, and thence to return main R M and through pipe N to bottom of circulator, and as the water fills the system the air passes up the vertical flow pipe to the air pipe into the expansion tank, which is open to the atmosphere through the overflow pipe, thus freeing the system of air. An extra pipe from the top of the expansion tank is sometimes carried outside the roof to allow the vapor to escape. Such a pipe is not necessary in a well-arranged system, as the water in the expansion tank should not be heated to the extent of giving off vapor or steam.

The emptying-valve and discharge shown in Fig. 30 should be placed on the lowest pipe N, Fig. 25, in the system. The pipe from this valve should be open and discharge in sight, and it should not be connected directly to any waste or sewer pipe, so that any leakage through it may be easily observed. This valve need not be large. In ordinary residences $\frac{3}{4}$-inch to 1 inch in diameter is ample, while $1\frac{1}{4}$ inches to $1\frac{1}{2}$ inches in diameter is necessary only on large systems.

TABLE II.—COTTAGE RESIDENCE. SURFACES IN RADIATORS PROPORTIONED.

Floor	ROOMS.	Sq. ft. of glass and its equivalent in exposed wall.	Multipliers.	Cubic feet of air cooled per hour by glass.	Contents of rooms in cubic feet.	Changes of air in rooms per hour	Total number of cubic feet of air to be warmed.	Multipliers.	Sq. ft. of surface required in rooms to warm air from 0 to 70°.	REMARKS.
FIRST FLOOR.	1. Front hall	40	× 75	= 3000	+ (1557	× 1)	= 4557	× .0092	= 42	
	2. Parlor	46	× 75	= 3450	+ (1930	× 2)	= 7310	× .0114	= 83	Indirect.
	3. Sitting room	40	× 75	= 3000	+ (1449	× 1)	= 4449	× .0092	= 41	
	4. Dining room	38	× 75	= 2850	+ (1681	× 2)	= 6212	× .0114	= 70	Indirect.
	5. Toilet	7	× 75	= 525	+ (105	× 1)	= 630	× .0092	= 6	
	6. Pantry	11	× 75	= 825	+ (360	× 1)	= 1185	× .0072	= 8	
	7. Kitchen	68	× 75	= 5100	+ (1391	× 1)	= 6491	× .0072	= 47	
	8. Back hall	26	× 75	= 1950	+ (735	× 1)	= 2685	× .0092	= 25	
SECOND FLOOR.	10. Alcove	35	× 75	= 2625	+ (480	× 1)	= 3105	× .0072	= 22	
	11. Bedroom A	41	× 75	= 3075	+ (1800	× 2)	= 6675	× .0114	= 76	Indirect.
	12. " B	51	× 75	= 3825	+ (1644	× 1)	= 5469	× .0072	= 40	
	13. " C	22	× 75	= 1650	+ (954	× 1)	= 2604	× .0072	= 19	
	14. " D	35	× 75	= 2625	+ (1005	× 1)	= 3630	× .0072	= 26	
	15. Bath room	9	× 75	= 665	+ (384	× 1)	= 1049	× .0092*	= 12	

* Use 1.25 for multiplier to raise to 80°.

Heating and Ventilating a Suburban Mansion with two Novelty Circulators, No. 12.

Fig. 31 is the front elevation, while Fig. 32 is a sectional elevation in which the course of the ventilating flues is indicated by dotted lines. Rectangular figures, near each of which is the letter R, denote the positions of the exhaust and exit registers. The position of the expansion tank is shown with its connections to and from flow, return and air pipes in bath room on second floor. The vertical return pipes at back of circulator are shown away from center in order to make clear the flow-pipe connections. The channel for return pipes from radiators on basement floor is denoted by dotted lines below the level of floor.

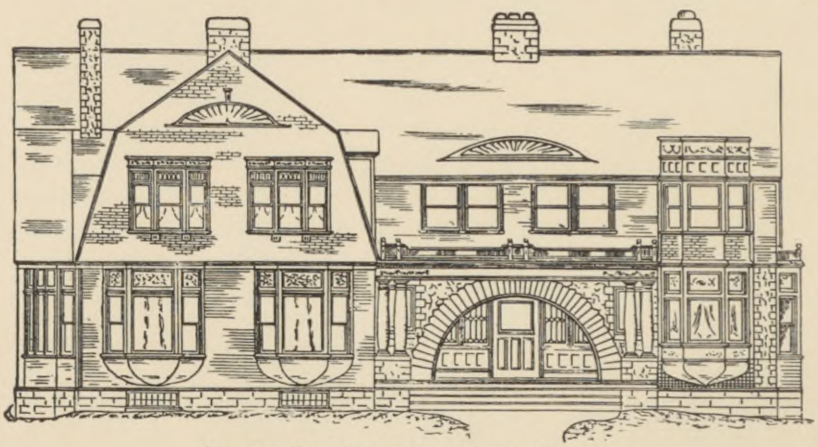


Fig. 31.—Front Elevation of Suburban Mansion.

Fig. 33 is the basement plan. Double lines in it indicate the flow pipes, single heavy lines the return pipes, dotted lines the air pipes, while double dotted lines denote the location of channel under floor of basement for return pipes from radiators on basement floor. The positions of the direct radiators in the servants' lavatory and dry room are also shown.

Fig. 34 is the ground or first-floor plan. The direct radiator in bath room and coil in lavatory, with the surface in each in square feet, are shown. The positions of the four vertical lines of flow and return pipes to radiators

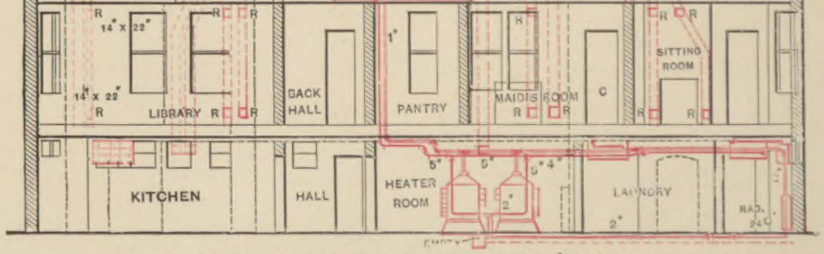


Fig. 32.—Sectional Longitudinal Elevation. Scale $\frac{1}{16}$ inch to the foot.

on chamber floor are indicated by circular points: in corner of landing in entrance hall leading to den; in closet off maid's room, leading to chamber V; in library near door to dining room, leading to nursery; and in butler's pantry, leading to bath room and chamber IV; and also to air and expansion pipe connections to expansion tank. It will be observed that the warm-air registers in the library and morning room are on the floor. This position is made necessary because there is no provision for vertical ducts in the walls. The warm-air registers being at as great a distance as possible from the exhaust register, the

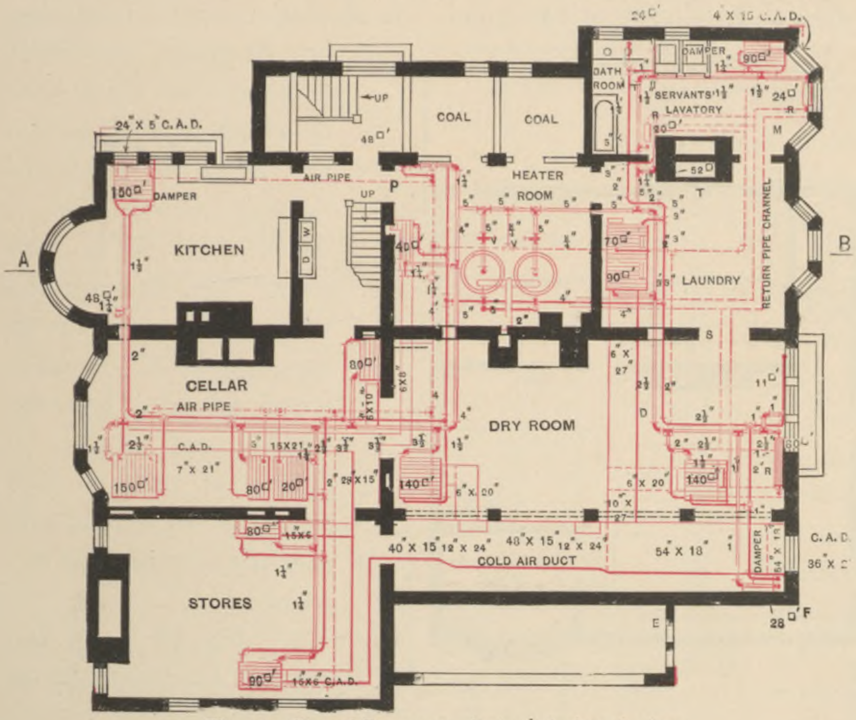


Fig. 33.—Plan of Basement. Scale $\frac{1}{16}$ inch to the foot.

arrangement will give satisfactory heating results. If the warm-air register on the floor were put near the exhaust register in the wall and above it, the heated air would pass directly out through the exhaust register. In the entrance hall two air-circulating registers are placed in the floor, through which the air within the house may be circulated when the damper in the main cold-air duct is closed.

Fig. 35 is the chamber floor plan. All the apartments are heated by direct radiation except chambers I,

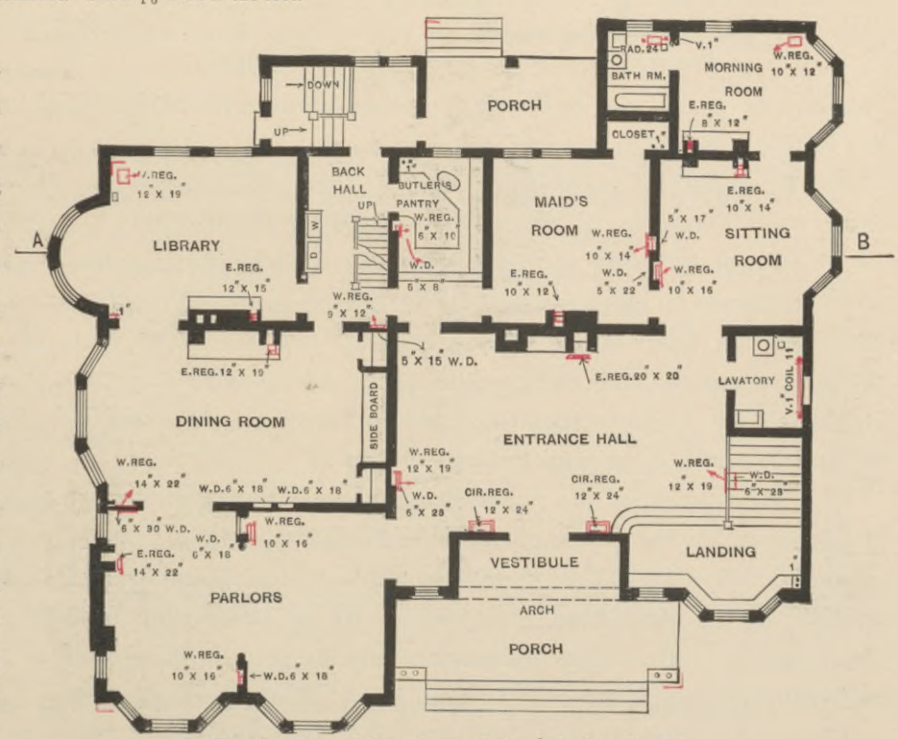


Fig. 34.—Plan of First Floor. Scale $\frac{1}{16}$ inch to the foot.

II, and III. The halls are heated from registers on floor beneath. In the design of this house no provision was made for the ventilation of the nursery or bath room. In the bath room the expansion tank is placed convenient to the vertical rising lines to which it is connected. Fig. 36 gives details of radiator connections in basement at K in bath room. Fig. 37 shows elevation of connection in basement at M to radiator in servants' lavatory. Figs. 38 and 39 give details of air ducts at E F and D E, as well as connections to radiator in dry room.

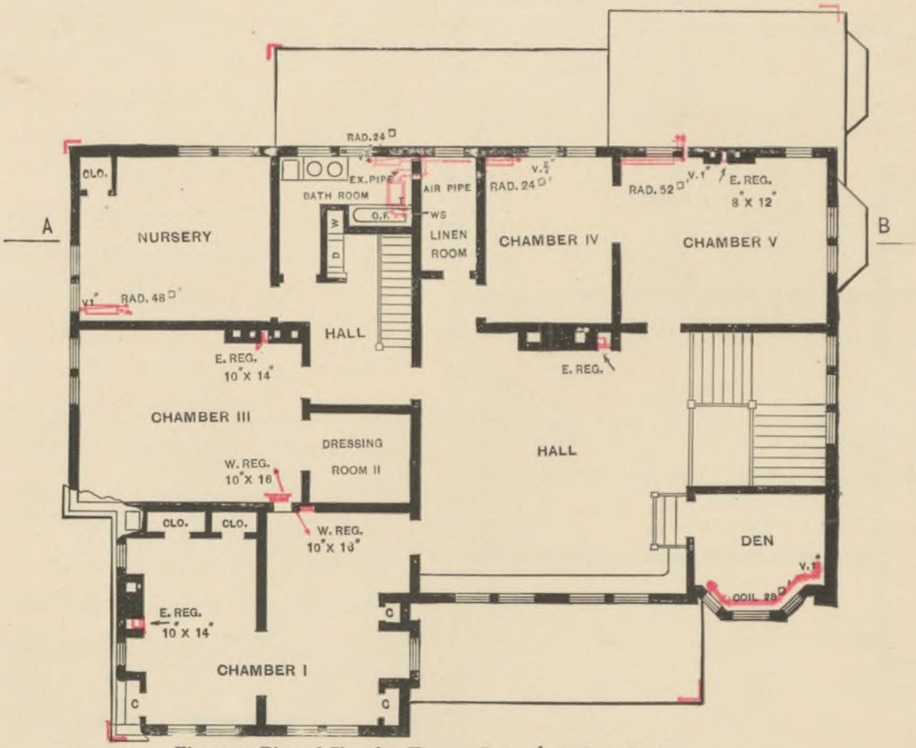


Fig. 35.—Plan of Chamber Floor. Scale $\frac{1}{16}$ inch to the foot.

Fig. 40 is an elevation in basement in laundry looking toward heater room. The circulator, main flow and return pipes are shown, as well as the air-pipe connections and radiator at K in bath room, and Fig. 41 shows the double connection of an air pipe at P.

Table No. III gives the contents, surfaces, and proportions, while Table No. IV shows the radiators proportioned.

In proportioning the surfaces in radiators for heating the two apartments in basement and all the apartments on ground or first floor, the temperature of the water is taken at 160°, and the same temperature is used in estimating for the bath room on chamber floor. The temperature used in calculating the rest of the surface, both direct and indirect, is 180°.

The location of the registers has already been referred to, and an examination of the places will indicate that there is little room for selection. The direct radiators on the chamber and ground floors have been arranged as far as practicable near the exposed walls. The radiator in the nursery is placed so as to simplify the piping. This room, it will be observed, projects out over the library bay window. The vertical lines to this

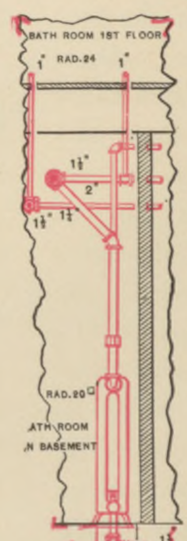


Fig. 36.—Radiator Connections at K in Basement.

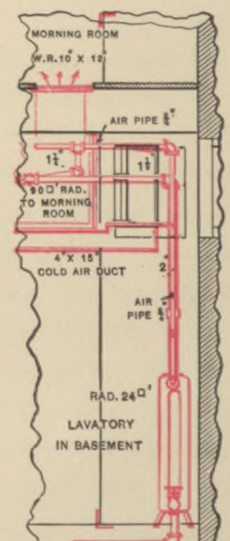


Fig. 37.—Radiator Connections at M in Basement.

radiator and the coil in the den are encased between the floor and ceiling in library and on landing.

The position of the radiators in the basement requires some remarks. By referring to Figs. 36 to 40 it will be observed that these radiators are below the level of the fire in circulator, and the return pipes from them are under the level of the floor of the basement. The flow pipes to these radiators are large and are placed on the more favorable points of the main flow from which the circulation to them is taken. The flow pipes are connected to the top of one end of the radiator, the air pipe being connected to the top of the other end. The return connection is to the lower part of the radiator at the air-pipe end. The water in these radiators circulates by gravity because there is no repulsive motion produced in the circulator when the water is taking up the heat, which if present would stop the motion toward displacement and hinder circulation.

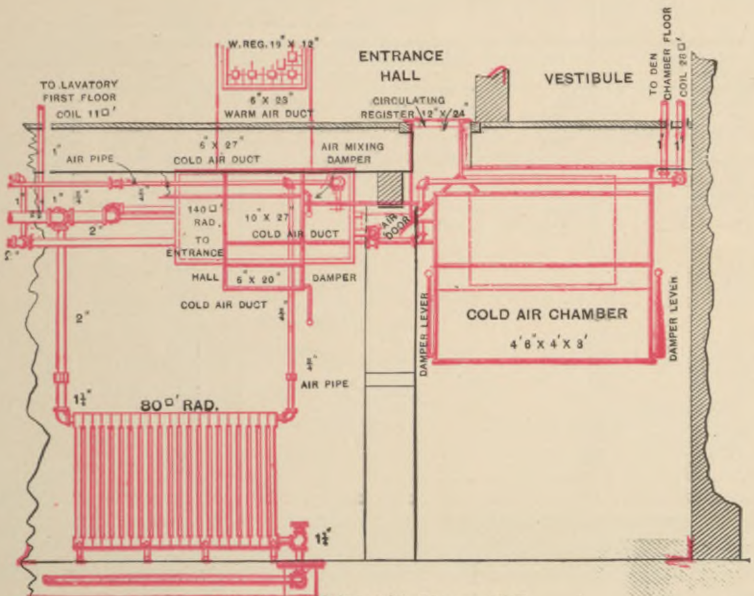


Fig. 38.—Details of Air Ducts at E F.

The warm-air flues and registers and cold-air ducts, as well as exhaust and exit registers, have been proportioned according to rules and tables given under "Supply and Emission of Heat." Each indirect radiator in addition to damper in cold-air duct is fitted with an air-mixing damper by which the air is permitted to pass in above the heating surface. This arrangement for admitting cold fresh air is very desirable, as the temperature of the air entering the room can be readily adjusted.

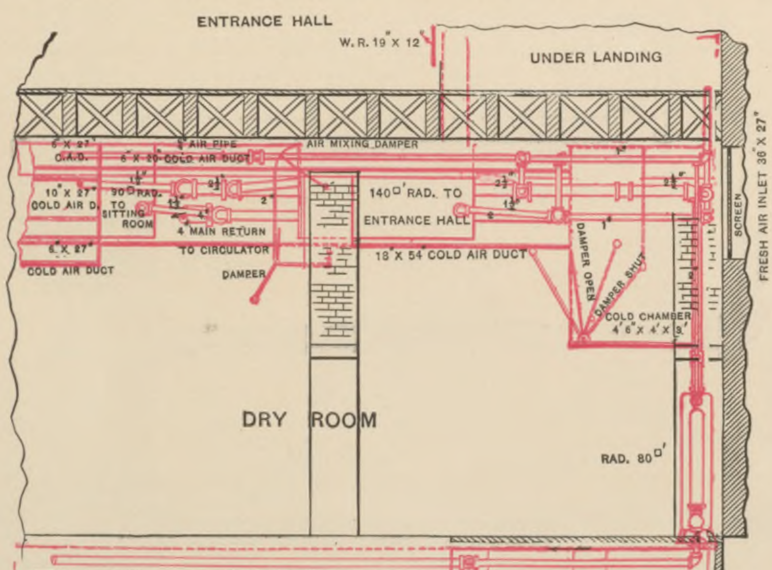


Fig. 39.—Details of Air Ducts at D E.

The main flow and return pipes have been calculated according to rules given under "Sizes of Main Flow and Return Pipes." 1655 square feet x .015 = 24.8 approximate area in square inches.

Five-inch pipe area = 19.99 square inches, which therefore is the size selected for the main flow and return. This size pipe is used from each circulator with a gate-valve in each flow, so that one heater may be used without the other. The valves are not actually necessary, and may be omitted because the circulator which is not in use will only become warm without affecting the circulation throughout the system to any great extent, especially if valves are placed on the 2-inch return pipe between the two heaters and to which are connected the radiators on the basement floor. When either of these 2-inch valves is closed, the circulation through the heater not in use will have to pass up the vertical main return, thus producing a slow action.

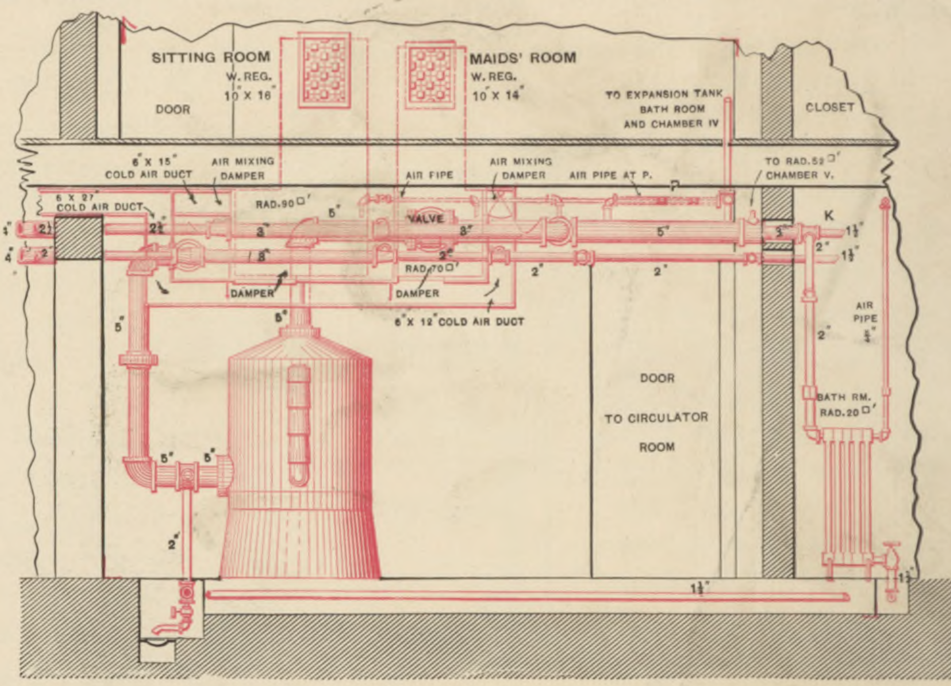


Fig. 40.—Elevation in Laundry Looking Toward Heater Room.

The air pipes are connected to all the indirect and direct radiators in basement, and to the vertical flow and return pipes, Fig. 41. The radiators and coils on the ground and chamber floors will require air cocks. The inclination of the main pipes and branches is upward from the heater to the radiators and vertical lines.

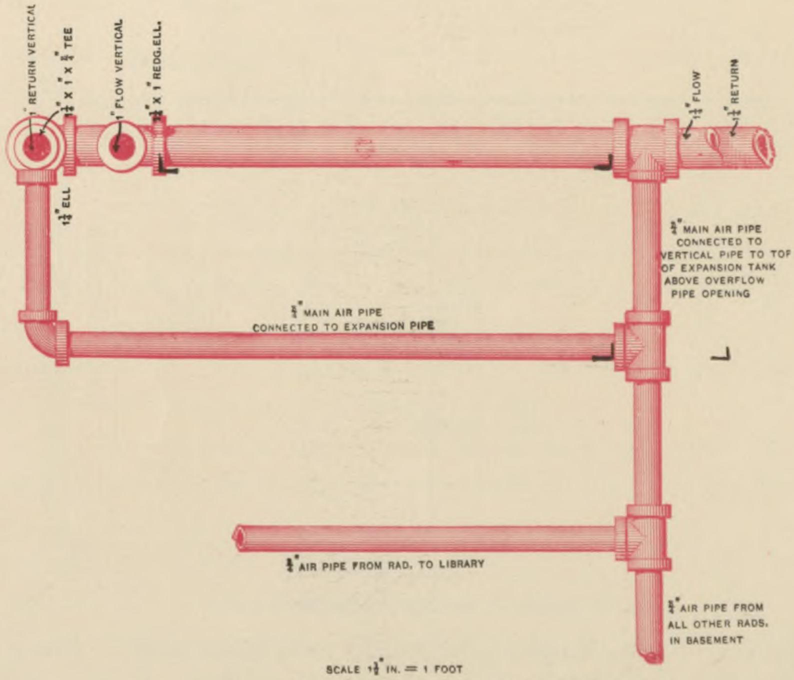


Fig. 41.—Flow and Return Pipes. Connection to Air Pipe at P.

TABLE III.—SUBURBAN MANSION. CONTENTS, SURFACES, PROPORTIONS, ETC., OF HOT-WATER HEATING APPARATUS.

	ROOMS.	Contents in cubic feet.	Exposed wall exclusive of glass surface, square feet.	Glass surface, square feet.	Equivalent to glass in square feet.*	Lineal feet of exposed wall.	Heating surface in radiators or coils in square feet. Direct.	Heating surface in radiators or coils in square feet. Indirect.	Diam. flow and return pipes to radiators.	Proportion of contents to surface in radiators.	Dimensions of warm-air pipe in inches.	Area of warm-air pipe in square inches.	Velocity of air per second in feet.	Changes of air per hour.	Dimensions of warm-air registers in inches.	Area of exhaust or exit flue in square inches.	Dimensions of exhaust flue register in inches.	Diameter of cold-air duct or fresh-air inlet in inches.	Area of cold-air duct or fresh-air inlet in square inches.
BASEMENT.	Dry room	5460	87	33	42	30	80		1¼	68									
	Laundry	1856	14	18	20	16													
	Lavatory	1280	30	30	33	30	44		1¼	29									
	Kitchen	1874	26	34	37	30													
FIRST FLOOR.	The halls	5900	357	117	153	54		360	1½	35	2–6x23, 1–5x15	351	1½	1	2–12x19, 1– 9x12	144	2–20x20	2–6x20, 1–6x10	300
	Lavatory	336	50	6	11	8	11		1	30									
	Parlors	3920	358	72	108	43		170	1¼	23	2–6x18	216	1½	2	2–10x16	120	2–14x22	2–6x15	180
	Dining room	3500	85	75	84	16		150	1½	23	6x30	180	1½	2	14x22	96	2–12x19	7x21	147
	Library	2560	202	88	108	29		150	1½	17	11x12	132	1½	2	12x19	96	2–12x15	5x24	120
	Back hall	1050																	
	Butler's pantry	750	38	18	22	5½		40	1¼	19	5x8	40	1½	2	6x10			6x8	48
	Maid's room	1610	44	36	40	8		70	1¼	23	5x17	85	1½	2	10x14	72	2–10x12	6x12	72
	Bath room	500	138	12	26	15	24		1	20									
	Morning room	1400	167	53	70	22		90	1¼	16	8x9	72	1½	2	10x12	72	2– 8x12	4x15	60
	Sitting room	2070	105	35	46	14		90	1¼	23	5x22	110	1½	2	10x16	72	2–10x14	6x15	90
SECOND FLOOR.	Hall	4850	261	72	98	35													
	Den	640	130	30	43	20	28		¾	23									
	Chamber No.1.	1986	113	30	41	15		60	1¼	33	6x18	108	2½	2	10x16	120	2–10x14	6x15	90
	" No.2.	1568	112	40	51	16		60	1¼	26				2					
	" No.3.	3087	174	26	43	21		80	1¼	38	6x18	108	2½	2	10x16	96	2–10x14	6x15	90
	Nursery	1975	131	50	63	19	48		1	41									
	Bath room	677	89	20	29	11½	24		¾	28									
	Back hall	1030																	
	Chamber No.4.	1396	80	20	28	10½	24		¾	50									
	" No.5.	2261	255	40	66	31	52		1	43						72	2–8x12		
	Totals	53236	3046	955	1262	500	335	1320		32†		1402				960			1197
							1655												

* On the basis that 10 square feet of exposed wall equals 1 square foot of glass.

† Average.

TABLE IV.—SUBURBAN MANSION. SURFACES IN RADIATORS PROPORTIONED.

	ROOMS.	Sq. ft. of glass and its equivalent in exposed wall.	Multipliers.	Cubic feet of air cooled per hour by glass.	Contents of rooms in cubic feet.	Changes of air in rooms per hour.	Total number of cubic feet of air to be warmed.	Multipliers.	Sq. ft. of surface required in rooms to warm air from 0 to 70°.	Remarks.
Basement.	Dry room	42	× 75	= 3150	+ (5460	× 1)	= 8610	× .0092	= 80	Direct.
	Lavatory	33	× 75	= 2475	+ (1280	× 1)	= 3755	× .0092*	= 44	Direct.
FIRST FLOOR.	The halls	251	× 75	= 18825	+(12830	× 1)	= 31655	× .0114	= 360	Indirect.
	Lavatory	11	× 75	= 825	+ (336	× 1)	= 1161	× .0092	= 11	Direct.
	Parlors	108	× 75	= 8100	+ (3920	× 2)	= 15940	× .0114	= 171	Indirect.
	Dining room	84	× 75	= 6300	+ (3500	× 2)	= 13300	× .0114	= 151	Indirect.
	Library	108	× 75	= 8100	+ (2560	× 2)	= 13100	× .0114	= 149	Indirect.
	Butler's pantry	22	× 75	= 1650	+ (750	× 2)	= 3350	× .0114	= 37	Indirect.
	Maid's room	40	× 75	= 3000	+ (1610	× 2)	= 6220	× .0114	= 70	Indirect.
	Bath room	26	× 75	= 1950	+ (500	× 1)	= 2450	× .0092	= 22	Direct.
	Morning room	70	× 75	= 5250	+ (1400	× 2)	= 8050	× .0114	= 90	Indirect.
	Sitting room	46	× 75	= 3450	+ (2070	× 2)	= 7590	× .0114	= 90	Indirect.
SECOND FLOOR.	The Den	43	× 75	= 3225	+ (640	× 1)	= 3865	× .0072	= 28	Direct.
	Chamber No. 1	41	× 75	= 3075	+ (1986	× 2)	= 7047	× .009	= 63	Indirect.
	" No. 2	51	× 75	= 3825	+ (1568	× 2)	= 6961	× .009	= 63	Indirect.
	" No. 3	43	× 75	= 3225	+ (3087	× 2)	= 9399	× .009	= 84	Indirect.
	Nursery	63	× 75	= 4725	+ (1975	× 1)	= 6700	× .0072	= 48	Direct.
	Bath room	29	× 75	= 2175	+ (677	× 1)	= 2852	× .0092	= 26	Direct.
	Chamber No. 4	28	× 75	= 2100	+ (1396	× 1)	= 3496	× .0072	= 25	Direct.
	" No. 5	66	× 75	= 4950	+ (2261	× 1)	= 7211	× .0072	= 52	Direct.

* Use 1.25 for multiplier to raise to 80°.

Heating and Ventilating a City Residence with the Novelty Circulator, No. 15.

FIG. 42 is sectional longitudinal elevation of a city residence. There are shown by dotted lines the smoke flue and ventilating flues for the front end of residence, for the wall in which they occur is supposed to be removed. The lines, however, indicate the position and extent of the flues, as well also as of the vertical warm-air ducts. Fig. 43 is a transverse sectional elevation in which the front wall of building is supposed to be removed. Dotted lines here also denote the vertical warm-air ducts, exhaust and ventilating flues. In these views the location of the circulator in basement, the position

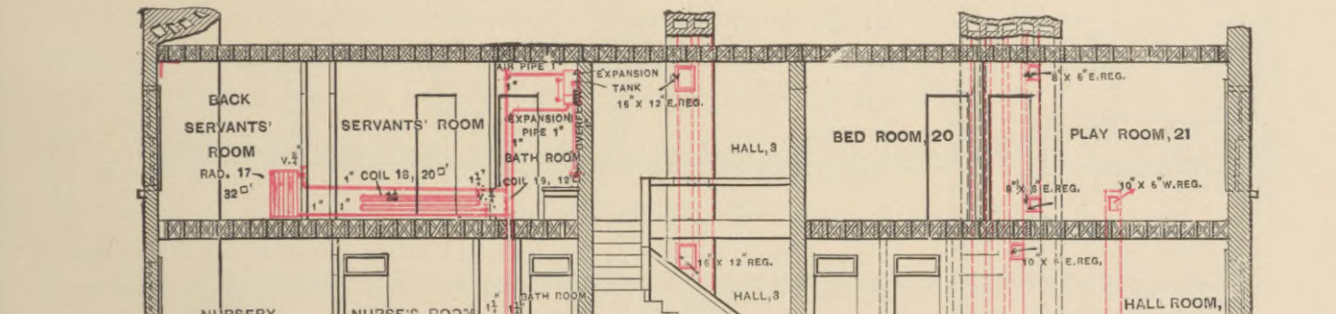


Fig. 42.—Sectional Longitudinal Elevation of City Residence. Scale 1/12 inch to the foot.

of the indirect radiators, the cold-air ducts near basement ceiling, the flow and return mains to vertical lines of pipe, to radiators and coils on upper floors, etc., can be readily traced. The position of expansion tank on fourth floor is also shown. The exhaust and exit registers to ventilating flues are indicated and their sizes are given.

Fig. 44 is a plan of basement. The circulator, it will be seen, is located in the front room, in which are also placed eight stacks of indirect radiators and main cold-air ducts. Two other indirect radiators are placed in the central hall of basement to heat dining room. The main flow and return pipes, shown in this figure, are placed a sufficient distance below the basement ceiling in front room to give an ascent to the flow and return connections to indirect radiators. Before passing into central hall and kitchen these pipes rise at L close to ceiling, and the connections to indirect radiators in central hall descend. The main flow and return pipes continue to ascend from the central hall to connections to coil in conservatory. In the plan only a portion of the main return is seen as it is located nearly under the main flow pipe. The part that is shown is indicated by a single heavy line, while the air pipes from the indirect radiators are shown by dotted lines. In the main cold-air duct near indirect radiator 3 is a damper. This damper is closed when air is taken from the hall through the air-circulating duct. By this arrangement the air in the hall and other parts of the house is circulated continuously until warm, through the indirect radiators (3) to the hall and (4) to the dining room. In cold weather and during the night it is economical to use this method of air circulation.

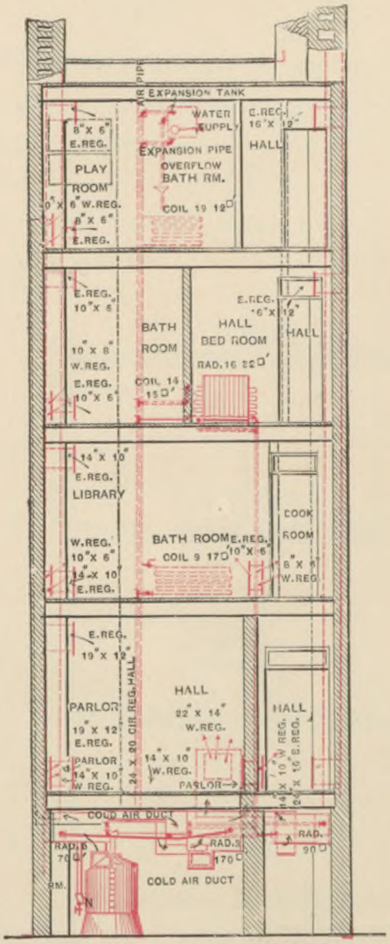


Fig. 43.—Sectional Transverse Elevation of City Residence. Scale $\frac{1}{12}$ inch to the foot.

Fig. 45 is plan of first floor. In this the location of the warm air, exhaust air, and circulating register are shown. The vertical lines of pipes to radiator in hall room (16) pass up in partition between the parlor (6) and vestibule. Similar lines to radiators in bath rooms and rooms at back of residence pass up along dining room (4) wall, but they are encased in a column against wall, as shown.

Fig. 46 is a plan of second floor. The position of registers and radiators is indicated. The vertical line of pipes to hall room (16) on third floor passes up in the partition between the library (10) and book room (11). One of the warm-air ducts heating library also heats the book room. The area of the top of the duct is divided before the register openings are reached. As the two openings are on the same level, the supply of warm air will be in proportion to the area of the registers. It is not good practice to supply two registers from the one warm-air duct, when one register is one floor above the other. The dotted lines on floor of book room and library indicate the position of trimmer beams to provide space from the warm-air duct to pass up in partition. The vertical line of pipes connecting to radiators and coils at back of house on third and fourth floors pass up through bath room. By these arrangements no pipes are exposed on first or second floor except in the bath room on the latter floor.

Fig. 47 is plan of third floor. One of the exit registers in ventilating flue of hall (3) is on this floor, another being on the fourth floor, each near the ceiling. On plan of fourth floor, Fig. 48, the position of expansion tank is shown with the expansion pipe connected from top of vertical return line to bottom of expansion tank, with an air pipe at top of tank and connected to top of vertical flow line and the overflow and water-supply pipes connected to tank as already described.

Fig. 49 shows details in basement, being an end view at H. The outline of the cold-air duct

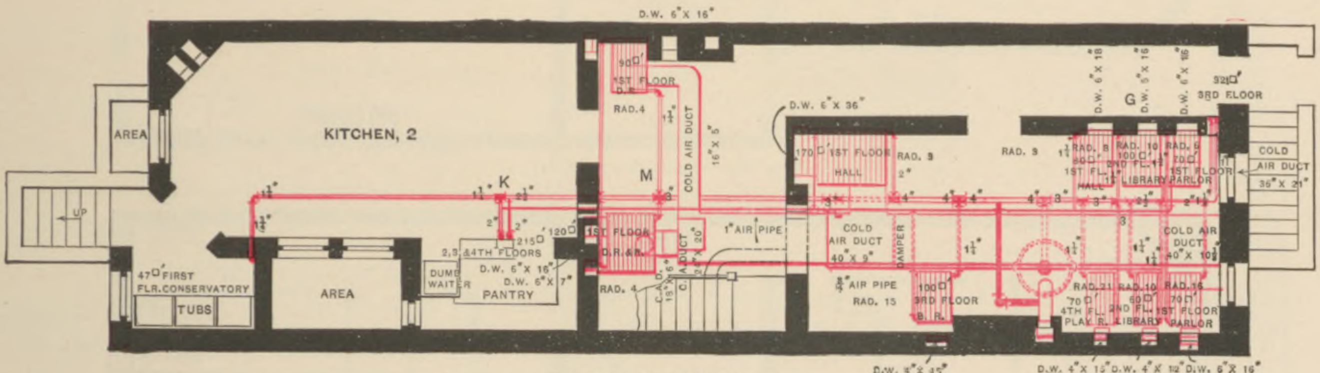


Fig. 44.—Plan of Basement.

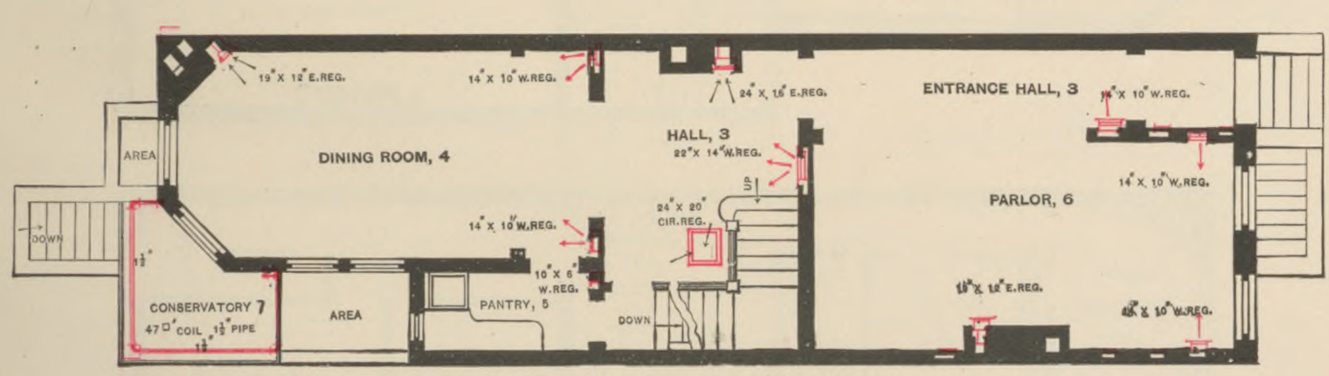


Fig. 45.—Plan of First Floor. Scale $\frac{1}{12}$ inch to the foot.

chamber is shown with the main branch 40 inches by 10 inches near ceiling, its 12½ by 12-inch branch to the left, and its 18½ by 12-inch branch to the right, with baffle plate B B opposite principal opening or inlet, which is 36 inches by 21 inches. The relative positions of the main flow and return pipes are indicated and the air pipe from radiator is also shown connected to main air pipe near ceiling. Fig. 50 shows details in basement, being a section at H to G. The sectional view of the cold-air chamber shows baffle plate B B opposite branch duct 18½ by 12 inches, so that the effect of the wind will be reduced in this branch duct. The air pipes may be connected to the top of the section of radiator farthest from the entrance of the flow as shown in this illustration, or a large nipple may be extended through the casing and have a reducing elbow on the end as shown in Fig. 29, cottage residence. Fig. 51, of details in basement at L, shows the main flow and return pipes and main air pipe as they rise and pass through the wall into central hall. Fig. 52 gives the elevation at M in central hall of basement, showing the connections of main flow and return pipes to indirect radiators

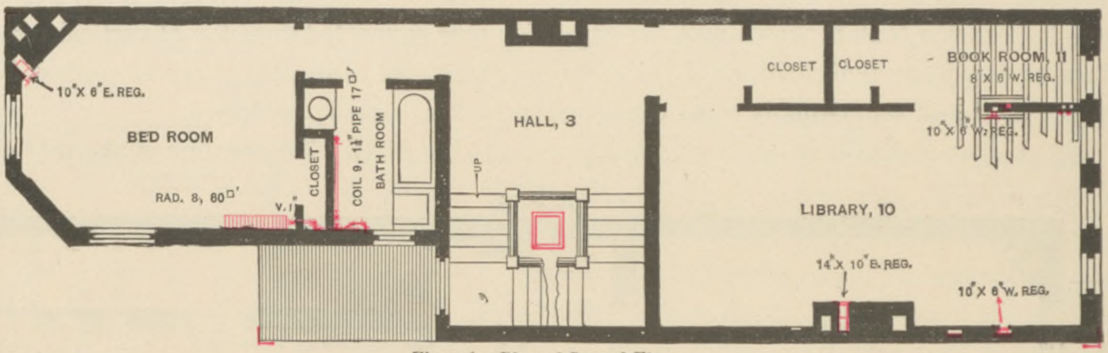


Fig. 46.—Plan of Second Floor.

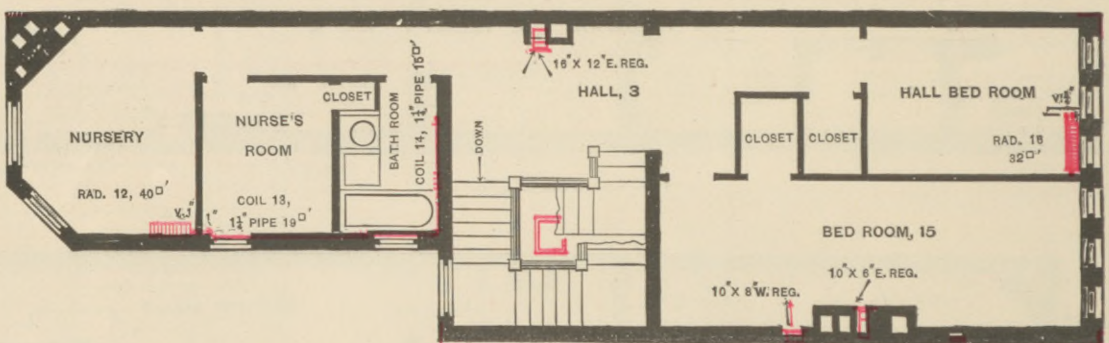


Fig. 47.—Plan of Third Floor.

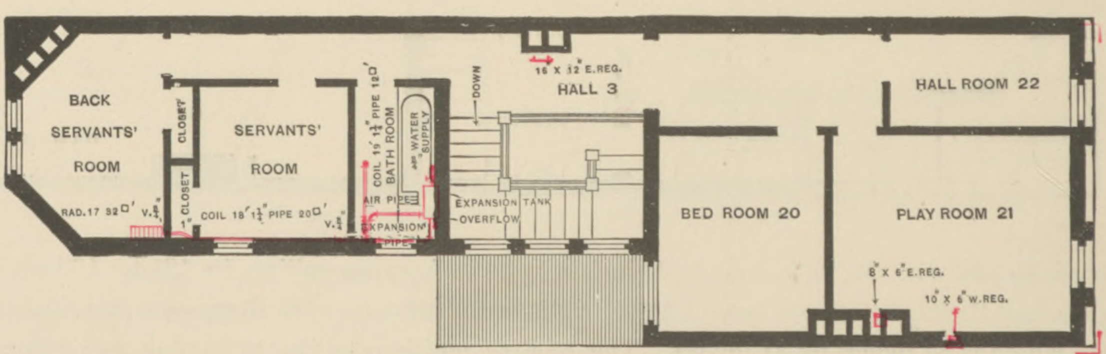


Fig. 48.—Plan of Fourth Floor. Scale $\frac{1}{12}$ inch to the foot.

(4) to dining room. These radiators are not connected to the main air pipe because the air in them can pass out through main flow pipe to vertical air pipe. In this view doors are shown in the air-circulating duct from central hall to cold-air duct. These doors are air-tight and kept closed when fresh air only is desired in dining room. Fig. 53 illustrates the main air-pipe connection to the

vertical flow and return pipes the tops of which are directly connected with the expansion tank at top and bottom, respectively. By this double connection of the main air pipe circulation is produced at all times through the pipe, and circulation is assisted through the indirect radiators. At the same time no air can accumulate to impede circulation.

In Table No. V are given the contents, surfaces, proportions, etc., while Table No. VI gives the surfaces in radiators as proportioned.

The surfaces in the indirect radiators in this job are proportioned with the temperature of the water at 160°, as shown in Table VI and by the rules given under "Supply and Emission of Heat." The surface in pipe coil in conservatory is proportioned per square foot of glass, Table XX. The direct radiators are proportioned with the temperature of the water at 180°. In proportioning surfaces in similar buildings this latter temperature may be usually adopted in direct radiators throughout the whole house.

In locating radiators and registers in city residences there is not much opportunity to exercise judgment in the selection of positions, though it is desirable to keep the radiators near exposed walls and windows. When deciding the position of the vertical warm-air flues or ducts, their openings in the basement or cellar should be conveniently arranged so that the indirect radiator will not occupy useful head room or obstruct the light in the cellar. At the time provision is made for the openings of the warm-air flues in the cellar the location of the fresh or cold-air inlet should be decided. It is more desirable to make a special opening for the cold-air inlet than to use one of the window openings. The position of the cold-air inlet should be such as to give ample space about it so that an air-receiving chamber may be constructed in order to prevent the blowing of the wind being felt at the registers. The register openings in the warm-air flues should be above the base-board.

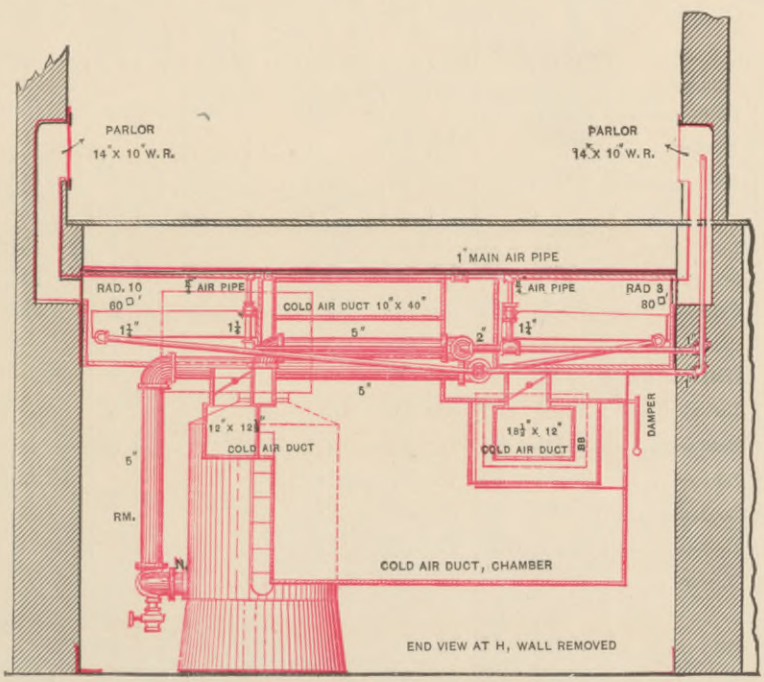


Fig. 49.—End View at H. Wall Removed.

The location of direct radiators should be such as to occupy the least useful space in each room, at the same time causing the connecting pipes and vertical lines to be exposed to view as little as possible. In small rooms, such as bath rooms, return bend wall coils will occupy less space than direct radiators. In the residence here illustrated it will be observed that the vertical lines of pipes are not exposed, except in the bath rooms, where their surfaces are useful for heating purposes in place

TABLE V.—CITY RESIDENCE. CONTENTS, SURFACES, PROPORTIONS, ETC., OF HOT-WATER HEATING APPARATUS.

Floor	ROOMS.	Contents in cubic feet.	Exposed wall exclusive of glass surface, square feet.	Glass surface, square feet.	Equivalent to glass in square feet.*	Lineal feet of exposed wall.	Heating surface in radiators or coils in square feet. Direct.	Heating surface in radiators or coils in square feet. Indirect.	Diam. flow and return pipes to radiators.	Proportion of contents to surface in radiators.	Dimensions of warm-air pipe in inches.	Area of warm-air pipe in square inches.	Velocity of air per second in feet.	Changes of air per hour.	Dimensions of warm-air registers in inches.	Area of exhaust or exit flue in square inches.	Dimensions of exhaust flue register in inches.	Diameter of cold-air duct or fresh-air inlet in inches.	Area of cold-air duct or fresh-air inlet in square inches.
Basement.	Hall	2328																	
	Kitchen	2304		12	12														
FIRST FLOOR.	Hall	3421		32	32			250	2 1¼	49	36x6 18x6	324	1½	1	22x14 14x10	144	24x16	15 10	177 78
	Dining room	3575	132	105	118	21½		180	1¼	20	2–16x6	192	1½	2	2–14x10	108	2–19x12	12 10	113 78
	Pantry	550	43	12	16	5		30		18	7x6	42	1½	2	10x6				
	Parlor	3575	87	56	65	13		140	1¼	26	2–16x6	192	1½	2	2–14x10	108	2–19x12	2–10	156
	Conservatory	735		105	105		47		1¼	15									
SECOND FLOOR.	Hall	2772	27	18	21	4½													
	Bed room	2210	180	58	76	23¾	60		1	37									
	Bath room	510	64	16	23	8	17		¾	30									
	Library	3250	83	48	57	13		160	1¼	24	12x4	128	2½	2	2–10x6	96	2–14x10	9	63
	Book room	600	36	16	20	5					16x5				8x6			7	38
THIRD FLOOR.	Hall	3177	26	19	22	4½											16x12		
	Nursery	1430	148	42	57	19	40		1	35									
	Nurse's room	720	65	19	26	8	19		¾	38									
	Bath room	540	45	16	21	6	15		¾	36									
	Bed room	2250	62	48	54	11		100	1¼	23	15x4	60	3	2	10x8	96	2–10x6	8	50
	Hall room	1275	51	39	44	9	32		¾	38									
FOURTH FLOOR.	Servants' room	988	121	36	48	16½	32		¾	30									
	" "	812	68	18	25	9	20		¾	40									
	Bath room	451	36	12	16	5	12		¾	38									
	Bed room	1140	30	18	21	5													
	Play room	1710	96	18	28	12		70	1¼	24	10x4	40	3½	2	10x6	96	2–8x6	6½	33
	Hall room	940	49	18	23	7													
	Hall	2832	60	54	60	12											16x12		
	Totals	41085	1509	835	990	218	294	930		34†		978				648			786
							1224												

* On the basis that 10 square feet of exposed wall equals 1 square foot of glass.

† Average.

of adding more to the coils. Each room that is ventilated has a separate ventilating flue. One flue should not be used for two rooms.

The warm-air flues or ducts are calculated with the following velocities in feet per second: $1\frac{1}{2}$ feet to the first floor, $2\frac{1}{2}$ feet to the second floor, 3 feet to the third floor, and $3\frac{1}{2}$ feet to the fourth floor. The areas of the warm-air flues or ducts are ascertained by using the multipliers given in Table XXVIII. The cubic feet of air in the hall, changed once in each hour, 12202 × .0266 = 324.5 square

TABLE VI.—CITY RESIDENCE. SURFACES IN RADIATORS PROPORTIONED.

Floor	ROOMS.	Sq. ft. of glass and its equivalent in exposed wall.	Multiplier.	Cubic feet of air cooled per hour by glass.	Contents of rooms in cubic feet.	Changes of air in rooms per hour.	Total number of cubic feet of air to be warmed.	Multiplier.	Sq. ft. of surface required in rooms to warm air from 0 to 70°.	REMARKS.
First Floor.	Halls	135	× 75	= 10125	+ (12202	× 1)	= 22327	× .0114	= 254	Indirect.
	Dining room	118	× 75	= 8850	+ (3575	× 2)	= 16000	× .0114	= 182	Indirect.
	Pantry	16	× 75	= 1200	+ (550	× 2)	= 2300	× .0114	= 26	Indirect.
	Parlor	65	× 75	= 4875	+ (3575	× 2)	= 12025	× .0114	= 137	Indirect.
	Conservatory	105	*						47	Direct.
Second Floor.	Bed room	76	× 75	= 5700	+ (2210	× 1)	= 7910	× .0072	= 58	Direct.
	Bath room	23	× 75	= 1725	+ (510	× 1)	= 2235	× .0072	= 16	Direct.
	Library / Book room	77	× 75	= 5775	+ (3850	× 2)	= 13475	× .0114	= 154	Indirect.
Third Floor.	Nursery	57	× 75	= 4275	+ (1430	× 1)	= 5705	× .0072	= 41	Direct.
	Nurse's room	26	× 75	= 1950	+ (720	× 1)	= 2670	× .0072	= 19	Direct.
	Bath room	21	× 75	= 1575	+ (540	× 1)	= 2115	× .0072	= 15	Direct.
	Bed room	54	× 75	= 4050	+ (2250	× 2)	= 8550	× .0114	= 97	Indirect.
	Hall room	44	× 75	= 3300	+ (1275	× 1)	= 4575	× .0072	= 33	Direct.
Fourth Floor.	Servants' room	48	× 75	= 3600	+ (988	× 1)	= 4588	× .0072	= 33	Direct.
	" "	25	× 75	= 1875	+ (812	× 1)	= 2687	× .0072	= 20	Direct.
	Bath room	16	× 75	= 1200	+ (451	× 1)	= 1651	× .0072	= 12	Direct.
	Play room	28	× 75	= 2100	+ (1710	× 2)	= 5520	× .0114	= 63	Indirect.

* Surface obtained by dividing by 2.19 as per Table XX.

inches, requiring two flues, one 36 by 6 inches, and one 18 by 6 inches. The cubic feet of air in parlor, 3575, to be changed twice in one hour × .053 = 189.4 square inches, requiring two flues each 16 by 6 inches = 96 square inches, or a total of 192 square inches. The play room on fourth floor contains 1710 cubic feet of air, which is to be changed twice in one hour, 1710 × .0228 = 38.98 square inches, requiring a flue 4 by 10 inches = 40 square inches. The sizes of the registers in warm-air and ventilating flues can be readily ascertained by reference to Table XXIX.

The size of main flow pipe is equal to 1224 (which is the square feet of surface in radiators) multiplied by .015 (see "Sizes of Main Flow and Return Pipes") = 18.36 square inches, which is the approximate area. The area of a 5-inch pipe being 19.9 square inches, this is the size for main flow and return pipes.

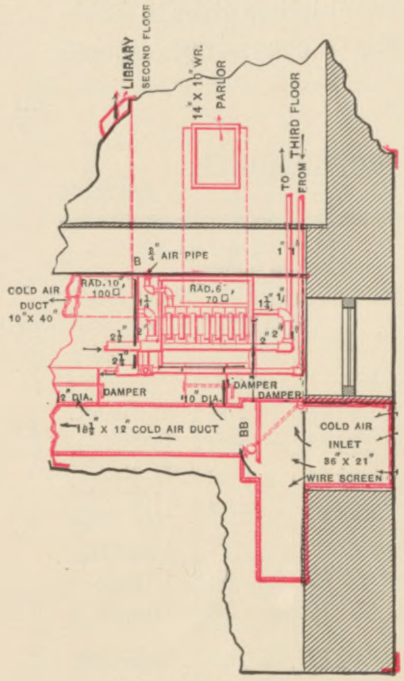


Fig. 50.—Section H to J.

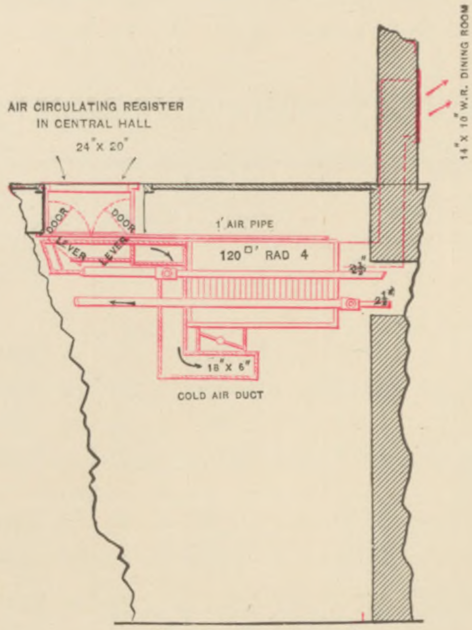


Fig. 52.—Elevation at M.

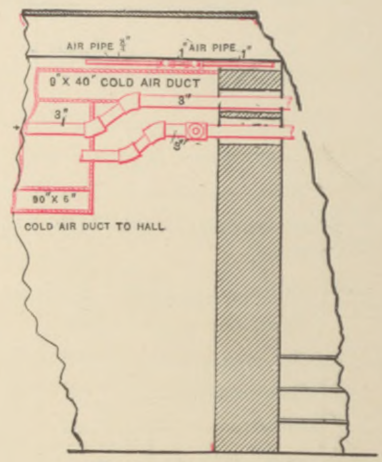


Fig. 51.—Elevation at L.

DETAILS IN BASEMENT.

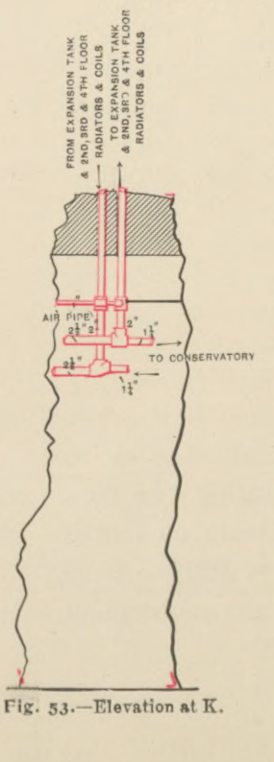


Fig. 53.—Elevation at K.

The size of the expansion tank is ascertained by the use of the multipliers in Table XXV. Thus 1224 by .025 = 30.6 gallons, or 1224 by 5.75 = 7038 cubic inches or 30.4 gallons. The location of the expansion tank is in the bath room on fourth floor, and its connections are similar to those in cottage residence.

Air-emission valves are necessary on all the direct radiators, on the coil in bath room, on third floor, and on coil in conservatory, which is composed of $1\frac{1}{2}$-inch pipes. The other coils do not require air cocks, as the manner in which they are connected to the vertical lines permits the water to displace the air and allow it to pass up the vertical pipes to expansion tank. The indirect radiators are provided with air pipes and arranged to allow the air to pass to the vertical flow and return pipes which are connected, as already shown and described, to expansion tank.

Heating a Railway Station with the Novelty Circulator, No. 14.*

FIG. 54 is a sectional elevation, and Fig. 55, immediately under it, is the plan. The circulator is located in the kitchen, on the same floor and level as the radiators. The main flow pipe passes vertically upward above the ceiling and inclines up from the circulator to the main tee at A to which the air pipe is connected. From this point all flow pipes incline toward the radiators. The main return pipe inclines from the radiators to the emptying-valve beneath the circulator. The position of the expansion tank is shown above the ceiling. It is placed as high as possible. The air pipe from the tee on main flow is connected to the upper part of the tank above water line, and the expansion pipe to the bottom of tank. This latter pipe is there connected directly to the lowest pipe of the main return. The flow pipes to all the radiators are connected to the top of the radiators. It will be observed that in filling the apparatus the water-supply enters the expansion tank and passes down the expansion pipe to the return and up the return into the radiators to the flow pipes, forcing the air to the highest point at A, where it finds vent through the air pipe into the expansion tank. By this arrangement the use of air cocks on the radiators is dispensed with. The overflow pipe from the expansion tank passes downward and discharges through an open end into sink in kitchen. This pipe may be used as an air pipe to expansion tank, if the latter is closed on the top.

The main flow pipe at A is continued in two parallel branch main pipes, which each have sub-branches to two and three radiators. By this arrangement a more uniform distribution of the temperature is induced. There is one main return pipe, to which the sub-branches are connected. The relative positions of circulator in kitchen and expansion tank above ceiling are shown.

Fig. 56 gives enlarged view of fittings and pipes at A on flow main. It will be observed that a hole for the air pipe is provided on the top or highest point of the main tee. The full size of the main pipe is continued in each of the branches to the elbows, where the reduction to the size of the branches is made after the change in direction has been given to the currents.

Fig. 57 shows the arrangement of fittings used at B and similar connections on flow main to branches. The central opening on tee in main branch is the same size as the other openings of tee. The sub-branch from the 3-inch main branch is connected by a 3-inch nipple into a 3 to 2-inch reducing elbow; on the 2-inch sub-branch is a 2-inch tee with 2-inch nipples in each outlet to radiator. One of these outlets is reduced by a reducing coupling to 1½-inch pipe which connects to two radiators, and the other outlet on the run is reduced by an elbow 2 to 1 inch, and connects to one radiator.

* In this system, which is an open one, the circulator is on the same level as the radiating surface, and therefore a larger size of circulator is used than would otherwise be needed.

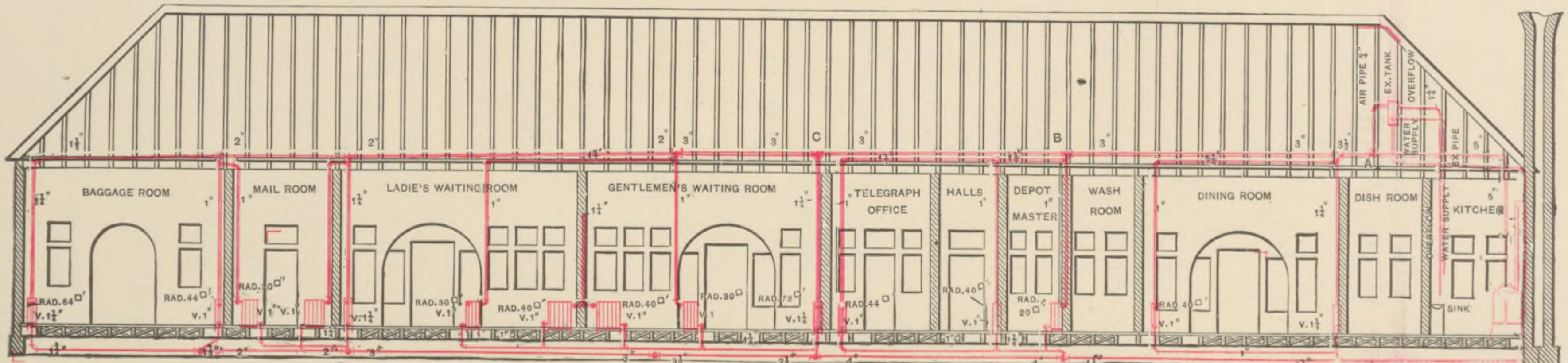


Fig. 54.—Railway Station. Sectional Longitudinal Elevation.

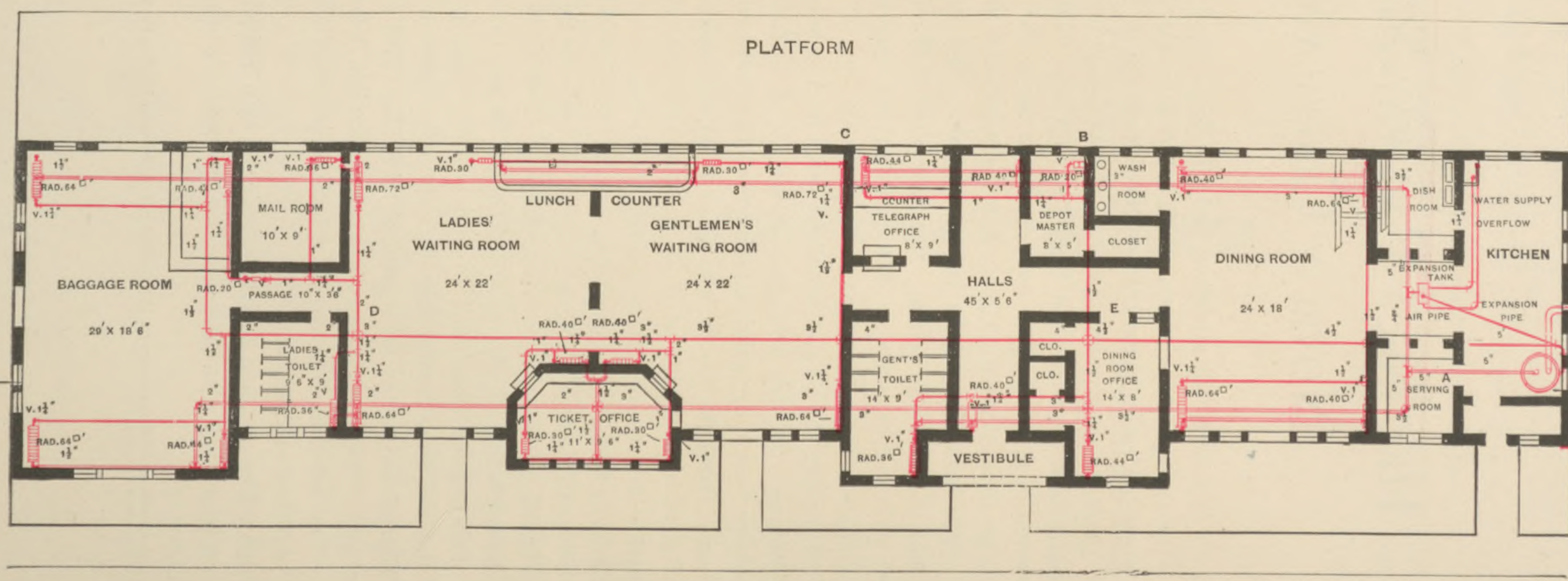


Fig. 55.—Plan of Railway Station. Scale $\frac{1}{16}$ inch to the foot.

Fig. 58 is branch flow pipe, at C, to one radiator. In the 3-inch branch main an even 3-inch tee is used, the outlet being the same size as the run. In the outlet is a 3-inch nipple with a reducing-coupling 3 to 1¼-inch, the size of flow pipe to radiator. This is preferable to using a bushing in tee 3-inch to 1¼-inch, or a tee with an opening reduced to 1¼-inch.

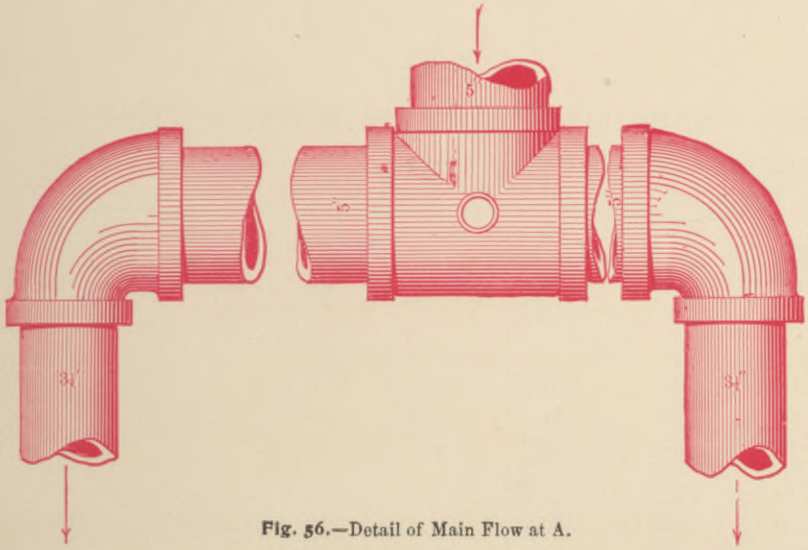


Fig. 56.—Detail of Main Flow at A.

The arrangement of fittings shown gives an opportunity for a reduction in the velocity of currents when a change of direction takes place, and tends to produce a more uniform distribution of temperature than where small openings are used.

In Fig. 59 the connections to a cross-fitting in main return pipe at D are shown. The 2-inch return main from radiators in baggage room enters the back of the cross on the run, and is connected to the latter by means of a bushing 3-inch to 2-inch, and flows in a direct course to the 3-inch main. The two side branch returns are connected to the cross by 3-inch nipples, and reducing couplings 3-inch to 2-inch and 3-inch to 1½-inch. By this enlargement of the space with the use of the 3-inch nipples in place of a 3 x 2-inch cross, or bushings, the velocities of the currents are reduced before change in the direction takes place.

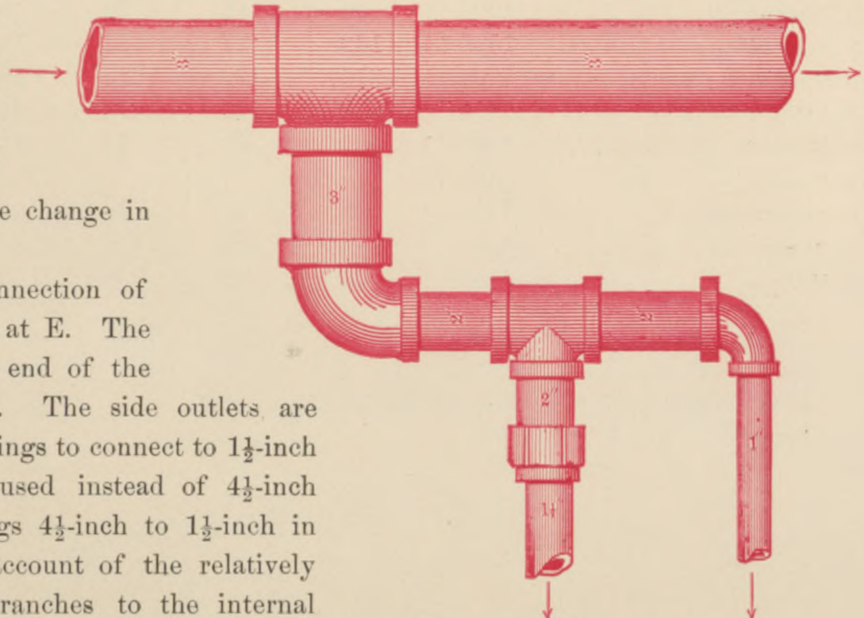


Fig. 57.—Detail of Branch Flow Pipe at B.

Fig. 60 is another connection of branches to main return pipe at E. The fitting is a 4½-inch cross, one end of the run being reduced to 4-inch. The side outlets are reduced by 4½ to 1½-inch bushings to connect to 1½-inch branches. Bushing may be used instead of 4½-inch nipples, and reducing couplings 4½-inch to 1½-inch in such an instance as this on account of the relatively small area of the 1½-inch branches to the internal capacity of the 4½-inch cross and bushings. The full-size 4½-inch cross with bushings is more desirable than a reduced fitting; that is, a cross 4½-inch on the run with 1½-inch side outlets. These are examples of the manner in which fittings and connections may be arranged to obtain the most satisfactory results.

TABLE VII.—CONTENTS, SURFACES, PROPORTIONS, ETC., IN HOT-WATER HEATING APPARATUS IN A RAILWAY STATION.

ROOMS.	Contents in cubic feet.	Exposed wall exclusive of glass surface. Square feet.	Glass surface in square feet.	Equivalent to glass in square feet.*	Lineal feet of exposed wall.	Heating surface in radiators or coils in square feet. Direct.	Dimensions of flow and return pipes to radiators in inches.	Proportion of contents to surface in radiators.
1. Kitchen	2520	310	96	127	29			
2. Dish room	784	74	24	31	7			
3. Serving room	784	74	24	31	7			
4. Passage	784							
5. Dining room	6048	312	192	223	36	208	1¼ and 1	31
6. Halls	3465	90	64	73	11	80	1	43
7. Depot master's room	560	52	18	23	5	20	1	28
8. Dining-room office	1568	169	27	44	14	44	1	35
9. Telegraph office	1008	84	42	50	9	44	1	22
10. Gents' toilet	1596	169	27	44	14	36	1	44
11. Gents' waiting room	6804	370	176	213	39			
12. Ladies' waiting room	6804	370	176	213	39	492	1¼ and 1	31
13. Ticket office	1463	150	60	75	15			
14. Passage	490							
15. Ladies' toilet	1197	90	36	45	9	36	1	33
16. Baggage room	7511	685	239	307	66	216	1¼	34
17. Mail room	1260	98	28	38	9	36	1	35
Totals	44646	3097	1229	1537	309	1212		33†

* On the basis that 10 square feet of exposed wall equals 1 square foot of glass.

† Average.

TABLE VIII.—RAILWAY STATION. SURFACES IN RADIATORS PROPORTIONED.

ROOMS.	Sq. ft. of glass and its equivalent in exposed wall.	Multipliers.	Cubic feet of air cooled per hour by glass.	Contents of rooms in cubic feet.	Changes of air in rooms per hour.	Total number of cubic feet of air to be warmed.	Multipliers.	Sq. ft. of surface required in rooms to warm air from 0 to 70°.	REMARKS.
4. Passage; 5. Dining room	223	× 75	= 16725	+(6832	× 1)	= 23557	× .0092	= 208	Direct.
6. Halls	73	× 75	= 5475	+(3465	× 1)	= 8940	× .0092	= 82	Direct.
7. Depot master's room	23	× 75	= 1725	+(560	× 1)	= 2285	× .0092	= 21	Direct.
8. Dining-room office	44	× 75	= 3300	+(1568	× 1)	= 4868	× .0092	= 45	Direct.
9. Telegraph office	50	× 75	= 3750	+(1008	× 1)	= 4758	× .0092	= 44	Direct.
10. Gents' toilet	44	× 75	= 3300	+(1596	× 1)	= 4896	× .0092*	= 35	Direct.
11. Gents' waiting room; 12. Ladies' waiting room; 13. Ticket office; 14. Passage	501	× 75	= 37575	+(15561	× 1)	= 53136	× .0092	= 492	Direct.
15. Ladies' toilet	45	× 75	= 3375	+(1197	× 1)	= 4572	× .0092†	= 37	Direct.
16. Baggage room	307	× 75	= 23025	+(7511	× 1)	= 30536	× .0092‡	= 219	Direct.
17. Mail room	38	× 75	= 2850	+(1260	× 1)	= 4110	× .0092	= 38	Direct.

* Use additional multiplier .78 to raise to 60°.
† Use additional multiplier .88 to raise to 65°.
‡ Use additional multiplier .78 to raise to 60°.

In proportioning the surfaces in the radiators the temperature of the circulating water has been taken at 160°. This is especially desirable in a railway station, as a larger extent of surface

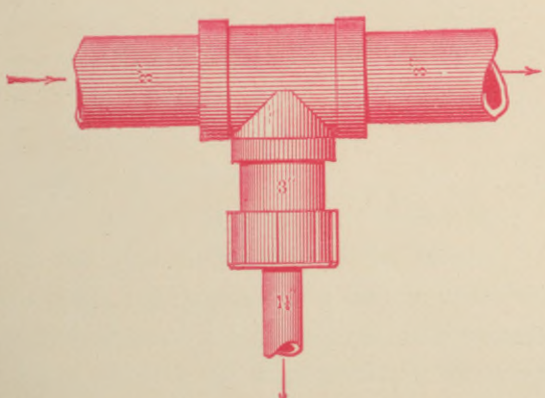


Fig. 58.—Branch Flow Pipe at C.

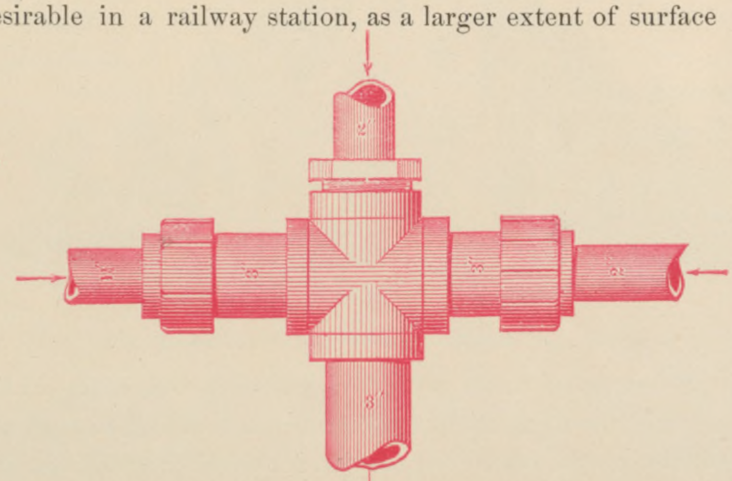


Fig. 59.—Main Return at D.

is necessary on account of the exposed condition of the rooms and the continuous opening and closing of the doors. Again, in a railway station of the kind illustrated the rooms are only occupied by a few during the greater portion of the time, so that it is more satisfactory to have a certain portion of surface at a low temperature than a smaller quantity of surface at a high temperature with a corresponding condition of temperature in the furnace of circulator. The radiators are located, so far as possible, near the doors and exposed walls, and each radiator is fitted with one valve on return pipe.

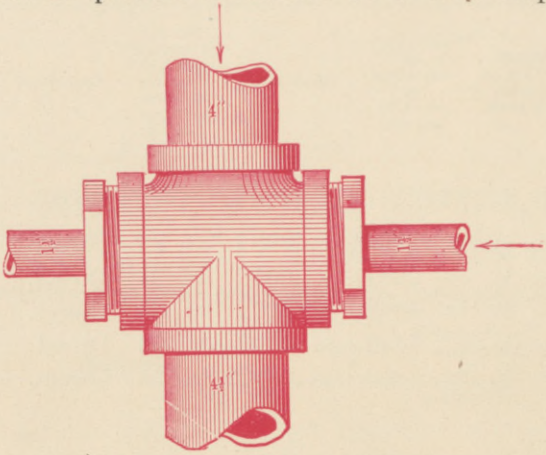


Fig. 60.—Detail of Main Return at E.

The sizes of flow and return pipes are given in accordance with rule explained under "Sizes of Main Flow and Return Pipes." 1216 square feet of surface × .015 = 18.24 square inches. Since the area of 5-inch pipe is 19.99 square inches, it is the one used.

The size of the expansion tank is ascertained by use of multipliers given under "Expansion Tanks." 1216 square feet of surface in radiators × .025 (Table XXV—A) = 30.4 gallons, or 7022 cubic inches; or 1216 x 5.75 (Table XXV—B) = 6992 cubic inches, the internal capacity of the expansion tank.

The emptying valve is on the lowest pipe of the return main below circulator. (See Sectional Elevation.)

Warming and Ventilating a Church and School with Two Novelty Circulators, No. 17.

FIG. 61 is a perspective view of the church and school, the smoke or ventilating flues being concealed by the towers and roofs. Fig. 62 is a sectional transverse elevation. In this the position of the circulators is shown, as well as the inclination of the main flow and return pipes by double light lines and single heavy lines respectively. The dotted lines indicate the main cold-air duct. The location of the indirect radiators near the side walls is seen, as well as the connections of warm-air ducts from indirect radiators to warm-air registers. The position of the exhaust or ventilating register in steps of platform is indicated, and dotted lines denote its connecting exit-air duct to ventilating flue. The height of the expansion tank is shown in class room (see I, Fig. 65,) with its overflow, supply, and expansion pipe connections. In the ventilating flue V, the height of the heating coil, also of the air pipes and of the damper, is shown. These parts are the same in the other or front ventilating flue.

Fig. 63 is a sectional longitudinal elevation. The two circulators appear in this view, as well as the main cold-air and air-circulating ducts. The position of the expansion tank is shown, and the warm-air registers in auditorium are seen beneath each window.

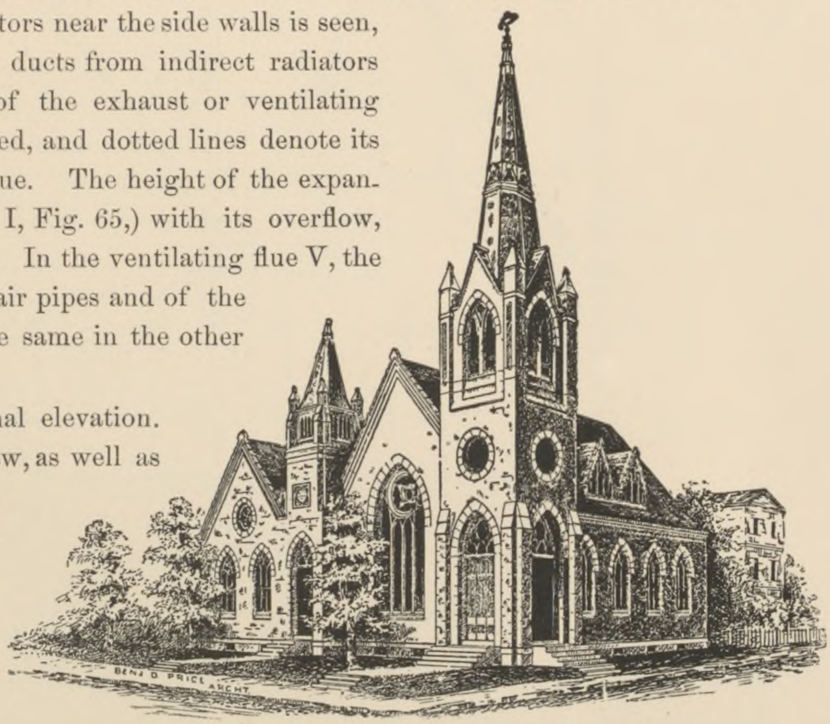


Fig. 61.—Perspective View of Church. Benj. D. Price, Architect.

Fig. 64 is a plan of basement. In this plan the location of the circulators, the smoke pipes, the main flow and return pipes and branches with sizes, the indirect radiators with surfaces in each, the cold- and warm-air ducts with the dimensions, the exit-air ducts and ventilating flues, and the air-circulating ducts are all distinctly shown. By the use of the air-circulating ducts provided, the air within the building can be at first heated, and when the building is not occupied it may be kept warm without taking in cold air or fresh air. The latter need only be used when ventilation is required. The air-circulating ducts are fitted with four doors, two of which are shown closed against the 72 by 27-inch main cold-air duct, the third is closed at the 42 by 27-inch exit-air duct, and the fourth is at the 54 by 36-inch exit-air duct. By opening the four doors communication is made between the exit-air register and the cold-air ducts, and by closing the two dampers in the upper part of the ventilating flues and the damper in cold-air duct at the cold-air inlet the exit and entrance of air into the building ceases, and, as the air is heated, the circulation is up through the warm-air ducts, and down through the exit-air ducts into the cold-air ducts to indirect radiators. When the air in the building has become heated by this plan and ventilation is needed, the doors in

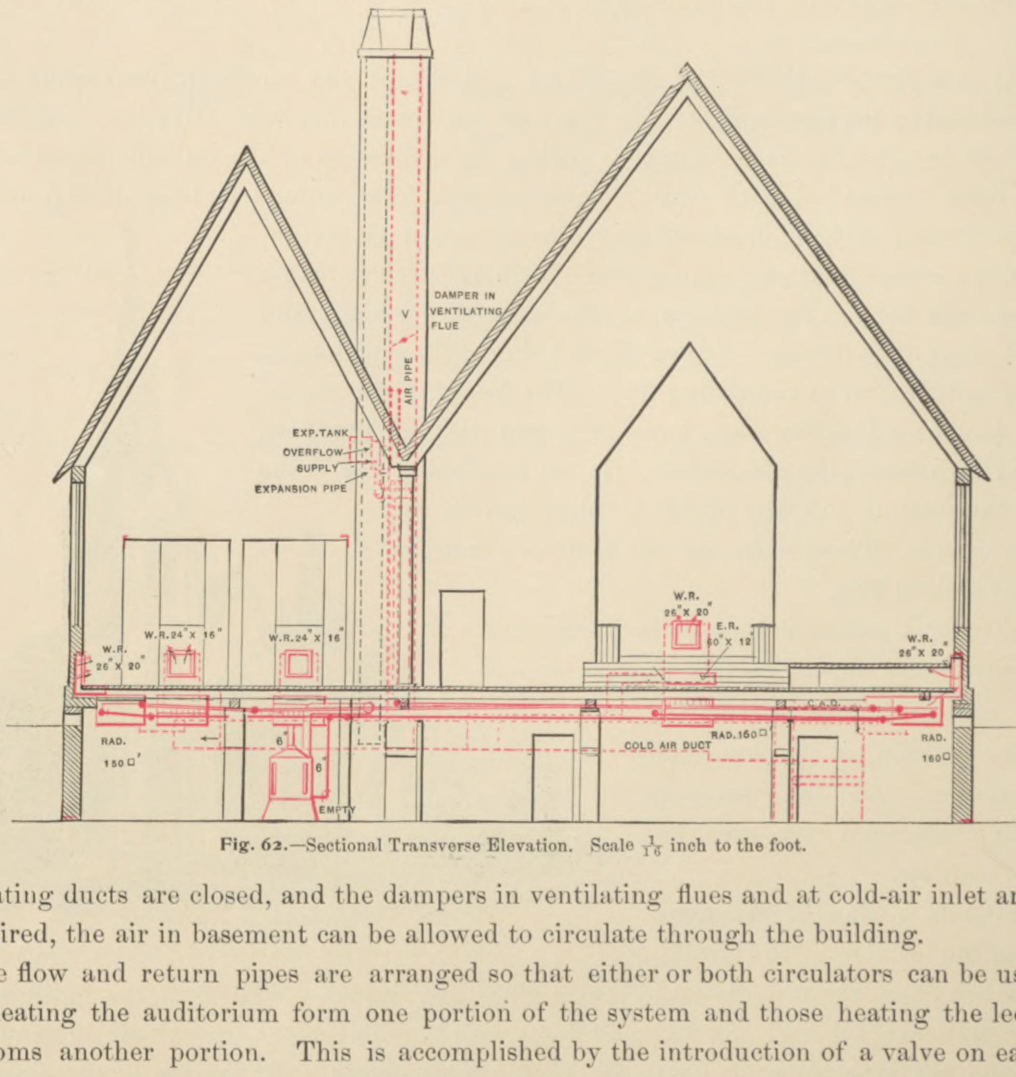


Fig. 62.—Sectional Transverse Elevation. Scale $\frac{1}{16}$ inch to the foot.

the circulating ducts are closed, and the dampers in ventilating flues and at cold-air inlet are opened. If it is desired, the air in basement can be allowed to circulate through the building.

The flow and return pipes are arranged so that either or both circulators can be used. The surfaces heating the auditorium form one portion of the system and those heating the lecture and school rooms another portion. This is accomplished by the introduction of a valve on each return main near circulator. Continuous circulation passes through each main flow pipe through the heating surfaces in the ventilating flues. The return from these surfaces in the small ventilating flue near circulators is connected directly to the circulators.

Fig. 65 is plan of main floor. The position of the warm-air registers is indicated by the letters W R, the exhaust or exit-air registers by letters E R. The latter registers are in the floor, excepting three and the one in the steps to platform. The three registers are placed as low as possible and the warm-air register in auditorium between the vestibules is placed as high as possible beneath the window. Direct radiators heat the two vestibules.

Fig. 66 illustrates the connections to direct radiator in vestibule. This radiator has double flow and return pipes. The object of this arrangement is to secure heat in this radiator with either portion of the system in use. A is flow pipe from auditorium main, B flow pipe from lecture-room main, D return pipe to auditorium main, E return pipe from lecture-room main. When the valve on main return of auditorium portion is closed, the circulation will be through the auditorium and lecture-room flow main and through the lecture-room return main to circulator. When this valve is open and the other closed on lecture-room return main, the circulation is through the two main flow pipes and the return main of the auditorium portion.

Fig. 67 gives details of heating surfaces in front or large ventilating flue or shaft. A is auditorium main flow, A¹ auditorium flow to coil in ventilating flue and air pipe, B is lecture-room flow,

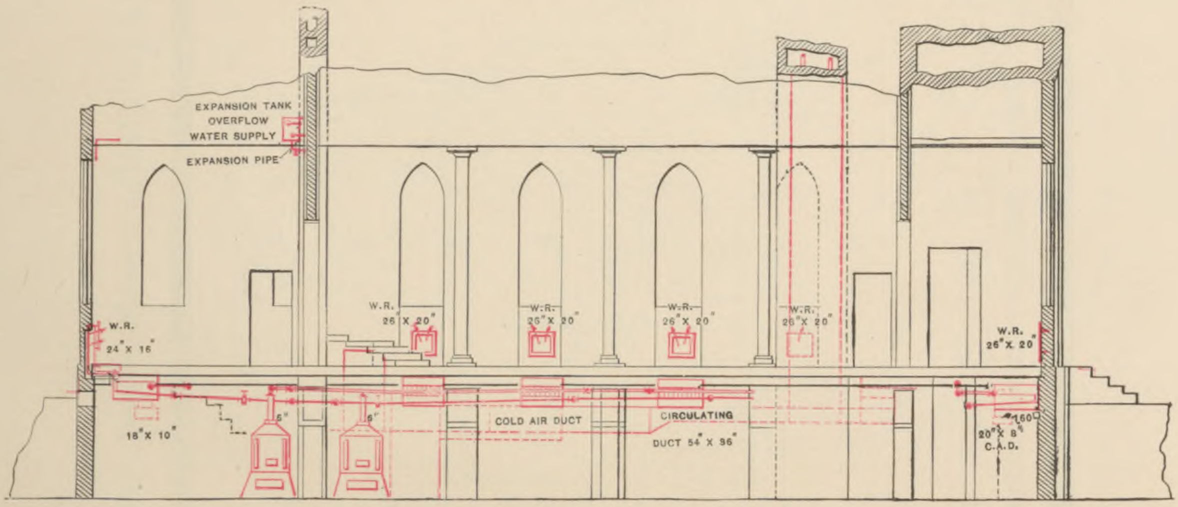


Fig. 63.—Sectional Longitudinal Elevation. Scale $\frac{1}{16}$ inch to the foot.

B¹ lecture-room flow to coil and air pipe. C provides continuous circulation in return main of either portion, D auditorium main return, D¹ auditorium return from coil, E lecture-room return, E¹ lecture-room return from coil. Air pipes extend above the coil and the level of expansion tank.

Fig. 68 and Fig. 69 are elevations and a plan of the heating surfaces and connections of expansion tank in and near the back or small ventilating shaft. A¹ and A are air pipes extending above the level of the expansion tank from the coil in ventilating shaft. B¹ is flow pipe from and air pipe to lecture-room main, B flow pipe from and air pipe to auditorium main. C¹ and C are return pipes of coils to the top of which is connected the expansion pipe D; the other ends of these pipes R¹ and R are connected direct to circulators; that is, between the circulators and the gate valves on the main return pipes. E is the water-supply pipe to expansion tank. It is passed up through the ventilating shaft, as well as G, the overflow pipe, in order to be concealed from view in class room. The end of overflow pipe is open and discharges into a sink in cellar and can be used as an air pipe to expansion tank if the latter is covered. From the details of connections described and illustrated in Figs. 68 and 69 it will be observed that a continuous circulation is secured in the main flow pipes. This is done in order to assist in maintaining a low temperature in whichever portion of the system is not in use.

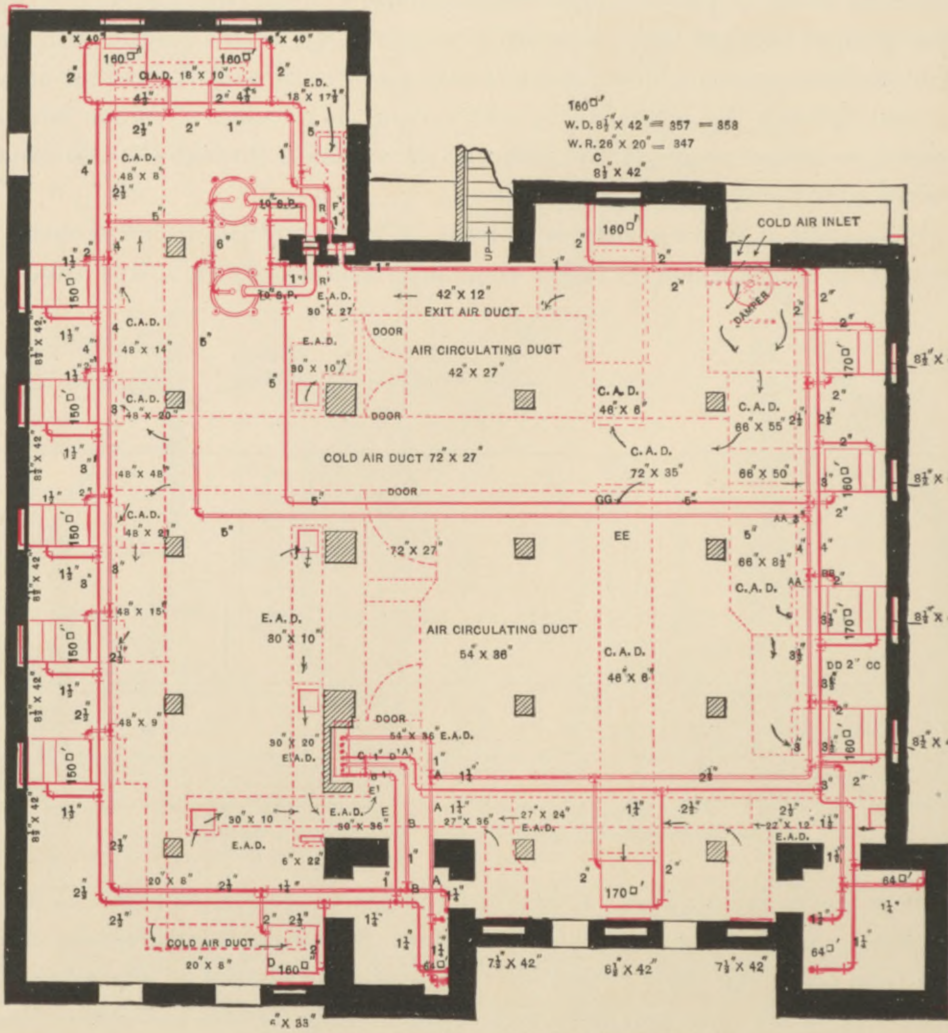


Fig. 64.—Basement Plan. Scale $\frac{1}{16}$ inch to the foot.

The air emission from the direct radiator is provided for by air cocks or valves. The arrangement of the main flow pipes provides for the continuous escape or emission of the air from the indirect radiators. The points A^1 and B^1, Fig. 67, are respectively the highest points on the front end of the auditorium and lecture-room flow pipe. The points F^1 and F, Fig. 69, are the highest points on the back main flow pipes of the lecture room and auditorium respectively. The main flow pipes incline upward from the circulator to the points just mentioned where they are open to the atmosphere through four air pipes. The branches from the main flow to the indirect radiators incline from the flow main to the radiator. This is shown in Fig. 70, where the point A A is higher than the point B B and the point C C higher than D D. The return main has its inclination downward toward the circulators and parallel to the main flow pipes.

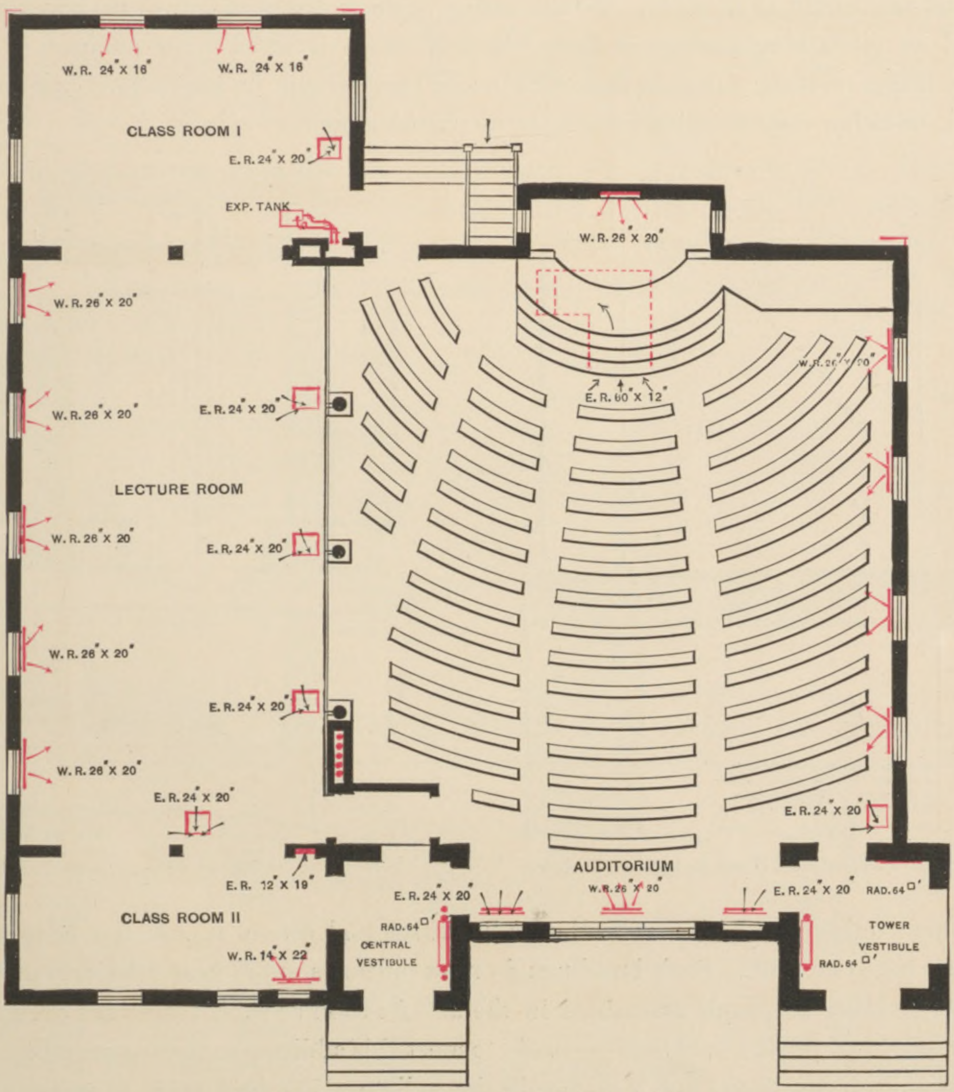


Fig. 65.—Plan of Main Floor. Scale $\frac{1}{16}$ inch to the foot.

The expansion tank is located as shown in class room I. Its contents are found by multiplying the square feet of surface in radiators 2502 by .02 and the product is the contents, namely 50 gallons, or 2502 by 4.5 = 11,259 cubic inches, or 48.7 gallons. (See Table XXV.)

Fig. 70 gives details of the cold and warm-air ducts and the relative inclinations of the flow and return mains and branches. The point F is higher than the point A A on the flow pipe at back of basement; the pipe at F connects to coil and air pipe in the back or small ventilating shaft. A A and D D are higher than E E on the central or main flow pipe and G G on the central main return. The levels at A, B, C, and D on the branch flow and return pipes have been described.

The warm-air ducts have a short part horizontal. This is necessary in order to keep the casing of the radiator out from the window of basement. Preferably the passages of warm-air ducts should be vertical and as straight as possible. To the casing of the indirect radiators are connected the cold-air duct and an air-mixing passage or duct. Each of these is fitted with damper, as shown. By reversing the levers on these dampers the cold-air duct damper will be kept closed and the air-mixing damper open, or either may be adjusted so as to be partially open or closed.

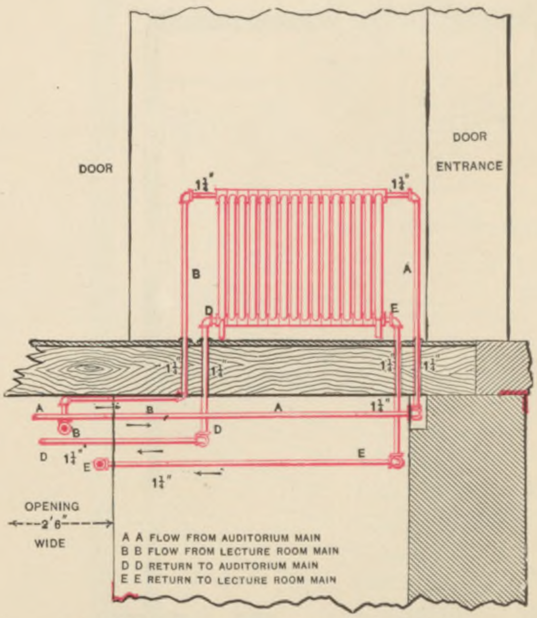


Fig. 66.—Connections to Direct Radiator in Vestibule.

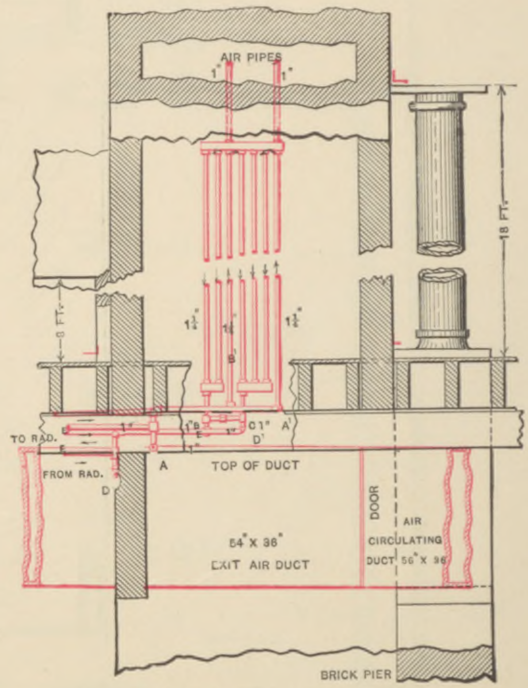


Fig. 67.—Front Ventilating Shaft.

In proportioning the surface in radiators in church and school rooms, the temperature of the water has been taken at 180°. Such buildings do not require as much heat relatively as dwellings, on account of the number of people assembled in them. As soon as such places are occupied the temperature increases, and provision should be made to meet this addition to the temperature. It is therefore desirable not to provide too much surface in the radiators, but preferably to make arrangements for quick heating up with a relatively small amount of heating surface and a proportionate increase in the temperature of the water. In quickly heating up, the circulating-air ducts will be found economical and useful, and with the proper use of the air-mixing dampers the temperature of buildings heated in the manner described will be under perfect control.

TABLE IX.—CHURCH AND SCHOOL ROOM. CONTENTS, PROPORTIONS, SURFACES, ETC.

ROOMS.	Contents in cubic feet.	Exposed wall exclusive of glass surface, square feet.	Glass surface, square feet.	Equivalent to glass in square feet.*	Lineal feet of exposed wall.	Heating surface in radiators or coils in square feet. Direct.	Indirect.	Proportion of contents to surface in radiators.	Dimensions of warm-air pipe in inches.	Area of warm-air pipe in square inches.	Velocity of air per second in feet in warm-air flue.	Changes of air per hour.	Dimensions of warm-air registers in inches.	Area of exhaust or exit flue in square inches.	Dimensions of exhaust flue registers in inches.	Heating surface in exhaust flue in sq. feet.	Size of cold-air duct or fresh-air inlet in inches.	Area of cold-air duct or fresh-air inlet in square inches.
Class room No. 1.	11646	1184	112	171	62		320	36	2–6x40	480	2	2	2–24x16	315	24x20		18x20	360
Lecture room......	29970	670	140	174	45		750	40	5–8½x42	1785	2	3	5–26x20	1200	4–24x20	35	5–42x7	1420
Class room No. 2.	4950	564	84	112	36		160	30	6x33	198	2	2	14x22	132	12x19		20x8	160
Auditorium........	70642	2906	352	497	125		990	71	6–8½x42	2142	2	1½	6–26x20	1476	3–24x20 1–60x12	55	6–46x6	1656
Tower vestibule..	3456	552	240	267	33	128		27										
Central vestibule	2590	212	100	110	9	64		40										
Ventilating flues							90											
Totals...........	123254	6088	1028	1331	310	192	2310	51†		4605				3123		90		3596
						2502				31.97‡				21.69‡				24.97‡

* On the basis that 20 square feet of exposed wall equals 1 square foot of glass.

† Average.

‡ Square feet.

TABLE X.—CHURCH AND SCHOOL ROOM. SURFACES IN RADIATORS PROPORTIONED.

ROOMS.	Square feet of glass and its equivalent in exposed wall.	Multipliers.	Cubic feet of air cooled per hour by glass.	Contents of rooms in cubic feet.	Change of air in rooms per hour.	Total number of cubic feet of air to be warmed.	Multipliers.	Square feet of surface to each room required to warm air from 0 to degree indicated in next column.	Remarks.
Class room No. 1......	171	× 75	=12825	+(11646	× 2)	= 36117	×.009	= 325	Indirect for 70°.
Lecture room...........	174	× 75	=13050	+(29970	× 3)	=102960	×.009 ×.78	= 722	Indirect for 60°.
Class room No. 2......	112	× 75	= 8400	+(4950	× 2)	= 18300	×.009	= 164	Indirect for 70°.
Auditorium.............	497	× 75	=37275	+(70642	× 1½)	=143238	×.009 ×.78	=1005	Indirect for 60°.
Tower vestibule......	267	× 75	=20025	+(3456	× 1)	= 23481	×.0072×.78	= 132	Direct for 60°.
Central vestibule.....	110	× 75	= 8250	+(2590	× 1)	= 10842	×.0072×.78	= 60	Direct for 60°.

TABLE XI.—PROPORTIONING MAIN FLOW AND RETURN PIPES IN CHURCH AND SCHOOL.

ROOM HEATED.	Square feet of surface supplied.	Multipliers.	Approximate area of pipe. Square inches.	Actual area of pipe. Square inches.	Size of pipe. Nominal inside diameter.
First Main:					
Class room I and ventilating flue	355	.015	5.32	4.78	2½ in.
Lecture and school rooms, etc	1384	.015	20.76	19.99	5 "
Lecture room, etc	879	.015	13.18	12.73	4 "
" " "	729	.015	10.93	12.73	4 "
" " "	579	.015	8.68	7.38	3 "
" " "	429	.015	6.43	7.38	3 "
Class room II, vestibule, etc	279	.015	4.18	4.78	2½ "
Second Main:					
Auditorium and ventilating flue	365	.015	5.49	4.78	2½ "
Auditorium, etc	525	.015	7.87	7.38	3 "
Auditorium, vestibule, and ventilating flues	1272	.015	19.08	19.99	5 "
" " " " "	747	.015	11.20	12.73	4 "
" " " " "	577	.015	8.65	9.88	3½ "
" " " " "	417	.015	6.25	7.38	3 "
" " " " "	289	.015	4.33	4.78	2½ "

QUANTITY OF AIR TO BE PASSED THROUGH VENTILATING FLUES PER HOUR, AND AREAS REQUIRED.

Class room I cubic contents × 2 changes = 23,292 cubic feet of air per hour.
Lecture room " " × 3 " = 89,910 " " "
Class room II " " × 2 " = 9,900 " " "
Auditorium " " × 1½ " = 105,963 " " "
Total, 229,065 cubic feet of air per hour.

229,065 cubic feet of air at a velocity of 3 feet per second × .0133 = 3046 square inches area in openings to vertical ventilating flues.

Openings to vertical ventilating flues.

1 opening 18 inches × 17½ inches = 315 square inches.
1 " 30 " × 27 " = 810 " "
1 " 54 " × 36 " = 1944 " "
Total in three openings, 3069 square inches.

CHANGES OF AIR IN ROOMS RELATIVE TO VENTILATION, CUBIC CONTENTS OF ROOM AND QUANTITY OF AIR PER HOUR BEING KNOWN.

Class room I is furnished for forty occupants, who each require an average of 600 cubic feet of air per hour.

$$600 \times 40 = \frac{24{,}000 \text{ cubic feet of air per hour}}{11{,}646 \text{ cubic feet of air in room}} = 2.06$$ the number of times the air in room should be changed per hour.

Lecture room is arranged to seat 200 persons, who each require an average of 400 cubic feet of air per hour.

$$400 \times 200 = \frac{80{,}000 \text{ cubic feet of air per hour}}{29{,}970 \text{ cubic feet of air in room}} = 2.66$$ the number of times the air in room should be changed per hour.

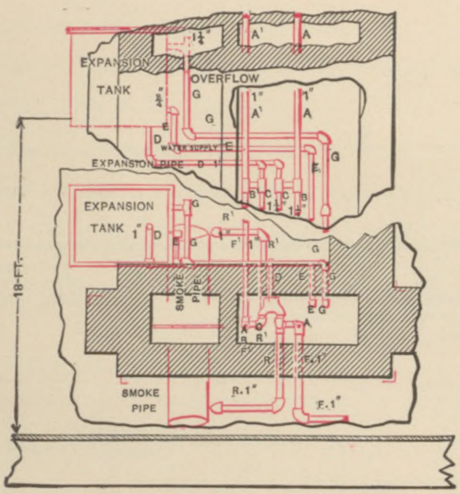


Fig. 68.—Elevation and Plan of Back Ventilating Shaft.

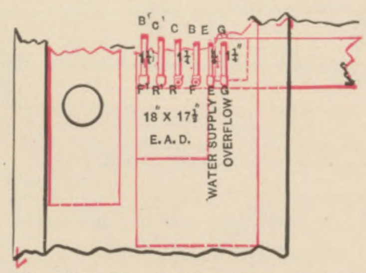


Fig. 69.—Elevation at Lower Part of Back Ventilating Shaft.

Class room II is to seat 20 occupants, and 450 cubic feet of air per person per hour should be provided.

$$450 \times 20 = \frac{9000 \text{ cubic feet of air per hour}}{4950 \text{ cubic feet of air in room}} = 1.81$$ the number of times the air in room should be changed per hour.

Auditorium seats 300 occupants, for whom 350 cubic feet of air per person per hour should be provided.

$$350 \times 300 = \frac{105{,}000 \text{ cubic feet of air per hour}}{70{,}642 \text{ cubic feet of air in auditorium}} = 1.48$$ the number of times the air in room should be changed per hour.

See "Air required for Ventilation," in chapter on "Air."

PROPORTIONING WARM-AIR DUCTS. THE VELOCITY OF AIR IN FEET PER SECOND AND THE NUMBER OF TIMES THE AIR IN ROOM IS CHANGED, PER HOUR, BEING KNOWN.

Class Room I.—11,646 cubic feet in room $\times .04$ (multiplier*) $= 465.8$ square inches.
2 ducts 6×40 inches $= 480$ square inches area.

Lecture Room.—29,970 cubic feet in room $\times .06$ (multiplier*) $= 1798.2$ square inches.
5 ducts $8\frac{1}{2} \times 42$ inches $= 1785$ square inches.

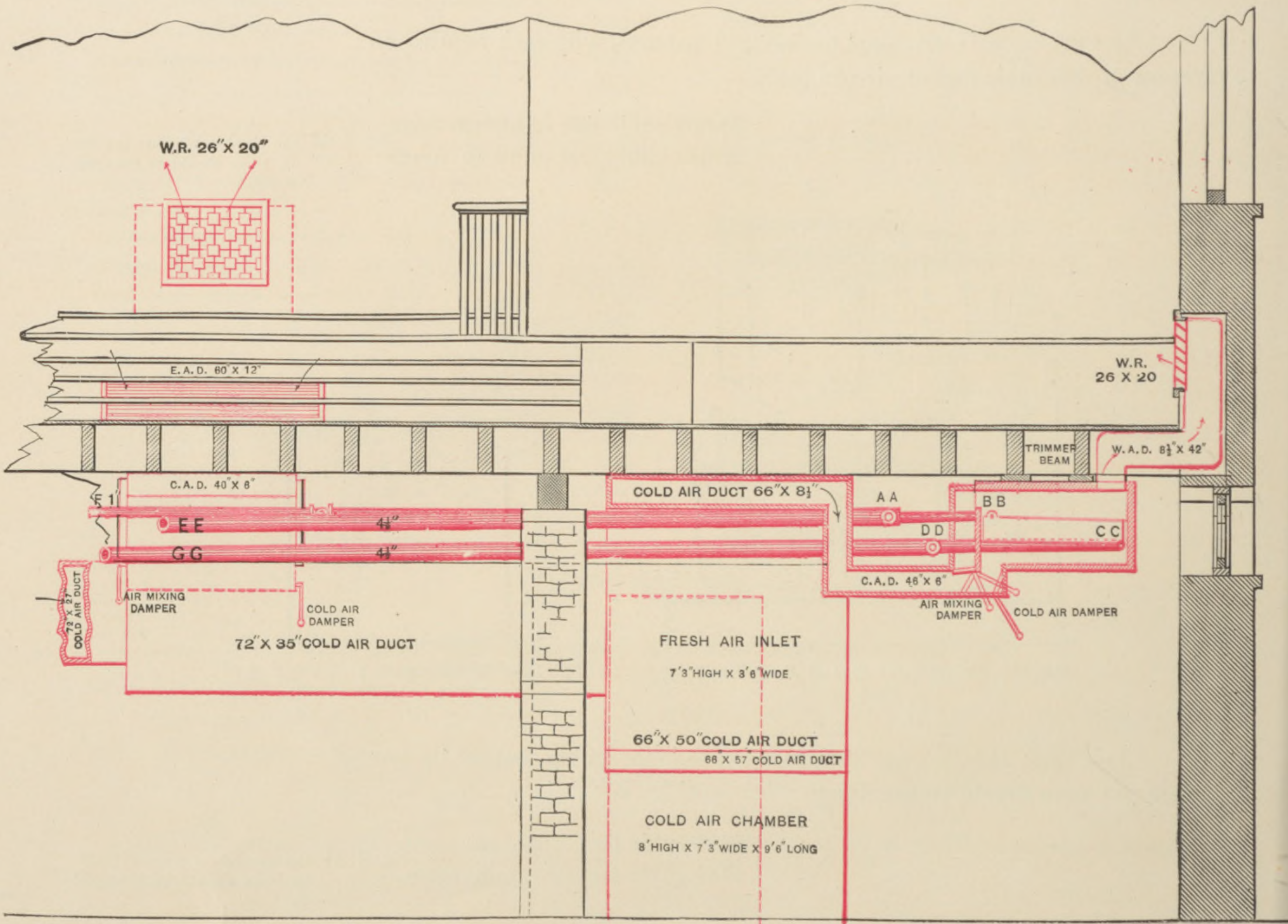


Fig. 70.—Details of Cold and Warm-Air Ducts.

Auditorium.—70,642 cubic feet in room $\times .03$ (multiplier*) $= 2119.2$ square inches.
6 ducts $8\frac{1}{2} \times 42$ inches $= 2142$ square inches.

ClassRoom II.—4950 cubic feet in room $\times .04$ (multiplier*) $= 198$ square inches.
1 duct 6×33 inches $= 198$ square inches.

* See Table XXVIII for multipliers.

In this case the velocity is taken at 2 feet per second and the air is changed in the auditorium $1\frac{1}{2}$ times per hour, in class rooms I and II 2 times per hour, and in lecture room 3 times per hour.

PROPORTIONING WARM-AIR REGISTERS, THE AREAS OF WARM-AIR DUCTS BEING KNOWN.

CLASS ROOM I.—480 × 1.33 = 638 square inches.
2 registers 24 × 16 inches = 768 square inches.
LECTURE ROOM.—1785 × 1.33 = 2374 square inches.
5 registers 26 × 20 inches = 2600 square inches.
CLASS ROOM II—198 × 1.33 = 263 square inches.
1 register 14 × 22 inches = 308 square inches.
AUDITORIUM.—2142 × 1.33 inches = 2849 square inches.
6 registers 26 × 20 inches = 3120 square inches.

The register sizes taken are somewhat larger than the figures show to be necessary, but are preferred because larger openings tend to reduce the velocity of the air at its entry into the room. See "Air" and rules therein.

PROPORTIONING HORIZONTAL EXHAUST AND VENTILATING DUCTS, IN WHICH THE VELOCITY OF THE AIR DOES NOT EXCEED 3 FEET PER SECOND.

CLASS ROOM I.—11,646 cubic feet of air in room ×.0266 (multiplier) = 310 square inches.
1 duct 18 × $17\frac{1}{2}$ inches = 315 square inches.
LECTURE ROOM.—29,970 cubic feet of air in room ×.0399 (multiplier) = 1195 square inches.
4 ducts 30 × 10 inches = 1200 square inches.
CLASS ROOM II.—4950 cubic feet of air in room ×.0266 (multiplier) = 131 square inches.
1 duct 22 × 6 inches = 132 square inches.
AUDITORIUM.—70,642 cubic feet of air in room ×.0199 (multiplier) = 1406 square inches.
3 ducts 12 × 27 inches = 972 square inches.
1 duct 12 × 42 inches = 504 square inches.
1476

The air is changed twice per hour in the class rooms, three times in the lecture room, and one and one-half times in the auditorium. For multipliers see "Air" and rules therein.

PROPORTIONING REGISTERS TO EXHAUST AND VENTILATING DUCTS WHEN THE VELOCITY IN THE LATTER EXCEEDS THE VELOCITY IN THE WARM-AIR DUCTS.

CLASS ROOM I.—315 square inches area of exhaust and ventilating duct × 1.5 = 472 square inches.
1 register 24 × 20 inches = 480 square inches.

LECTURE ROOM.—1200 square inches area of ventilating ducts × 1.5 = 1800 square inches.
4 registers 24 × 20 inches = 1920 square inches.

CLASS ROOM II.—132 square inches area of ventilating duct × 1.5 = 198 square inches.
1 register 12 × 19 inches = 228 square inches.

AUDITORIUM.—1476 square inches area of ventilating ducts × 1.5 = 2214 square inches.
3 registers 24 × 20 inches = 1440 square inches.
1 register 60 × 12 inches = 720 square inches.
2160

See "Air" and rules therein.

PROPORTIONING FRESH OR COLD-AIR DUCTS, THE AREAS OF WARM-AIR DUCTS BEING KNOWN.

CLASS ROOM I.—465.8 square inches area of warm-air duct × .8 = 372 square inches.
1 duct 18 × 20 inches = 360 square inches.

LECTURE ROOM.—1798 square inches area of warm-air duct × .8 = 1438 square inches.
5 ducts 42 × 7 inches = 1420 square inches.

CLASS ROOM II.—198 square inches area of warm-air duct × .8 = 158 square inches.
1 duct 20 × 8 inches = 160 square inches.

AUDITORIUM.—2119 square inches area of warm-air ducts × .8 = 1695 square inches.
6 ducts 46 × 6 inches = 1656 square inches.

See "Air" and rules therein.

VERTICAL VENTILATING FLUES.

Each flue is 60 feet high. The small flue is 30 × 12 inches = 360 square inches = 2.5 square feet. The large flue is 54 × 12 inches = 648 square inches = 4.5 square feet. Total vertical flue area 1008 square inches = 7 square feet.

At a velocity in vertical flue of 10 feet per second 229,065 cubic feet of air will be discharged in one hour through a flue area of 916 square inches, or 6.36 square feet.

229,065 × .004 = 916.2 square inches. (See Table XXVIII in "Air.")

To maintain a velocity of 10 feet per second in a ventilating flue 60 feet high, calculate as follows:

Velocity squared = 10 × 10 = 100 divided by constant A 5.375 (see Table XXX) = 18.6° excess of temperature required in ventilating flue above outside temperature. Therefore if the temperature of the air in the ventilating flues is 50°, and the external atmosphere 30°, a velocity a little in excess of 10 feet per second is maintained in the ventilating flue. As the outside temperature decreases, the velocity in flue increases. These are the velocities and proportions of temperatures and areas necessary to simultaneously ventilate the school rooms, lecture room, and auditorium.

To ventilate the school rooms and lecture room at one time, and the auditorium at another, since all the apartments may not be used at the same time, reduces the velocity in the ventilating flues to a great extent.

The school rooms and lecture room require 123,102 cubic feet of air per hour through ventilating flue of 1008 square inches area, $1008 \div 123{,}102 = .0081$, which in Table XXVIII indicates that the velocity in a flue of this area is 5 feet per second. The velocity squared, $5 \times 5 = 25 \div 5.375$ (see Table XXX) $= 4.6°$, which is the excess of temperature required above that of the outside temperature to maintain a velocity of 5 feet per second.

For the auditorium the calculation may be thus given: $\frac{1008}{105963} = .0094$, which indicates a velocity according to Table XXVIII of $4\frac{1}{4}$ feet per second. The velocity squared, $4.25 \times 4.25 = 18.06 \div 5.375 = 3.54°$, which is the excess of temperature required above that of the outside atmosphere.

To use the large ventilating flue only for the school rooms and lecture room requires a velocity of $7\frac{1}{2}$ feet per second, and an excess of temperature of $10\frac{1}{2}°$ above that of the outside atmosphere. The calculation is as follows: $\frac{648}{123102} = .0052$, or a velocity of $7\frac{1}{2}$ feet per second. (See table XXVIII.)

The velocity squared, $7.5 \times 7.5 = \frac{56.25}{5.375 \text{ (constant A, Table XXX)}} = 10.5°$ excess of temperature.

HEATING SURFACE IN EXHAUST OR VENTILATING FLUES.

It is an advantage to place a small quantity of heating surface in the ventilating flue in order to heat the surfaces of the flue so that the temperature of the air exhausted from the rooms will not be quickly reduced on entering the ventilating flue. This heating surface also tends to create a velocity at the first application of heat to the system, and prevents tendency to down currents by irregular winds.

An approximate way of proportioning this heating surface is to divide the surface of the sides of the flue in square feet by 12; the result will be the square feet of heating surface.

The large flue in the church and schools measures 11 lineal feet in its side walls, which multiplied by 60 feet its height equals 660 square feet of surface in walls, and this divided by 12 equals 55 square feet of surface in heating pipes.

The surface required in the small flue is thus ascertained: $7 \times 60 = \frac{420}{12} = 35$ square feet in heating pipes.

To ventilate the school rooms and lecture room in the summer time it will be necessary to increase the temperature of the air from these rooms about 5° above the temperature of the outside atmosphere. Taking the temperature of the rooms at the same temperature as the outside atmosphere, say 70°, 123,102 cubic feet of air is to be raised 5°. The surface required in ventilating flues to heat this quantity of air 5° may be thus ascertained:

Multiply the weight of a cubic foot of air at 70°, .0748 pounds (see Table XXII), by the specific heat of air, .238 (see Table XXXII); the result is .0178 unit of heat necessary to raise 1 cubic foot 1°. The increase of temperature 5° multiplied by .0178 gives .089 unit of heat required to raise the temperature of 1 cubic foot of air 5° in 1 hour. The cubic feet of air to be heated are 123,102, which $\times$ .089 = the total number of units of heat per hour, 10,956. One square foot of surface with water at 160°, and surrounding air 75°, will approximately emit 127.5 units of heat per hour. Hence 10,956 divided by 127.5 equals 86 square feet of heating surface necessary in flues to maintain a velocity of 5 feet per second. It therefore appears that with 90 square feet of surface in ventilating flues an adequate ventilation may be had in the summer time.

To maintain a velocity of 10 feet per second with an excess of temperature in the flues of 20°, which is more desirable than 5°, in order to ventilate all the building at one time in the summer, will require a greater quantity of surface, which may be ascertained as follows:

$$\frac{\left.\begin{array}{c}\text{Weight in pound or cubic foot}\\ \text{of air at stated temperature}\end{array}\right\} \times \text{specific heat of air} \times \left\{\begin{array}{c}\text{Number of degrees difference between}\\ \text{air in flue and outside atmosphere}\end{array}\right\} \times \left\{\begin{array}{c}\text{Cubic feet of air to be}\\ \text{heated per hour}\end{array}\right.}{\text{Units of heat emitted approximately per square foot of surface}} = \left\{\begin{array}{l}\text{Number of square}\\ \text{feet required in}\\ \text{heating surface.}\end{array}\right.$$

Substituting figures in this formula, we have the following as the calculation for ventilating the entire building:

$$\frac{.0748 \times .238 \times 20 \times 229{,}065}{(\,(160-90) \times 2.25) = 157.5} = 518 \text{ square feet of heating surface.}$$

The heating surface should be placed at the base of the flue, or extended up from the base, preferably to putting this surface at the top of the flue.

The number of heat units emitted per 1° difference between temperature of surface and temperature of air is increased with the increase in volume of air.

Warming and Ventilating a City Office, using the Novelty Circulator No. II.*

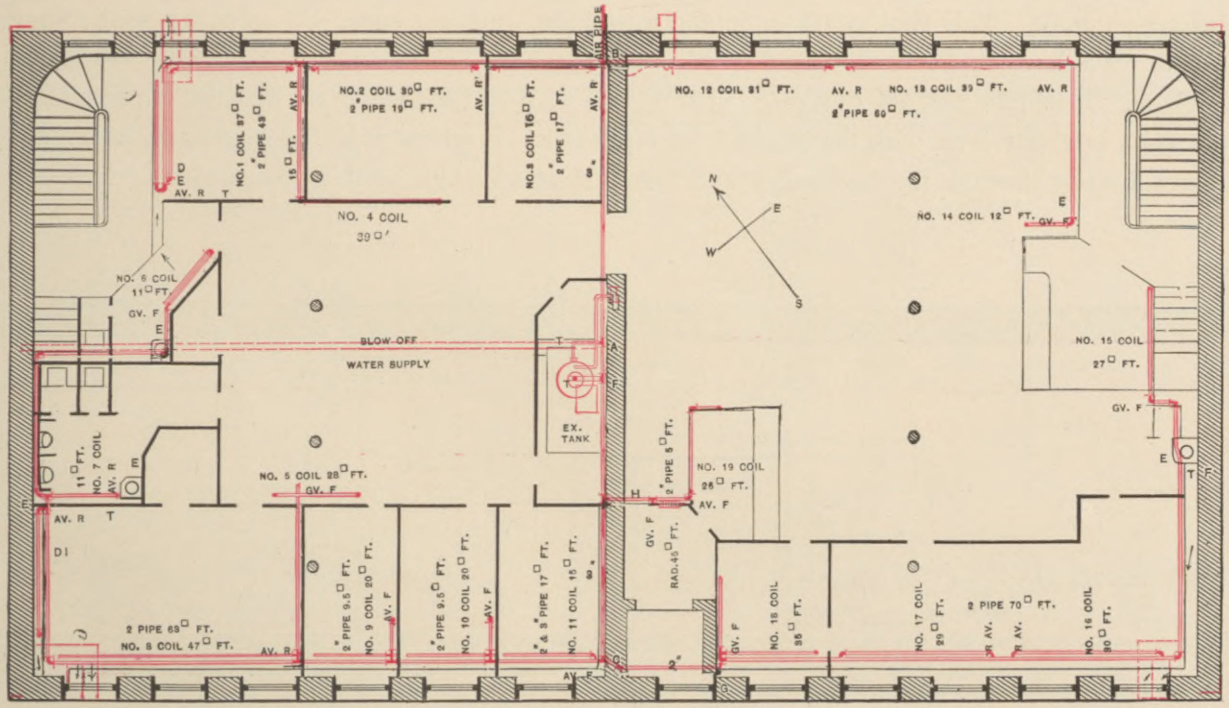


Fig. 71.—Floor Plan of City Office. Approximate scale $\frac{1}{16}$ inch to the foot.

THE premises herein referred to are the offices of the *Iron Age*, *Metal Worker*, etc., Nos. 96–102 Reade street, New York, in which the Novelty Circulator was installed in October, 1890. Gas is used as fuel, and nothing could better demonstrate the practical economy of the Novelty Circulator than the experience of the two seasons which have passed, and the small quantity of gas required. The premises have been abundantly and thoroughly warmed, and yet the consumption of gas through ordinary winter weather has averaged as little as 500 feet per day, and in the severe weather of January, 1892, it averaged less than 800 feet per day. (See *Metal Worker*, January 30, 1892.)

* In this system, which is an open one, the circulator is on the same level as the radiating surface, and therefore a larger size of circulator is used than would otherwise be needed.

Fig. 71 is floor plan, indicating the manner in which the space is apportioned to the various office requirements. The position of the circulator is shown to be nearly central. The distribution of the heating surface in the pipes and coils is also given. The blow-off or emptying pipe and water supply pass between the beams and beneath the floor from the heater to the west wall, and these are the only two pipes connected with the system which are not between the floor and ceiling of the floor heated.

Fig. 72 is an elevation of the apparatus to larger scale, and shows the relative levels of the circulator, the floor main, the coils, and the one radiator employed, the return main, and the expansion tank. This view is taken in the west room looking east. By referring to the numbers of the coils they can be readily located on plan, Fig. 71. The distance of each coil from circulator is given. It will be noticed that one coil is no less than 74 feet away, and that the upper pipe of all the coils is about level with the return inlet on heater. It will also be observed that the circulation passes directly through the flow mains and not to the tank, thus heating the surfaces by circulation

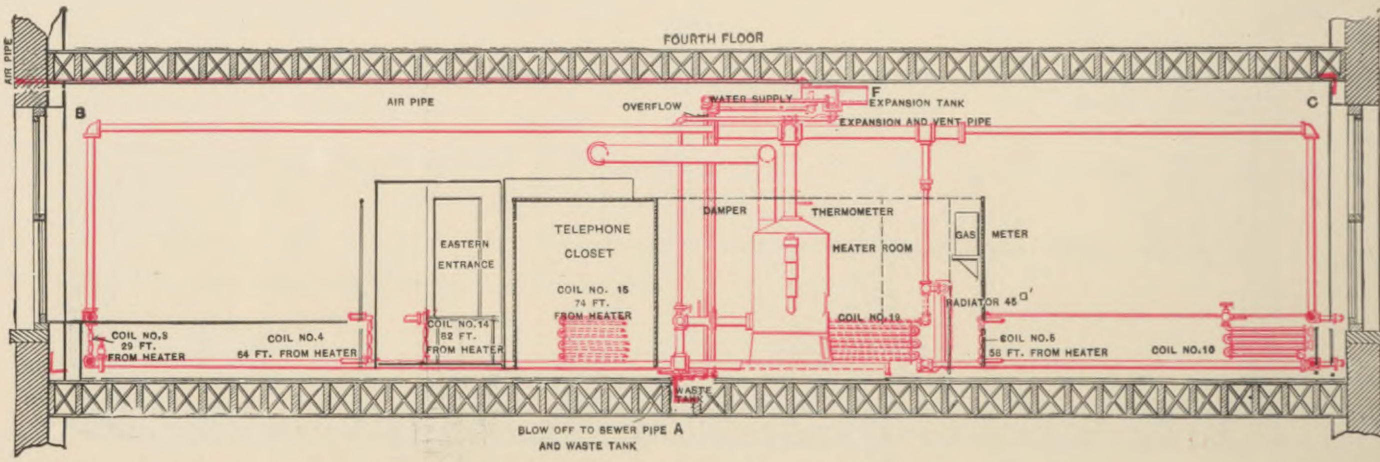


Fig. 72.—Sectional Transverse Elevation Showing Circulator, Coils, etc.

direct from the heater without having the temperature of the water reduced in a tank, as is sometimes done to assist circulation in the return pipes. The location of the gas meter is shown, through which city gas is passed to the fire-box of the circulator and used as fuel. By this use of gas all the inconvenience, dust, and labor of coal fires is dispensed with, and the cost in this instance, as already mentioned, scarcely exceeds coal and the accompanying expense of handling and storing, removing ashes, etc.

Fig. 73 shows No. 5 coil on partition. The flow and return connections are seen coming through the partition. Fig. 74 is section through ventilating duct which passes along the outside walls, the top forming an extension to the window-sills and the sides forming supports for the coils and pipes as shown. Fig. 75 shows the manner of connecting coils Nos. 9 and 10 to the 2-inch flow and return pipes. Fig. 76 gives the manner of connecting coil No. 12 and others of the same kind,

Fig. 77 shows details at A (Fig. 71) of the blow-off, water supply, and return main. The waste tank below the floor is also shown. This tank is made necessary on account of the trimmer beam over which the blow-off pipe and overflow pass, as in the installation of this work no beams were allowed to be cut. When emptying the system the water flows out until the level of the bottom of the pipe over trimmer beam is reached. The plug in blow-off is then opened, and the rest of the water flows into the waste tank, from which it is removed by hand pump and pail. In Fig. 78 are shown details at F in the plan, indicating the relative positions of main flow pipe, air pipe, expansion pipe, and expansion tank.

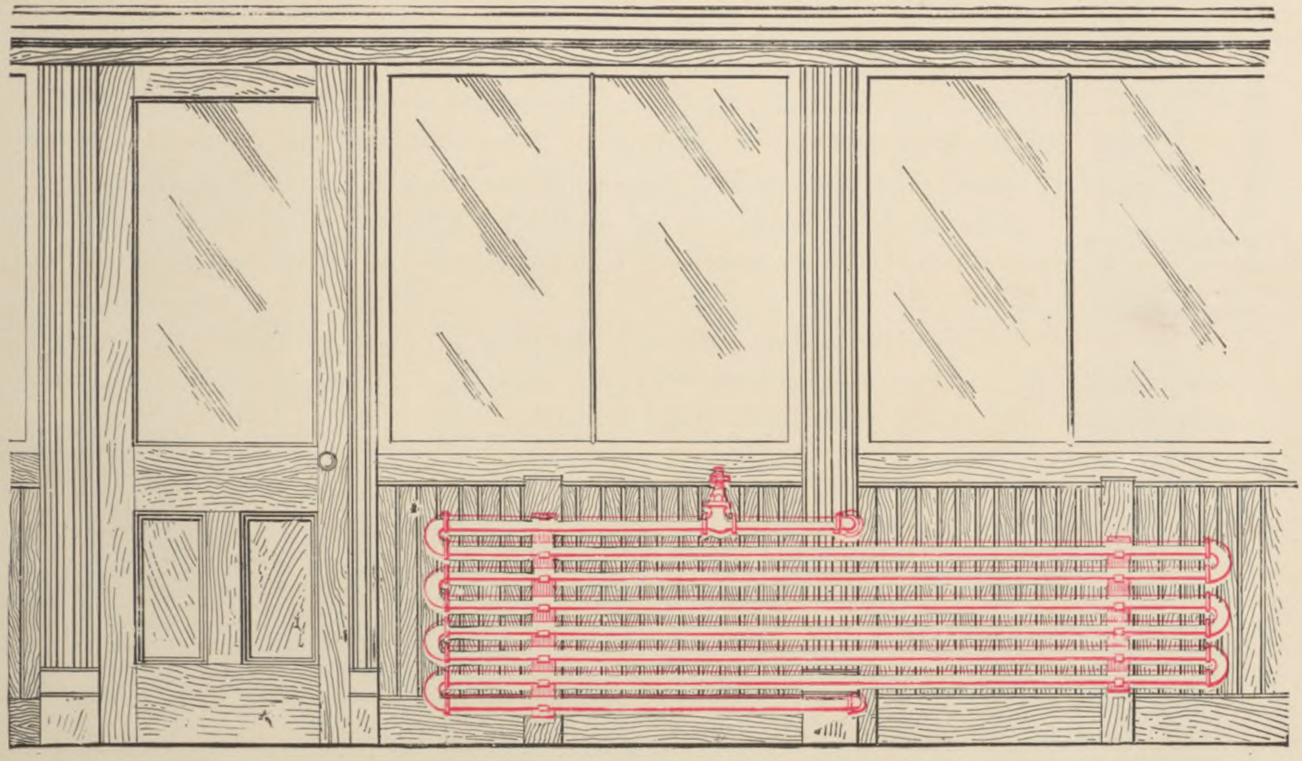


Fig. 73.—Coil No. 5 on Partition.

In proportioning the surfaces in coils and radiators for this office the external temperature was taken at zero, and the internal temperature at 70°. The east office contains in actual space, exclusive of halls and elevator shaft, 26,373 cubic feet of air, 572 square feet of exposed wall, and 352 square feet of glass. Taking the wall at a ratio of 20 square feet of its exposed surface as equivalent in cooling effect to one square foot of glass, the calculation is 352 + 28 = 380 square feet of glass and its equivalent. This multiplied by 75, a constant = 28,500 + 26,373 = 54,873. Multiplying this in turn by .0072 constant for water temperature of 180° = 394 square feet of heating surface in coils.

The west office contains 27,003 cubic feet of space exclusive of stairways, 680 square feet of exposed wall, and 352 square feet of glass. Taking the wall at the same ratio to glass as in the east office the figures are 352 + 34 = 386 square feet of glass and its equivalent. This multiplied by 75 = 28,950 + 27,003 = 55,953. This in turn multiplied by .0072 = 403 square feet. To this 15 per cent. more surface was added on account of the space being divided into several small compartments and therefore more difficult to heat, making the surface required in coils 463 square feet.

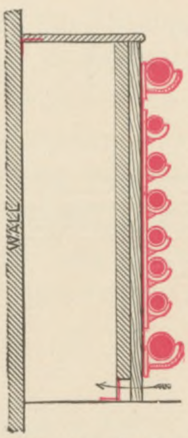


Fig. 74.—Section Through Ventilating Duct.

The surface actually installed is as follows: East office, 274 square feet in coils and radiator, and 135 square feet in 2-inch flow and return pipes, making a total of 409 square feet, which is equal to a proportion of 1 square foot of surface to 64 cubic feet of space. In the west office there are 290 square feet in coils and 177 square feet in 2- and 3-inch flow and return pipes, making a total of 467 square feet, which is equal to a proportion of 1 square foot of surface to 58 cubic feet of space. The east and west offices together contain a total of 53,376 cubic feet of space, and have 876 square feet of direct heating surface in coils, radiators, and pipes, which is equal to a proportion of 1 square foot of heating surface in coils, etc., to 60 cubic feet of space.

The entire system contains 350 gallons of water. The expansion tank has a total capacity of 31 gallons, and below overflow a capacity of 24 gallons. This rather large capacity was provided on account of the shape of the tank.

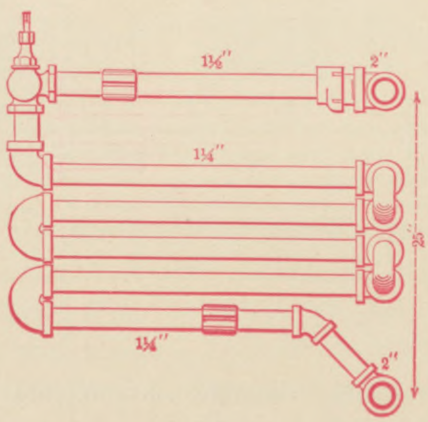


Fig. 75.—Detail of Coils Nos. 9 and 10.

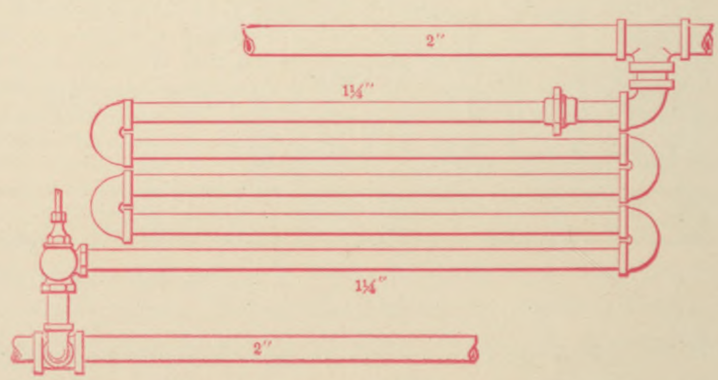


Fig. 76.—Detail of Coil No. 12.

To more fully describe this system, which is uncommon in hot-water heating practice, the specification of the work, and in accordance with which the apparatus was installed, is appended. It is of use here also as a specimen of short specifications, which are at the same time inclusive and descriptive,—something much needed in hot-water heating work.

SPECIFICATION

of certain pipes, valves, and fittings, etc., to be erected on third floor at 96, 98, 100, and 102 Reade street, New York.

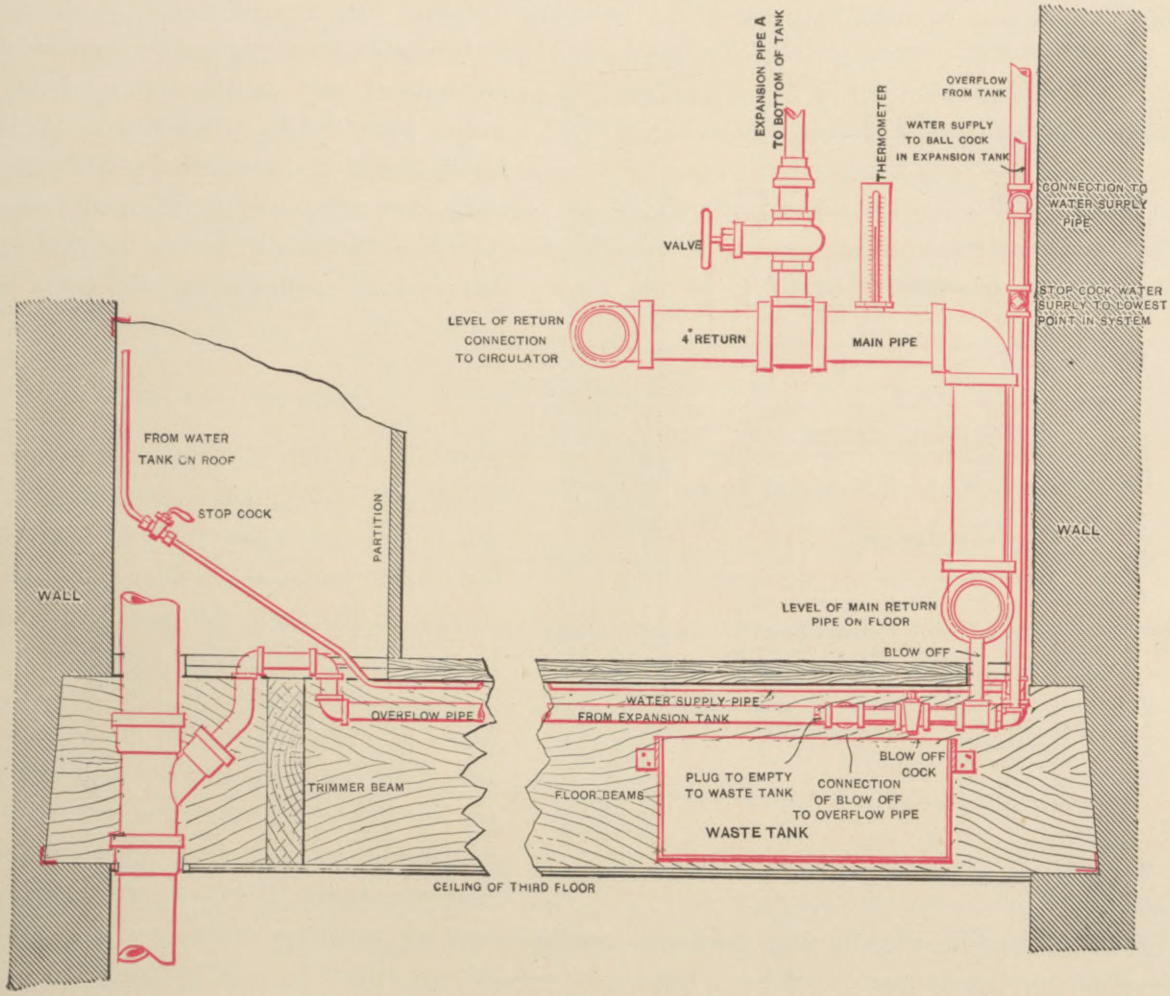


Fig. 77.—Details at A of Blow-off Waste Tank, etc.

The pipes are to be arranged as shown on plan, Fig. 71. From top of heater a 6-inch vertical flow pipe is to be connected to elbow (6 inch). In this pipe there is to be a flange union and a hole tapped ($\frac{3}{4}$-inch pipe) for thermometer at T. The pipe will be about 4 feet from heater to elbow. From elbow 6-inch pipe leads to 6-inch tee as shown on plan; the top of this tee is to be tapped ($1\frac{1}{2}$-inch pipe), F, Fig. 71, for air-vent. For 3 feet on north side of tee the 6-inch pipe is to be continued (see plan) to flange union, one flange for 6-inch pipe and the other tapped eccentrically for 3-inch pipe, so that the top of 3-inch pipe will be level with top of 6-inch pipe, and on south side to tee H, Fig. 71. These 6 and 3-inch pipes are to be level from end to end, and about 30 inches from ceiling. At each end, B and C, Figs. 71 and 72, there are to be vertical 3-inch pipes about 7 feet long, at the lower end of which pipes there are to be 3-inch tees, 2-inch on the run, to be reduced by nipples and reducing couplings 3-inch to 2-inch at C, south end, a 3-inch to 2-inch reducing elbow may be used in place of one reducing coupling. On the north side, B, the center of this tee is to be 24¾ inches from the floor (new floor), and on the south side, C, 26 inches from the floor (new floor). At these levels 2-inch mains continue, without any inclination whatever, to the east as far as coils Nos. 14 and 15, and to the west as far as reducing coupling to coil No. 6 and point marked D.

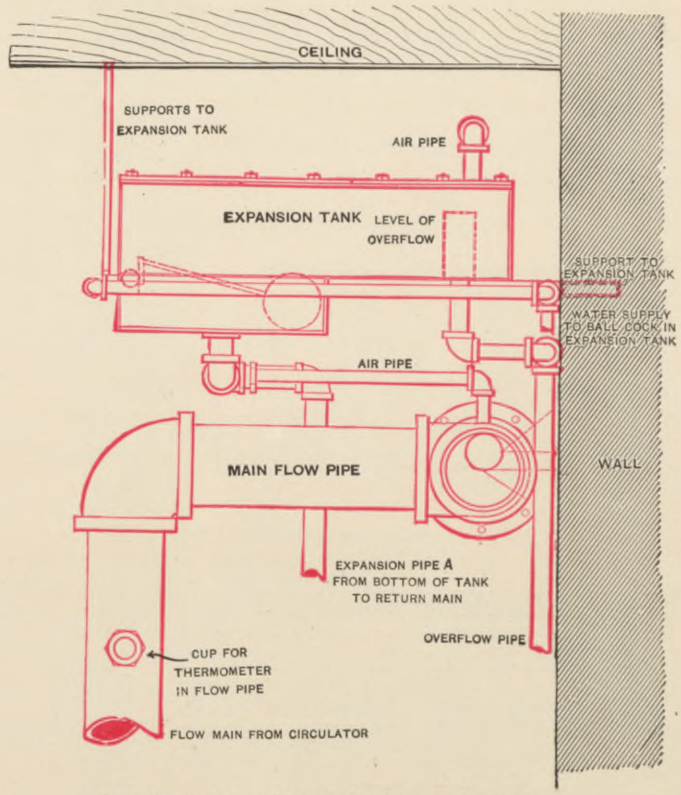


Fig. 78.—Details at F of Air Pipe, Expansion Tank, etc.

MAIN RETURN PIPES.

From coils Nos. 15 and 16 on the south side the 2-inch return pipes begin and incline at C where the 3 x 2 x 2-inch tee is 3-inch to center above floor and from coil No. 14 on the north side and point marked D, the 2-inch return pipes begin and incline to B, where the center of the 2 x 2 x 3-inch tee is 2¾ inches above the floor. From B and C the main returns are of 3-inch pipe and incline to A, where the center of the 3-inch pipe is 2 inches above the floor. Between A and B is a flange union. At A (see Fig. 77) a 4-inch tee receives the 3-inch return mains and a vertical 4-inch pipe goes upward to level of opening in the circulator. The under side of this 4-inch tee is tapped (¾-inch pipe) for blow-off or emptying pipe and water supply ¾-inch connection. In the 4-inch between elbow and heater is 4-inch tee with 1¼-inch outlet for expansion pipe; there is also a flange union, and the top of pipe is tapped (¾-inch pipe) for thermometer marked T on plan.

BRANCH FLOW PIPES.

The branch flow pipes to coils Nos. 4 and 5, Fig. 73, are 2-inch pipe perfectly level with 2-inch main with 2-inch elbows, nipples, and eccentric reducing couplings. The 1¼-inch flow pipes to coils

Nos. 6 and 7, also to Nos. 9 and 10 (Fig. 75), and Nos. 14, 15, and 18, are level and connect to main by 2-inch nipple and eccentric reducing couplings. These couplings are used so that the top of all flow pipes are level. The coils Nos. 1, 2, 3, 8, and 11, and also No. 12 (Fig. 76), and Nos. 13, 16, and 17, are connected to 2-inch mains by 2-inch tees, facing down, with 2-inch nipple and 2-inch to 1¼-inch reducing elbows, and coil No. 19 by 1¼-inch pipe.

BRANCH RETURN PIPES.

The lowest pipes of coils Nos. 14 and 15 are connected to 2-inch main return pipe by 2 to 1¼-inch eccentric couplings, so that the under side of 1¼-inch and 2-inch pipes will be level. The lowest pipes of coils 4 and 5 are connected to 2-inch branch return pipes by 2-inch to 1¼-inch reducing elbows. The lowest pipes of coils Nos. 9, 10, and 18 are connected to 2-inch main returns to tees 2 x 2 x 1¼-inch, and coils Nos. 1, 2, 3, 8, 11, 12, 13, 16, and 17 are connected to 2-inch main return by tees 2 x 2 x 1¼-inch, with outlet facing horizontally. The position of these tees will be about 6 inches beyond return bends so as to allow for valve. Coil No. 19 is connected by 1¼-inch pipe to 2 x 1¼ x 1¼-inch tee.

RADIATORS AND COILS.

There are to be nineteen return bend coils, as shown on plan, and of the sizes given, of 1¼-inch pipe, and also one radiator 45 inches high with 45 square feet of surface of the "Perfection" pattern.

VALVES.

Six coils Nos. 4, 5, 6, 14, 15, and 18, the radiator and circulating pipes are to have gate valves of the Rensselaer pattern and the other coils are to have ordinary angle valves, with hard seats. Valves are to be nickel-plated and fitted with keys; in all, fourteen (14) angle valves and eleven (11) gate valves.

CIRCULATING PIPES.

At the points marked E E E (see Fig. 71) there are to be ¾-inch pipes between the flow and return pipes. On these pipes are to be the ¾-inch gate valves above mentioned. The flow pipes are to be connected to these pipes E by 2 x 2 x 1¼-inch crosses, and 1¼ to ¾-inch bushings, and 2 x ¾-inch tees on the return connection. At D and D′ the circulating pipes for heating ventilator shafts are to be placed as shown on plan.

CONNECTIONS, BRACKETS, AND HOOK PLATES.

At flow and return end of each coil are to be means of disconnection, either right and left couplings and nipples, or other approved methods. On the circulating pipes right and left couplings are to be used.

The 3-inch main flow pipe is to be supported on brackets of approved pattern from wall. Single 2-inch hook plates are to be used on the 2-inch flow and return mains and branches where necessary. Hook plates 4, 5, 6, and 8 pipes high are to be used on the coils, and the coil pipes are to be level and kept on the same vertical center line as the 2-inch pipe by the use, if necessary, of a neat wood filling piece to be supplied by contractor. All hook plates are to be screwed to the wood casing and partitions which will be provided for the purpose.

FINISHING PLATES.

Where the flow and return pipes pass through the office partitions, wall plates or casings at each side are to be provided; these are to be for 2-inch and 1¼-inch pipes.

HOLES IN WALLS.

At B two holes for 2-inch flow and return pipes are to be cut and the same number at C and H through 16-inch walls. At B near ceiling a hole through main wall for air pipe is to be cut, and near C in 8-inch wall in elevator shaft two holes for 2-inch pipes are to be cut. These holes when the pipes are in are to be neatly fitted up and finished at each side round the pipes.

BLOW-OFF.

Connection between main 4-inch return tee and waste pipe is to be made with ¾-inch pipe and ¾-inch gate valve. The waste pipe will have a 1-inch tee on it to receive blow-off and it will be below the 4-inch main tee. (See Fig. 77.)

OVERFLOW.

The overflow of 1-inch pipe is also to be connected to tee on waste pipe and to 1-inch outlet on reducing elbow (2-inch to 1-inch) on bottom of expansion tank. (See Fig. 78.)

EXPANSION TANK.

The location of this tank is shown on plan by dotted lines, directly above heater. It is to be placed as near ceiling as possible. The main 6-inch x 3-inch flow pipes are to be at least 6 inches below it. It is to be fitted with a ball and cock which is to be connected to the water-supply pipe (¾-inch) which is near the circulator. The tank is to have a 1-inch pipe overflow connected to waste as above described. The expansion pipe is to be connected to bottom of tank of 1¼ pipe to tee on 4-inch main return pipe. To this expansion pipe the ½-inch air pipe from 6-inch tee on main flow is to be connected to the outlet of a horizontal 1¼ x 1¼ x ½-inch tee, the position of this tee to be such as to cause the ½-inch pipe to incline down from it to the ½-inch elbow on nipple in 6-inch tee. From this tee (1¼ x 1¼ x ½-inch) is to be a 1¼-inch elbow with 1¼-inch pipe to elbow (1¼) on bottom of tank. This (1¼-inch) pipe is to incline up to elbow on bottom of tank. (See Fig. 78.)

The tank is to be of plate-iron or cast-iron, and bottom and top are to be properly stayed. The top is to have opening with cover of sufficient size to get at ball cock for repairs, etc. The joint of this cover to be tight. The joint of 1-inch air pipe to top of tank is also to be tight. The dimensions of the tank inside are 32 inches long by 30 inches wide. A height of 5 inches is necessary for expansion of water. To edge of vertical overflow pipe (2 inches) the height will be 6 inches and to under side of top of tank 7½ inches, making the tank measure 32 inches long, 30 inches wide, and 7½ inches deep with a pocket or drop from bottom of tank 4½ inches by 16 inches long by 8 inches wide for ball of supply cock, making the greatest depth of tank 12 inches. To the bottom of this drop or pocket the expansion pipe is to be connected and at the lower part of the pocket near the bottom and near the top of tank a water gauge with glass is to be fitted. In addition to the supply through ball cock in tank, there is to be a ¾-inch supply with gate valve already specified, through emptying pipe to 4-inch tee on return main pipe. (See Fig. 77.) Under this contract the expansion tank furnished with the pipes and fittings as described, is to be provided and placed in position with all requisite supports from wall to partition.

PROTECTION FROM FIRE.

Wood-work near pipes is to be protected in accordance with the rules and regulations which apply to steam pipes of the Fire Department and Board of Fire Underwriters of New York.

MATERIALS AND WORKMANSHIP.

All the materials described and referred to in this specification and the accompanying plan and details are to be supplied, placed in position, and left in complete working order. The entire apparatus is to be tested by the contractor, who is to make all joints tight. The workmanship is to be of the best kind, and all levels are to be accurately adhered to and carried out.

Supply and Emission of Heat.*

By John J. Hogan.

IN order to ascertain the number of square feet of surface in radiators or pipes required to heat a definite space or an apartment, some of the enclosing walls of which are exposed to the exterior atmosphere and have windows, it is necessary to know the cooling effect of such exposed surfaces. The quantity of heat required to warm incoming air, and the loss of heat through such surfaces, may be closely approximated through the assistance of tables and formulas here given. The quantity of air to be warmed can be definitely ascertained, and knowing its temperature, the quantity of heat needed to warm it the requisite number of degrees, is readily determined.

The heat given off by each square foot of surface at certain temperatures under given conditions has been approximately determined by experiment. When these data are known it is not a difficult matter to ascertain the quantity of surface in radiators required for direct radiation. In deciding the surfaces required for indirect radiation, attention is necessary to other points, in addition to the loss of heat through glass and walls, the air to be warmed, and the heat given off by each square foot of surface.

An examination of Table XII shows that the temperature which the incoming air has to acquire to provide for the loss of heat through glass, etc., is greater than is possible in hot-water circulation, if the quantity of incoming air is less than half the quantity of air cooled. Under such circumstances more air must be admitted at the lower temperature. To admit more air proper provision is necessary in the ventilating flues to allow the air to ascend freely from the radiators. This is especially desirable in well constructed and tightly finished buildings where there are no openings left near windows or doors through which the heated air may escape. Any one of the following tables or forms may be used to ascertain the quantity of surface required in direct or indirect radiation. It will be observed that forms 1, 2, and 3 give more definite results than forms 4 and 5, which are mere approximations.

From Table XII it is apparent that a square foot of indirect radiating surface does relatively less heating than a square foot of direct radiating surface when the incoming air is less than the quantity of the air cooled by glass and exposed wall. When the quantity of air passing over the surfaces of the indirect radiator is greatly in excess of the air cooled by the exposed walls and glass, the average temperature within the casing of an indirect radiator is low, and each square foot of surface does more effective heating than the same surface in a direct radiator. It is therefore evident, in designing an indirect heating apparatus, that particular care should be taken to provide a circulation of air through the indirect radiators.

TABLE XII.—TEMPERATURES OF AIR IN CASINGS OF INDIRECT RADIATORS WHEN TEMPERATURE OF AIR IN ROOM IS 70° FAHR. AND TEMPERATURE OF EXTERNAL ATMOSPHERE IS ZERO.*

Proportion of incoming air to quantity of air cooled by glass and its equivalent.	Temperature of air in casing at bottom of radiators.	Temperature of incoming air in casing at top of radiators required to offset cooling effect of walls and windows.	Internal temperature of air in room.	Total temperature of air in casing at top of radiator required to offset cooling effect of walls and windows.	Average temperature of air in casing.
	DEGREES FAHR.				
.25	0	280°	+ 70°	= 350°	175°
.5	0	140°	+ 70°	= 210°	105°
.75	0	93.3°	+ 70°	= 163.6°	81.8°
1.	0	70°	+ 70°	= 140°	70°
2.	0	35°	+ 70°	= 105°	52.5°
3.	0	23.3°	+ 70°	= 93.3°	46.6°
4.	0	17.5°	+ 70°	= 87.5°	43.75°
5.	0	14°	+ 70°	= 84°	42°
6.	0	11.6°	+ 70°	= 81.6°	40.8°
7.	0	10°	+ 70°	= 80°	40°
8.	0	8.75°	+ 70°	= 78.75°	39.37°
9.	0	7.75°	+ 70°	= 77.75°	38.87°
10.	0	7°	+ 70°	= 77°	38.5°

For the purposes of this treatise, rules and directions for proportioning surfaces in radiators under various specified conditions may be arranged in five forms or propositions: (1) General Formulæ; (2) Proportioning Surfaces in Radiators to Glass, Exposed Wall, and Cubic Contents of Apartments; (3) Surfaces required to Warm Incoming Air; (4) Proportioning Surfaces in Radiators to Cubic Contents of Apartments, and (5) Proportioning Surfaces in Radiators to Lineal Feet of Exposed Wall.

FORM I.—FORMULÆ FOR PROPORTIONING RADIATING SURFACES.*

	DEFINITIONS.	Reference letter or constant.
1.	Square feet of glass and its equivalent in exposed wall	= G.
2.	Number of degrees of difference between outside and inside temperatures	= D.
3.	Cubic feet of air cooled per square foot of glass (1.279 per minute Hood) per hour for each degree of difference in temperature between the inside and outside atmosphere 1.279 × 60 minutes	= 76.74
4.	Thermal capacity of one cubic foot of air at 0 = weight of one cubic foot of air at 0 or .0864 × specific heat of air or .238	= .02056
5.	Loss of heat through glass and its equivalent in exposed wall in units of heat per hour	= H. U. G.
6.	Cubic feet of air to be warmed per hour	= C.
7.	Units of heat required to warm air per hour	= H. U. A.
	G. × D. × 76.74 × .02056 = H. U. G.	
	D. × .02056 × C. = H. U. A.	
8.	Degrees of heat to be added to air in rooms in indirect heating to overcome cooling effect of glass and exposed wall	= A. D.
	$\frac{\text{H. U. G.}}{.02056 \times \text{C.}} = \text{A. D.}$	
9.	Inside temperature of room or apartment in degrees Fahr.	= I. T.
10.	Total heat of incoming air in degrees Fahr.	= T. H.
	A. D. + I. T. = T. H.	
11.	Outside temperature	= O. T.
12.	Average temperature of air in degrees Fahr. within the casing of indirect radiators	= A. T.
	If above zero $\frac{\text{T. H.} + \text{O. T.}}{2} = \text{A. T.}$ If below zero $\frac{\text{T. H.} - \text{O. T.}}{2} = \text{A. T.}$	
13.	Temperature of surface of radiators in degrees Fahr.	= R.
14.	Heat units emitted per square foot of surface of radiator for each degree of difference between the temperature of the surface of radiator and the internal temperature of room or apartment (I. T.) for direct radiation or the average temperature of air within the casing (A. T.) for indirect radiation	= H. U. D.
15.	Heat units emitted per square foot of surface of radiators per hour	= H. U. S.
	R. − I. T. × H. U. D. = H. U. S. for direct radiation.	
	R. − A. T. × H. U. D. = H. U. S. for indirect radiation.	
16.	$\frac{\text{H. U. G.} + \text{H. U. A.}}{\text{H. U. S.}}$ = SQUARE FEET OF SURFACE REQUIRED IN RADIATOR.	
17.	For direct radiation H. U. D.	= 1.6 to 1.8.
18.	For indirect radiation when the quantity of air to be warmed does not exceed three times the quantity of air to be cooled by glass and exposed wall, H. U. D.	= 1.3 to 1.5.
19.	For indirect radiation when the quantity of air to be warmed exceeds three times the quantity of air cooled by glass and exposed wall, H. U. D.	= 1.6 to 2.5.
20.	When the air is forced through radiators mechanically by means of fans, blowers, etc., H. U. D.	= 3 to 7.

FORM 2.—PROPORTIONING SURFACES IN RADIATORS TO GLASS, EXPOSED WALL, AND CUBIC CONTENTS OF APARTMENTS.*

Multiply the square feet of glass and its equivalent by 1.25 and the resulting product by 60. This gives the cubic feet of air cooled per hour by the glass. To this add the cubic feet of air to be warmed per hour, which may be the cubic contents of the room, multiplied by 1, 2, 3, or 4, depending on the number of times it is proposed to change the air, and the result will be the total cubic feet of air to be warmed per hour.

Multiply the total cubic feet of air to be warmed per hour by the units of heat required to raise 1 cubic foot of air to the required temperature, as given in Table XVI, and divide this product by the number of units of heat per square foot per hour emitted from radiators according to Table XIII. The result is the square feet of surface required in radiator.

TABLE XIII.—UNITS OF HEAT PER SQUARE FOOT OF SURFACE PER HOUR EMITTED IN DIRECT AND INDIRECT RADIATORS (APPROXIMATE).†

	A.	B.	C.
Average temperature of water in radiators in degrees Fahr.	Units of heat emitted approximately per square foot per hour by direct radiators, the temperature of room being 70°.	Units of heat emitted approximately per square foot per hour by indirect radiators to maintain incoming fresh air in room at 70°, when the quantity of air to be warmed does not exceed three times the quantity of air to be cooled by glass and exposed wall.	Units of heat emitted approximately per square foot per hour by indirect radiators to maintain incoming fresh air in room at 70°, when the quantity of air exceeds three times the quantity of air to be cooled by glass and exposed wall.
140°	115°	92	174
150°	135°	109	198
160°	155°	126	222
170°	177°	143	247
180°	199°	161	274
190°	222°	179	301
200°	246°	198	330
210°	270°	217	418

FORM 3.—SURFACES REQUIRED TO WARM INCOMING AIR.

The foregoing rule may be simplified as follows: The square feet of glass and its equivalent multiplied by 75, (1.25 × 60) equals the number of cubic feet of air cooled by the glass and its equivalent in exposed wall per hour. To this product add the cubic feet of air to be warmed per hour and the sum is the total work to be done expressed in the number of cubic feet of air to be warmed per hour. The total number of cubic feet of air to be warmed per hour when multiplied by the multiplier in Table XIV opposite any desired temperature of water in the radiators, and in the column for direct or indirect radiation, gives as the product the required number of square feet of surfaces in radiators, when the external temperature is 0 Fahr. and the temperature of the apartment warmed 70° Fah.

TABLE XIV.—MULTIPLIERS FOR ASCERTAINING SQUARE FEET OF SURFACE REQUIRED IN RADIATORS.*

Average temperature of water in radiators in degrees Fahr.	External temperature 0 Fahr. Temperature in apartment 70° Fahr.		
	Direct Radiation.	Indirect Radiation. When the quantity of air to be warmed does not exceed three times the quantity of air to be cooled by glass and exposed walls, the	Indirect Radiation. When the quantity of air to be warmed exceeds three times the quantity of air to be cooled by glass and exposed wall, the
	Square feet of surface in radiators = total number of cubic feet of air to be warmed, multiplied by,		
	Multiplier **A.**	Multiplier **B.**	Multiplier **C.**
140°	.0123	.0155	.0082
150°	.0106	.013	.0072
160°	.0092	.0114	.0064
170°	.0081	.01	.0058
180°	.0072	.009	.0052
190°	.0064	.008	.0047
200°	.0068	.0072	.0043
210°	.0053	.0066	.0034

For other temperatures, see Table XXI.

FORM 4.—PROPORTIONING SURFACE IN RADIATORS TO CUBIC CONTENTS OF APARTMENTS.

External temperature 0 Fahr.
Internal temperature 70° Fahr.
Temperature of water in radiators 160° Fahr.

Description of Apartments Warmed.	Direct Radiation.	Indirect Radiation.
	One square foot of surface in radiators, heats.	
Dwelling apartments on first floor	25 to 35 cubic feet.	15 to 25 cubic feet.
Dwelling apartments on second and upper floors	30 to 45 " "	20 to 30 " "
Dwelling bath rooms	15 to 25 " "	10 to 20 " "
Dwelling halls	20 to 30 " "	15 to 25 " "
School rooms, offices, etc.	30 to 60 " "	25 to 40 " "
Factories, stores, etc.	45 to 70 " "	25 to 40 " "
Auditoriums, churches, etc.	80 to 100 " "	50 to 80 " "

RELATIVE COOLING EFFECT OF GLASS AND WALLS APPROXIMATELY STATED FOR PRACTICAL PURPOSES.

One square foot of glass will cool 75 cubic feet of air one degree per hour for each degree of difference of temperature between the external and internal atmospheres.

The cooling effect of 10 square feet of exposed wall, 8 to 12 inches in thickness, is equal to one square foot of glass.

The cooling effect of 15 square feet of exposed wall, 14 to 26 inches in thickness, is equal to one square foot of glass.

The cooling effect of 20 square feet of exposed wall, 28 to 38 inches in thickness, is equal to one square foot of glass.

LOSS IN UNITS OF HEAT PER SQUARE FOOT OF GLASS PER HOUR FOR A DIFFERENCE OF 1° BETWEEN THE EXTERNAL AND INTERNAL AIR.*

Window glass, single	1.57
Window glass, double	.83
Glass of large surface as in conservatories, greenhouses, etc	1.05

FORM 5.—PROPORTIONING SURFACES IN RADIATORS TO LINEAL FEET OF EXPOSED WALL IN APARTMENTS.*

EXTERNAL TEMPERATURE 0 FAHR. INTERNAL TEMPERATURE 70° FAHR.

RULE FOR DIRECT RADIATION.

Multiply the number of lineal feet of exposed wall by 7 for apartments having a height of 10 feet or under, and to the product for every addition to the height of 2 feet or fraction thereof, add one (or fraction of one) and divide the sum by 3. The result will be the number of square feet of surface in radiator.

a. For apartments with one wall exposed, or in which the exposed walls do not exceed two-fifths of all the surrounding walls, add one-fifth of the length of the exposed wall to the lineal feet and proceed as above stated.

b. For entrance halls of rectangular form, multiply the width of the exposed wall or end by the height of the hall and by .9 and the result will be the number of square feet required in radiator.

RULE FOR INDIRECT RADIATION.

Multiply the number of lineal feet of exposed wall by 11 for apartments having a height of 10 feet or under, and to the product for every addition to the height of 2 feet or a fraction thereof add 1, (or a fraction of 1) and divide the sum by 3. The result will be the square feet of surface for indirect radiation.

a. For apartments with one wall exposed, or in which the exposed walls are less than two-fifths of all the surrounding walls, add one-fifth of the length of the exposed wall to the lineal feet, and proceed as above stated.

b. For entrance halls of rectangular form, multiply the width of the exposed end by the height of the hall and by 1.4, and the result is the number of square feet of indirect radiating surface.

TABLE XV.—MULTIPLIERS FOR ASCERTAINING THE SURFACES IN RADIATORS PER LINEAL FOOT OF EXPOSED WALL.†

External temperature 0 Fahr.
Internal temperature 70° Fahr.

HEIGHT OF ROOMS.	10 FT.		12 FT.		14 FT.		16 FT.		18 FT.		20 FT.	
	Direct.	Indirect.	Direct.	Indirect.	Direct.	Indirect.	Direct.	Indirect.	Direct.	Indirect.	Direct.	Indirect.
Dwellings, stores, offices, banks, etc	7	11	8	12	9	14	10	15	11	17	12	18
Schoolhouses, large halls, churches, etc	11	17	12	18	13	20	14	21	15	23	16	24

For intermediate heights allow proportionately. For other differences of temperature, see Table XXI.

TABLE XVI.—UNITS OF HEAT REQUIRED PER HOUR TO HEAT ONE CUBIC FOOT OF AIR AT DIFFERENT TEMPERATURES.

Temperature of external air.	Temperature of air in room.				
	50°	60°	70°	80°	90°
	Units of heat required per hour.				
0 degrees	1.028	1.234	1.439	1.645	1.851
10 "	.805	1.007	1.208	1.409	1.611
20 "	.59	.787	.984	1.181	1.378
30 "	.385	.578	.77	.963	1.155
40 "	.188	.376	.564	.752	.94

TABLE XVII.—LOSS IN UNITS OF HEAT PER SQUARE FOOT PER HOUR THROUGH EXPOSED WALL FOR A DIFFERENCE OF 1° BETWEEN THE EXTERNAL AND INTERNAL AIR WHEN ALL SIDES OF ROOM ARE EXPOSED.

Thickness of wall in inches.	Brick.	Thickness of wall in inches.	Stone.
4½	.231	6	.261
9	.191	12	.234
14	.159	18	.212
18	.14	24	.194
27	.111	30	.179
36	.092	36	.166

TABLE XVIII.—LOSS IN UNITS OF HEAT PER SQUARE FOOT PER HOUR THROUGH EXPOSED WALL FOR A DIFFERENCE OF 1° BETWEEN THE EXTERNAL AND INTERNAL AIR WHEN ONLY ONE WALL OF THE ROOM IS EXPOSED.

Thickness of wall in inches.	Brick.	Thickness of wall in inches.	Stone.
4½	.371	6	.453
9	.275	12	.379
14	.213	18	.324
18	.182	24	.284
27	.136	30	.257
36	.108	36	.228

TABLE XIX.—SURFACES REQUIRED IN HEATING PIPES OR RADIATORS TO MAINTAIN VARIOUS TEMPERATURES IN CONSERVATORIES, THE EXTERNAL TEMPERATURE BEING 0 FAHR.*

Temperature of house in degrees Fahr.	Units of heat lost per square foot of glass per hour.	Units of heat required to heat one cubic foot of air per hour from 0 Fahr.	Temperature of water in heating pipes. 140°		160°		180°		200°	
			Ratio of heat units emitted per square foot of heating surface in pipes, approximated.	Square feet of surface in heating pipes or radiators required per 100 square feet of glass.	Ratio of heat units emitted per square foot of heating surface in pipes, approximated.	Square feet of surface in heating pipes or radiators required per 100 square feet of glass.	Ratio of heat units emitted per square foot of heating surface in pipes, approximated.	Square feet of surface in heating pipes or radiators required per 100 square feet of glass.	Ratio of heat units emitted per square foot of heating surface in pipes, approximated	Square feet of surface in heating pipes or radiators required per 100 square feet of glass.
A.	B.	C.	D.	E.	D.	E.	D.	E.	D.	E.
40	44	.822	207	23	251	19	318	15	367	13
45	47.25	.925	195	27.5	249	21.5	298	18	358	15
50	52.5	1.028	183	32.5	234	25.5	284	21	341	17.5
55	57.75	1.130	172	38	222	29.5	273	24	328	20
60	63	1.234	157	45.5	207	34.5	251	27.5	318	23
65	68.85	1.336	145	53.5	195	39.5	249	31	298	26
70	73.5	1.439	132	63	183	45.5	234	35.5	284	29
75	78.75	1.542	123	72.5	172	52	222	40	273	32.5
80	84	1.645	111	86	157	61	207	46	251	36.5
85	89.25	1.747	99	102	145	70	195	52	249	40.5

B = A × 1.05 average loss in units of heat per square foot of glass per hour for the difference of 1° Fahr.

C = 0.238 specific heat of air × .0864 weight of 1 cubic foot of air at 0 in pounds × A, number of degrees difference between internal and external temperatures.

D = approximated ratio of emission of heat in units from heating surfaces of pipes or radiators by contact of air per square foot per hour at various differences of temperatures.

$$E = \frac{B + (C \times 7)}{D} \times 100.$$

7 = proportion of space in cubic feet to 1 square foot of glass. When this proportion is increased to 8, add 4 per cent. to the surface in pipes, and when increased to 9 add 8 per cent. to the surface in pipes.

When 4-inch pipe is used, add 7.5 per cent. to the actual surface obtained in the foregoing tables.

TABLE XX.—GLASS SURFACE AND ITS EQUIVALENT, IN PROPORTION TO HEATING SURFACES IN PIPES, REQUIRED TO MAINTAIN VARIOUS TEMPERATURES IN CONSERVATORIES, EXTERNAL TEMPERATURE BEING 0 FAHR.*

Temperature of air in house.	Temperature of water in heating pipes.			
	140°	160°	180°	200°
	Square feet of glass and its equivalent proportioned to one square foot of surface in heating pipes or radiators.			
40°	4.33	5.25	6.66	7.69
45°	3.63	4.65	5.55	6.66
50°	3.07	3.92	4.76	5.71
55°	2.63	3.39	4.16	5.
60°	2.19	2.89	3.63	4.33
65°	1.86	2.53	3.22	3.84
70°	1.58	2.19	2.81	3.44
75°	1.37	1.92	2.5	3.07
80°	1.16	1.63	2.17	2.73
85°	.99	1.42	1.92	2.46

For other temperatures, see Table XXI.

TABLE XXI.—RELATIVE PROPORTIONS OF SURFACES FOR DIFFERENT TEMPERATURES.†

Temperature of external atmosphere.	Temperature of air in rooms. Degrees Fahr.				
	60°	65°	70°	75°	80°
30° Fahr. (above)	.39	.48	.57	.67	.78
25° " "	.46	.54	.64	.74	.86
20° " "	.52	.61	.71	.82	.94
15° " "	.59	.68	.78	.89	1.02
10° " "	.65	.75	.85	.97	1.09
5° " "	.72	.82	.92	1.04	1.17
0 " "	.78	.88	1.	1.12	1.25
5° Fahr. (below)	.85	.95	1.06	1.19	1.33
10° " "	.91	1.02	1.13	1.26	1.41
15° " "	.97	1.09	1.21	1.34	1.48
20° " "	1.04	1.15	1.28	1.41	1.56
25° " "	1.11	1.22	1.35	1.49	1.64
30° " "	1.17	1.29	1.42	1.56	1.71
35° " "	1.24	1.36	1.49	1.64	1.79
40° " "	1.30	1.43	1.56	1.71	1.88
45° " "	1.37	1.5	1.63	1.79	1.95
50° " "	1.43	1.56	1.7	1.85	2.03

NOTE TO TABLE XXI.

When the quantity of surface required for zero external and 70° internal temperature is ascertained by any of the preceding rules, the surface necessary for other external temperatures varying from 30° above to 50° below zero and internal temperatures varying from 60° to 80° above can be ascertained by decreasing or increasing the surface in the proportion given in Table XXI, zero externally and 70° internally being unity.

TABLE XXII.—WEIGHT OF DRY AIR.

Fahr.	Weight per cubic foot, pounds.	Fahr.	Weight per cubic foot, pounds.	Fahr.	Weight per cubic foot, pounds.	Fahr.	Weight per cubic foot, pounds.	Fahr.	Weight per cubic foot, pounds.
0°	.0864	24°	.0821	48°	.0782	72°	.0746	142°	.0659
1°	.0861	25°	.0819	49°	.078	73°	.0745	152°	.0649
2°	.086	26°	.0817	50°	.078	74°	.0743	162°	.0638
3°	.0858	27°	.0816	51°	.0776	75°	.0742	172°	.0628
4°	.0855	28°	.0814	52°	.0774	76°	.0741	182°	.0618
5°	.0853	29°	.0813	53°	.0773	77°	.0739	192°	.0609
6°	.0852	30°	.0812	54°	.0772	78°	.0738	202°	.06
7°	.085	31°	.0809	55°	.0771	79°	.0736	212°	.0595
8°	.0848	32°	.0807	56°	.0769	80°	.0735	250°	.0559
9°	.0846	33°	.0805	57°	.0767	81°	.0734	300°	.0522
10°	.0845	34°	.0804	58°	.0766	82°	.0733	350°	.049
11°	.0843	35°	.0802	59°	.0765	83°	.0731	400°	.0461
12°	.0842	36°	.0801	60°	.0763	84°	.073	450°	.0436
13°	.084	37°	.0799	61°	.0762	85°	.0728	500°	.0413
14°	.0838	38°	.0797	62°	.0761	86°	.0727	600°	.0376
15°	.0837	39°	.0796	63°	.0758	87°	.0725	700°	.0338
16°	.0835	40°	.0794	64°	.0757	88°	.0724	800°	.0315
17°	.0833	41°	.0793	65°	.0756	89°	.0723	900°	.0292
18°	.0831	42°	.0791	66°	.0754	90°	.0721	1000°	.0268
19°	.083	43°	.0789	67°	.0752	92°	.072		
20°	.0828	44°	.0788	68°	.0751	102°	.0707		
21°	.0826	45°	.0786	69°	.075	112°	.0694		
22°	.0824	46°	.0784	70°	.0748	122°	.0684		
23°	.0822	47°	.0783	71°	.0747	132°	.0671		

TABLE XXIII.—VOLUME OF AIR AT VARIOUS TEMPERATURES.

Fahr.	Volume.	Fahr.	Volume.	Fahr.	Volume.	Fahr.	Volume.
0°	.933	55°	1.047	130°	1.204	240°	1.433
5°	.943	60°	1.058	140°	1.224	250°	1.453
10°	.954	65°	1.068	150°	1.245	275°	1.505
15°	.964	70°	1.079	160°	1.266	300°	1.558
20°	.975	75°	1.089	170°	1.287	350°	1.662
25°	.985	80°	1.099	180°	1.308	400°	1.765
30°	.996	85°	1.11	190°	1.329	450°	1.87
32°	1.	90°	1.121	200°	1.349	500°	1.974
35°	1.006	95°	1.131	210°	1.37	550°	2.078
40°	1.016	100°	1.141	212°	1.374	600°	2.183
45°	1.027	110°	1.162	220°	1.391	700°	2.391
50°	1.037	120°	1.183	230°	1.412	1000°	3.016

Flow and Return Pipes.

To proportion pipe areas to radiating surface the use of multipliers is convenient. When the surface to be supplied exceeds 2500 feet, multiply the number of square feet by .01 for indirect radiation, and by .008 for direct radiation, and the product gives the approximate area of pipe in square inches. The actual size of the pipe will be the pipe which has the area nearest to that found by the calculation.

TABLE XXIV.—SIZES OF FLOW AND RETURN PIPES APPROXIMATELY PROPORTIONED TO SURFACE IN RADIATORS.*

Size of pipe. Nominal diameter, inches.	Mains.		Branches and Risers.			
	Square feet of surface in indirect radiators in cellar or basement.	Square feet of surface in direct radiators on one or more floors. Average.	Square feet of surface in radiators on first floor, or 10 ft. to 15 ft. above level of fire in circulator.	Square feet of surface in radiators on second floor, or 15 ft. to 25 ft. above level of fire in circulator.	Square feet of surface in radiators on third floor, or 25 ft. to 35 ft. above level of fire in circulator.	Square feet of surface in radiators on fourth floor, or 35 ft. to 45 ft. above level of fire in circulator.
¾				40	45	50
1			50	75	80	85
1¼	100	135	110	120	135	150
1½	135	220	180	195	210	230
2	225	350	290	320	350	370
2½	320	460	400	490	525	550
3	500	675	620	650	690	730
3½	650	850	820	870	920	970
4	850	1100	1050	1120	1185	1250
4½	1050	1350	1325	1400	1485	1560
5	1350	1700				
6	2900	3600				
7	3900	4800				
8	5000	6200				
9	6300	7700				
10	7900	9800				
11	9500	11800				
12	11400	14000				

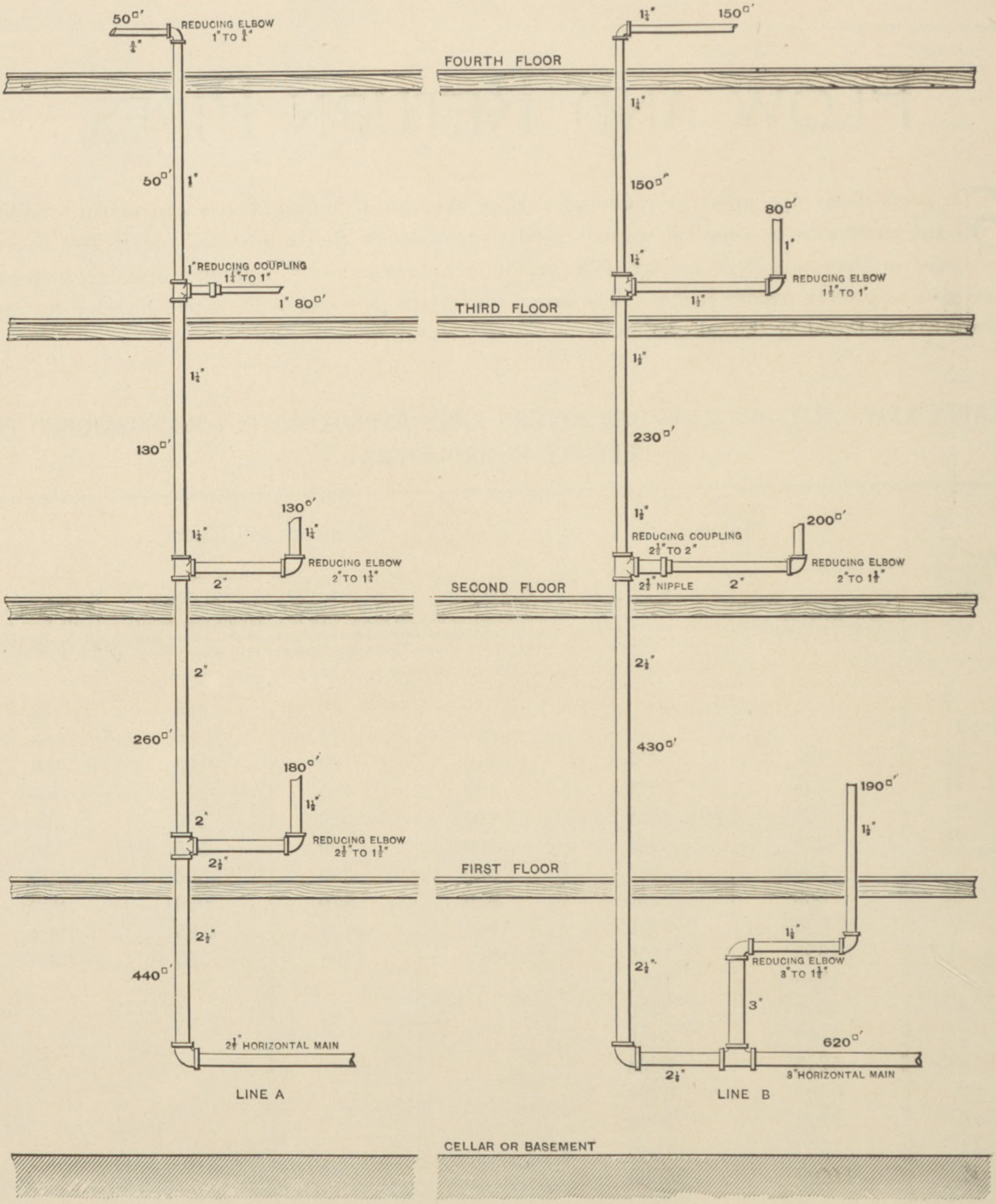


Fig. 79.—Diagram of Vertical Lines of Pipe Proportioned to Obtain Uniform Temperatures.

When the surface to be supplied does not exceed 2500 feet, multiply the number of square feet by .015 for indirect radiation, and by .011 for direct radiation, and the product gives the approximate area of pipe in square inches. The size of pipe to be used will be that having area nearest to the figures given by the calculation. These rules are applicable where 2-inch and larger pipes are used.

In Fig. 79 are diagrams of vertical lines of pipes proportioned to the surfaces in radiators from Table XXIV. The object of these proportions is to attain as uniform a temperature as possible in all radiators on all floors at the same time. The use of reducing fittings is illustrated in these diagrams. It is generally more desirable to supply the circulation to radiators on the first floor direct from the horizontal main pipe in cellar, as shown in "Line B," than from the lower part of the vertical line, as shown in "Line A." By maintaining the side opening at the same area as the "run" the velocity of the current is diminished at the moment a change in direction takes place, on account of the increased space within the fitting. To accomplish this, reducing couplings and reducings elbows are used.

EXPANSION TANKS.

To ascertain the actual and exact size of the expansion tank, the internal cubic capacity, or capacity in gallons, of all the pipes, radiators, coils, and boiler in the apparatus has to be determined. If the water in the system is raised to a temperature of 212° Fahr., its volume will be increased by $\frac{1}{23}$, or $4\frac{2}{3}$ per cent. of its bulk; and this is the least space that may be provided. In practice, the actual size of the expansion tanks is much larger, as when the system is filled there are generally several inches of water in the tank, so that its level is noticeable in the glass water-gauge. Above this level, space for the expansion of the heater water is provided, and it is desirable that some height be added, so that the overflow pipe and air pipe may be connected to the expansion tank in such manner that the greatest increase of volume in the water will not cause overflow into either of these pipes. The actual size of the expansion tank may therefore be from 6 per cent. to 8 per cent. of the internal capacity of the entire apparatus.

The calculation of the internal capacity of the pipes, radiators, coils, and circulator will be assisted by the use of the table (XLII), which gives the capacity of pipes. The length of the pipes is to be taken from center to center of fittings, and 5 per cent. added to provide for the larger internal diameter of elbows, tees, and couplings. The internal capacity of radiators varies. Some are equal to 1-inch pipe, others to $1\frac{1}{4}$ and $1\frac{1}{2}$-inch pipe per square foot of surface. To the capacity of these two items is to be added the capacity of the circulator. In order to dispense with the calculations just described, the use of the multipliers is suggested as a ready means of obtaining sizes of expansion tanks. (See Table XXV.)

TABLE XXV.—PROPORTIONING EXPANSION TANKS.*

A.—To ascertain required capacity of expansion tank in GALLONS.				B.—To ascertain required capacity of expansion tank in CUBIC INCHES.			
	For heating apparatus having less than 1000 square feet of surface in radiators.	For heating apparatus having from 1000 to 2000 square feet of surface in radiators.	For heating apparatus having over 2000 square feet of surface in radiators.		For heating apparatus having less than 1000 square feet of surface in radiators.	For heating apparatus having from 1000 to 2000 square feet of surface in radiators.	For heating apparatus having over 2000 square feet of surface in radiators.
Multiply the square feet of surface in radiators by	.03	.025	.02	Multiply the square feet of surface in radiators by	7.	5.75	4.5

TABLE XXVI.—SIZES OF EXPANSION TANKS PROPORTIONED TO SURFACES IN RADIATORS.†

Surface in radiators.	Capacity of tank (approximate).	Capacity of tank (approximate).
225 square feet.	7 gallons.	1575 cubic inches.
320 " "	10 "	2240 " "
475 " "	15 "	3500 " "
675 " "	20 "	4725 " "
850 " "	26 "	6050 " "
1100 " "	28 "	6325 " "
1350 " "	34 "	7763 " "
1900 " "	48 "	10925 " "
2600 " "	52 "	11700 " "
3800 " "	76 "	17100 " "
5000 " "	100 "	22500 " "
6500 " "	130 "	29250 " "
8000 " "	160 "	36000 " "
9500 " "	190 "	42750 " "
11500 " "	230 "	51750 " "

TABLE XXVII.—INCREASE IN VOLUME OF WATER AT VARIOUS TEMPERATURES.

Increase of temperature of water from	Percentage of increase in volume.	Proportion of increase in volume.
39° to 100°	.0068	1–148
39° " 110°	.0089	1–112
39° " 120°	.0114	1–88
39° " 140°	.0166	1–60
39° " 160°	.0231	1–43
39° " 180°	.0303	1–33
39° " 200°	.0382	1–26
39° " 212°	.044	1–23

AIR.

FOR each Fahrenheit degree of change in its temperature air expands or contracts $\frac{1}{480}$, or .002083 of its volume.

Taking 32° Fahr. as unity and multiplying the number of degrees below or above this temperature by .002083, the result is the contraction or expansion, as the case may be, of the volume of air. The volume of air at 32° Fahr. is 7 per cent. greater than at 0 Fahr., at 70° 15 per cent. greater than at 0 Fahr., and at 120° 26 per cent. greater than at 0 Fahr.

At 0° Fahr. 11.574 cubic feet of air weighs 1 pound.

At 32°	"	12.39	"	"	"	"
At 62°	"	13.14	"	"	"	"
At 70°	"	13.35	"	"	"	"
At 120°	"	14.66	"	"	"	"

At 0° Fahr. .02056 unit of heat will raise one cubic foot of air one degree in temperature.

From this we derive the following:

.02056 × 70° = 1.439 units required to heat one cubic foot of air from 0 to 70°.

.02056 × 65° = 1.336 units required to heat one cubic foot of air from 5 to 70°.

.02056 × 60° = 1.233 units required to heat one cubic foot of air from 10 to 70°.

Specific gravity of water = 1.

Specific gravity of air = .001293 under one atmosphere.

Volume of water = 1.

Volume of the same weight of air at 32° = 773.283.

AIR REQUIRED FOR VENTILATION.

Each adult requires from 250 to 300 cubic feet of air per hour in sparsely occupied rooms. In theaters, assembly rooms, churches, etc., provision should be made to admit from 400 to 1500 cubic feet of air per hour for each person, and where prolonged sittings take place this quantity should be increased to 2000 cubic feet per hour per person. In school rooms children should be provided with 600 cubic feet and grown persons 1200 cubic feet of air per hour, unless the space is crowded, and then the quantity should be increased. In enforcing the Massachusetts law the chief of the district police requires 30 cubic feet of fresh air per minute for each pupil, or 1800 cubic feet per hour. This requirement represents the most advanced American practice. From 2000 to 3000 cubic feet of air per hour per occupant is required in hospitals and workshops. Each cubic foot of gas burned for illumination will consume from 8 to 12 cubic feet of air per hour.

In indirect radiation in dwellings the air in the rooms should be changed at least twice every hour. Less frequent changes may be provided in halls and other buildings, dependent of course on the quantity of air required for ventilating purposes. By dividing this latter quantity by the cubic contents in feet in the apartment, the number of times the air is to be changed each hour is ascertained. Thus:

$$\text{Number of times air is to be changed per hour} = \frac{\text{Cubic feet of air per hour required for ventilation.}}{\text{Cubic feet of contents of apartment.}}$$

ASCERTAINING THE AREA OF WARM-AIR FLUES.

To ascertain the area of warm-air flues in square inches when the velocity of air in flue in feet per second is known, multiply the contents of the room in cubic feet by the number in the column, which gives the required number of changes of air in Table XXVIII.

TABLE XXVIII.—WARM-AIR FLUES.*

Velocity in flue in feet per second.	One change of air per hour.	Two changes of air per hour.	Three changes of air per hour.	Four changes of air per hour.	Five changes of air per hour.
$1\frac{1}{2}$ feet.	.0266	.053	.079	.106	.133
2 "	.02	.04	.06	.08	.1
$2\frac{1}{2}$ "	.016	.032	.048	.064	.08
3 "	.0133	.0266	.0399	.053	.066
$3\frac{1}{2}$ "	.0114	.0228	.0342	.0457	.057
4 "	.01	.02	.03	.04	.05
$4\frac{1}{2}$ "	.0089	.0178	.0267	.0346	.0445
5 "	.008	.016	.024	.032	.04
$5\frac{1}{2}$ "	.0073	.0146	.0219	.029	.0365
6 "	.0066	.0133	.0198	.026	.033
$6\frac{1}{2}$ "	.0061	.0122	.0183	.0244	.03
7 "	.0057	.0114	.0171	.0228	.028
$7\frac{1}{2}$ "	.0053	.0106	.0159	.0212	.26
10 "	.004	.008	.012	.016	.02

The velocity of the air in main vertical ventilating flues should not be less than 6 feet per second.

The velocity in horizontal exit ducts from apartments to main ventilating flue should not exceed 3 feet per second.

The velocity of the incoming air at registers should not exceed 3 feet per second, and if the velocity in flue exceeds this it may be reduced at the register by enlarging area of register beyond that of flue.

In a dwelling room the air may be moved with the temperature at 60° to 70°, at a velocity of $2\frac{1}{2}$ to $3\frac{1}{2}$ feet per second. It should not be permitted to exceed a velocity of 5 feet per second.

In proportioning warm-air flues for dwellings the velocity to first floor may be estimated at $1\frac{1}{2}$ feet per second, to second floor $2\frac{1}{2}$ feet per second, and to the upper floors at 4 feet per second.

The areas of fresh or cold-air inlet flues or ducts are equal to the areas of the warm-air flues or ducts multiplied by .75.

TABLE XXIX.—DIMENSIONS OF REGISTERS FOR WARM-AIR AND VENTILATING DUCTS.

Size of opening. Inches.	Nominal area of opening. Square inches.	Effective area of opening. Square Inches.	Opening to admit body of register. Inches.	Extreme dimensions of register face. Inches.
6 x 10	60	40	$6\frac{1}{8}$ x 10	$7\frac{7}{8}$ x 12
8 x 10	80	53	8 x 10	$9\frac{5}{8}$ x $11\frac{5}{8}$
8 x 12	96	64	8 x 12	$9\frac{3}{4}$ x $13\frac{5}{8}$
8 x 15	120	80	8 x 15	$9\frac{3}{4}$ x $16\frac{5}{8}$
9 x 12	108	72	9 x $12\frac{1}{8}$	$10\frac{3}{4}$ x $13\frac{3}{4}$
9 x 14	126	84	9 x 14	11 x 16
10 x 12	120	80	10 x 12	$11\frac{3}{4}$ x $13\frac{7}{8}$
10 x 14	140	93	$10\frac{1}{8}$ x $14\frac{1}{8}$	$12\frac{1}{4}$ x $16\frac{1}{8}$
10 x 16	160	107	10 x 16	12 x 18
12 x 15	180	120	$12\frac{1}{8}$ x $15\frac{1}{4}$	$13\frac{1}{2}$ x $16\frac{3}{4}$
12 x 19	228	152	$12\frac{1}{8}$ x $19\frac{1}{4}$	$14\frac{3}{8}$ x 21
14 x 22	308	205	$14\frac{1}{4}$ x 22	$16\frac{1}{2}$ x $24\frac{1}{8}$
15 x 25	375	250	$15\frac{5}{8}$ x $25\frac{1}{2}$	$17\frac{7}{8}$ x $27\frac{3}{4}$
16 x 20	320	213	$16\frac{1}{8}$ x $20\frac{1}{2}$	$17\frac{5}{8}$ x $22\frac{1}{8}$
16 x 24	384	256	$16\frac{3}{8}$ x $24\frac{1}{2}$	$18\frac{3}{8}$ x 27
20 x 20	400	267	$20\frac{1}{4}$ x $20\frac{1}{4}$	$22\frac{1}{4}$ x $22\frac{1}{4}$
20 x 24	480	320	20 x 24	$22\frac{1}{4}$ x 26
20 x 26	520	347	$20\frac{1}{4}$ x $26\frac{1}{4}$	$22\frac{7}{8}$ x $28\frac{7}{8}$
21 x 29	609	403	$20\frac{3}{4}$ x 29	$23\frac{5}{8}$ x $31\frac{1}{2}$
27 x 27	729	486	27 x 27	$29\frac{1}{8}$ x $29\frac{1}{8}$
27 x 38	1026	684	27 x 38	$29\frac{1}{4}$ x $40\frac{1}{4}$
30 x 30	900	600	$30\frac{1}{4}$ x $30\frac{1}{4}$	$32\frac{3}{4}$ x $32\frac{3}{4}$

PROPORTIONING AREAS OF WARM-AIR FLUES TO SQUARE FEET OF SURFACE IN INDIRECT RADIATORS.

Proportions sometimes used in practice are as follows:

For each square foot of surface in indirect radiator 2 square inches in warm-air flue to first floor.

For each square foot of surface in indirect radiator 1½ square inches in warm-air flue to second floor.

For each square foot of surface in indirect radiator 1 square inch in warm-air flue to third and other floors.

Cold-air ducts have one-quarter less area in square inches than warm-air flues.

VENTILATING FLUES AND CHIMNEYS.

The following rules for ascertaining the velocity of air currents at various temperatures in ventilating flues and chimneys will be found useful:

If the height of a chimney in feet be multiplied by 43 and divided by 480, the result will be the constant A which appears in Table XXX.

$$\frac{\text{Height in feet}}{480} \times 43 = \text{Constant A.}$$

In this equation 43 equals the accelerating force of gravity (32.2 feet per second) multiplied by 2 and divided by the coefficient of friction .5 plus 1, thus:

$$\frac{32.2 \times 2}{.5 + 1} = \frac{64.4}{1.5} = 43.$$

The square root of the product of the difference in degrees of temperature between the inside and outside atmosphere multiplied by A (as given in Table XXX) equals the velocity of draft in flue in feet per second, thus:

$\sqrt{\text{Difference in degrees of temperature} \times \text{A}}$ = the velocity of draft in feet per second.

TABLE XXX.—THE CONSTANT "A" IN VENTILATING FLUES AND CHIMNEYS.*

Height of chimneys in feet.																
30	35	40	45	50	55	60	65	70	75	80	90	100	110	120	130	140
Constant "A."																
2.687	3.134	3.582	4.031	4.472	4.923	5.375	5.822	6.269	6.716	7.164	8.062	8.956	9.847	10.750	11.610	12.513

Again, the velocity in feet per second squared and divided by A (as given in the table) equals the difference in temperature in degrees between the inside atmosphere and the outside atmosphere necessary to maintain the velocity, thus:

$$\frac{\text{Velocity in feet per second}^2}{\text{A}} = \text{difference in temperature in degrees.}$$

The following formula is also of frequent use:

$$\frac{\text{Cubic feet of air discharged per second}}{\text{Velocity in feet per second.}} = \text{area of flue in square feet.}$$

TABLE XXXI.—SIZES OF SMOKE FLUES IN CHIMNEYS FOR HOT-WATER HEATING SYSTEMS.*

Diameter in inches.	Area in square inches.	Area in square feet.	Square of approximate area, in inches.	HEIGHT OF CHIMNEY. 50 FT.	60 FT.	70 FT.	80 FT.	90 FT.	Contents of building to be heated in cubic feet.
				Surface in radiators in square feet.					
9	63.6	.44	8x8	800	1000				up to 40,000
12	113.	.79	11x11	1200	1400	1600			40,000 to 60,000
15	176.7	1.23	14x14	1800	2200	2600			60,000 to 100,000
18	254.4	1.78	16x16	3000	3400	3800			100,000 to 150,000
21	346.3	2.4	19x19	4200	4600	5000			150,000 to 300,000
24	452.3	3.14	22x22	6000	6500	7000	7500		200,000 to 450,000
27	572.5	3.97	24x24	8000	8500	9000	10000		300,000 to 600,000
30	706.8	4.9	27x27	10000	11000	12000	13000	14000	400,000 to 800,000
33	855.3	5.93	30x30		14000	15000	16000	17000	500,000 to 1,000,000
36	1017.8	7.06	32x32		17000	18000	19000	20000	600,000 to 1,250,000

No flue, whether for fresh air, warm air, foul air, or smoke should be less than 32 square inches in area.

HEAT.

THE quantity of heat which it is necessary to impart to 1 pound of water at 32° Fahr., to raise its temperature 1°, is sufficient to raise 769 pounds 1 foot high in 1 minute. This is termed the mechanical equivalent of heat.

A unit of temperature is 1° Fahr., or $\frac{1}{180}$ part of distance between freezing point, 32,° and boiling point, 212°, on Fahrenheit scale.

A unit of heat (British thermal unit) is the quantity of heat required to raise 1 pound of water 1° Fahr. in temperature.

A French calorie, or unit of heat, is the quantity of heat required to raise 1 kilogramme (2.204 pounds) of water 1° centigrade (1.8° Fahr.) in temperature.

A French unit of heat is equal to 3.96832 British units.

Degrees Fahr. equal degrees centigrade, multiplied by 9 and divided by 5, plus 32, thus:

$$\text{Degrees Fahr.} = \frac{\text{Degrees Cent.} \times 9}{5} + 32.$$

Degrees Cent. equal degrees Fahr., less 32 multipled by 5 and divided by 9, thus:

$$\text{Degrees Cent.} = \frac{\text{Degrees Fahr.} - 32 \times 5}{9}$$

Degrees Cent. $\times$ 1.8 + 32 = Degrees Fahr.

Degrees Fahr. — 32 $\div$ 1.8 = Degrees Cent.

The melting point of ice is 32° Fahr. and 0° Cent.

The boiling point of water is 212° Fahr. and 100° Cent.

The specific heat of a body is its capacity for heat, or the quantity of heat required to raise the temperature of the body 1° Fahr., compared with that required to raise the temperature of a quantity of water of equal weight 1°. The unit of heat (B. T. U.) is that which is required to raise the temperature of 1 pound of water 1° from 32° to 33° Fahr., and the specific heat of another body is expressed by the quantity of heat, in units, necessary to raise the temperature of 1 pound weight of such body 1°.

The specific gravity of solids and liquids and of gases and vapors is their relative weight or density, water being taken as unity, at atmospheric pressure, and a certain temperature, say 62°, as in Table XXXII.

It will be noticed in Table XXXII that the specific heat of water increases with the temperature. The increase being so little, $1\frac{3}{10}$ per cent. at 212°, it is usual to consider the specific heat uniform at all ordinary temperatures for practical purposes.

TABLE XXXII.—SPECIFIC HEAT AND SPECIFIC GRAVITY.

	Specific heat.	Specific gravity.	One cubic foot. Weight in pounds.	One cubic inch. Weight in pounds.
Water at 30° Fahr	1.	.9999	62.38	.03610485
Water at 39° Fahr	1.	1.	62.39	.03610842
Water at 62° Fahr	1.0004	1.	62.32	.03606
Water at 212° Fahr	1.013	.9585	59.76	.03461322
Ice at 32° Fahr	.504	.93	57.96	.03354
Cast-iron	.1298	7.087	441.6	.2556
Wrought-iron	.11379	7.788	485.3	.2809
Zinc	.0955	6.861	427.6	.2474
Copper	.0951	8.607	536.4	.3104
Tin	.0569	7.291	454.4	.263
Lead	.0314	11.352	707.3	.4094
Pine wood	.65	.483	30.1	.01742
Oak wood	.57	.777	48.42	.02802
Glass	.19768	2.76	172.	.0995
Burnt clay or brick	.185	1.841	114.	.0664
Air at 62° Fahr	.238	.001293	.0761	
Vapor of water (steam)	.475	.000805	.0475	
Steam at 212° Fahr		.000621		

Cubic feet of air at 62° Fahr. in 1 pound. = 13.14.

Water with perfect freedom of motion is the best absorbent of heat, excepting mercury.

The effects of heat may be summarized:

Water boils (under atmospheric pressure, 14.7 pounds absolute) at .... 212° Fahr.
Mercury " " " " at .... 676° "
Sulphur " " " " " .... 838° "
Cast-iron melts (maximum) at .... 2786° "
" " (minimum) " .... 1920° "
Wrought-iron melts (maximum) at .... 3945° "
" " (minimum) " .... 2730° "
Zinc melts at .... 773° "
Copper melts at .... 1996° "
Tin " " .... 442° "
Lead " " .... 612° "
Iron red-hot in daylight at .... 1272° "
" " in the dark " .... 800° "

Lowest luminosity of iron in the dark at	635° Fahr.
Steel becomes dark blue at	600° "
Steel " purple at	530° "
Steel " brown at	490° "
Steel " faint yellow at	430° "
Water freezes at	32° "
Sea-water freezes at	28° "
Heat of a common fire	790° "

TABLE XXXIII.—EXPANSION OF BODIES BY HEAT.

	EXPANSION FOR 1° FAHR.	
	In length.	In volume.
Water 40° to 212°		.0002519
Ice—17° to + 30	.0000843	.000253
Cast-iron	.000006167	.000018501
Wrought-iron	.000006689	.000020067
Zinc	.000017268	.000051806
Copper	.000010088	.000030264
Tin	.000013102	.000039307
Lead	.000015876	.000047628
Brick	.000003057	.00000917

The use of Table XXXIII is simple. For example, the temperature of a wrought-iron pipe is increased 200° above the temperature at which it was when placed in position, and its length is 120 feet. Then $120 \times 12 = 1440$ inches $\times$ .000006689 (found in column opposite wrought-iron) = .00963 $\times$ 200° increase of temperature = 1.926, or nearly 2 inches is the additional length to the pipe when heated.

A system of heating contains 1000 gallons of water at 40° Fahr., and is to be heated to 200°. The form by which to ascertain the increase in volume of water at the high temperature is $1000 \times .0002519 = .2519 \times (200 - 40)\ 160° = 40.3$ gallons.

TRANSMISSION OF HEAT.

Heat is transmitted by radiation, by contact of air, and by conduction. From the heating pipes or radiator heat is transmitted by radiation to the walls, floors, ceiling, furniture, and other solid bodies which have surfaces of a lower temperature than the temperature of the pipes or radiator.

From the heating pipes or radiators heat is transmitted to the air by contact, if the air is of a lesser temperature than that of the surfaces of the pipes or radiators. From the water within the heating pipes or radiators heat is transmitted by conduction to the external surfaces of the metal forming the heating pipes or radiators. The heat transmitted to the walls and ceilings by radiation is lost through them by conduction, when the temperature of the sides of the walls or ceilings affected by radiation is greater than the temperature of the outer side of the walls or ceilings.

The heat transmitted to the surfaces of furniture and other bodies by radiation is absorbed by conduction until their surfaces have attained a higher temperature than the air when these surfaces transmit heat to the air by contact and to the walls, if of a lower temperature, by radiation. The power of the air to absorb heat by contact with heated surfaces is owing principally to the extreme mobility of its particles, the disturbed condition of the air when in contact with these surfaces, and the rapidity of its motion over the heated surfaces. Air without motion absorbs and conducts heat slowly. Air cannot be appreciably heated directly by radiant heat, but only by contact with heated bodies. When the heating pipes or radiators are enclosed, as in the case of indirect radiators, the walls of the case being approximately of the same temperature as the heating surfaces, heat is given off by contact only to the air passing through. The radiating and heat-absorbing powers of bodies are equal. The reflective power is inversely as the radiating power.

TABLE XXXIV.—HEAT UNITS IN WATER AND WEIGHT OF WATER IN POUNDS PER CUBIC FOOT.

Temperature Fahr.	Heat units per pound.	Weight, pounds per cubic foot.	Temperature Fahr.	Heat units per pound.	Weight, pounds per cubic foot.	Temperature Fahr.	Heat units per pound.	Weight, pounds per cubic foot.	Temperature Fahr.	Heat units per pound.	Weight, pounds per cubic foot.
32°	0.	62.38	110°	78.11	61.89	145°	113.28	61.28	179°	147.53	60.57
35°	3.	62.42	112°	80.12	61.86	146°	114.28	61.26	180°	148.54	60.55
40°	8.	62.42	113°	81.12	61.84	147°	115.29	61.24	181°	149.55	60.53
45°	13.	62.42	114°	82.13	61.83	148°	116.29	61.22	182°	150.56	60.50
50°	18.	62.41	115°	83.13	61.82	149°	117.30	61.20	183°	151.57	60.48
52°	20.	62.40	116°	84.13	61.80	150°	118.31	61.18	184°	152.58	60.46
54°	22.01	62.40	117°	85.14	61.78	151°	119.31	61.16	185°	153.59	60.44
56°	24.01	62.39	118°	86.14	61.77	152°	120.32	61.14	186°	154.60	60.41
58°	26.01	63.38	119°	87.15	61.75	153°	121.33	61.12	187°	155.61	60.39
60°	28.01	62.37	120°	88.15	61.74	154°	122.33	61.10	188°	156 62	60.37
62°	30.01	62.36	121°	89.15	61.72	155°	123.34	61.08	189°	157.63	60.34
64°	32.01	62.35	122°	90.16	61.70	156°	124.35	61.06	190°	158.64	60.32
66°	34.02	62.34	123°	91.16	61.68	157°	125.35	61.04	191°	159.65	60.29
68°	36.02	62.33	124°	92.17	61.67	158°	126.36	61.02	192°	160.67	60.27
70°	38.02	62.31	125°	93.17	61.65	159°	127.37	61.	193°	161.68	60.25
72°	40.02	62.30	126°	94.17	61.63	160°	128.37	60.98	194°	162.69	60.22
74°	42.02	62.28	127°	95.18	61.61	161°	129.38	60.96	195°	163.70	60.20
76°	44.03	62.27	128°	96.18	61.60	162°	130.39	60.94	196°	164.71	60.17
78°	46.03	62.25	129°	97.19	61.58	163°	131.40	60.92	197°	165.72	60.15
80°	48.04	62.23	130°	98.19	61.56	164°	132.41	60.90	198°	166.73	60.12
82°	50.04	62.21	131°	99.20	61.54	165°	133.41	60.87	199°	167.74	60.10
84°	52.04	62.19	132°	100.20	61.52	166°	134.42	60.85	200°	168.75	60.07
86°	54.05	62.17	133°	101.21	61.51	167°	135.43	60.83	201°	169.77	60.05
88°	56.05	62.15	134°	102.21	61.49	168°	136.44	60.81	202°	170.78	60.02
90°	58.06	62.13	135°	103.22	61.47	169°	137.45	60.79	203°	171.79	60.
92°	60.06	62.11	136°	104.22	61.45	170°	138.45	60.77	204°	172.80	59.97
94°	62.06	62.09	137°	105.23	61.43	171°	139.46	60.75	205°	173.81	59.95
96°	64.07	62.07	138°	106.23	61.41	172°	140.47	60.73	206°	174.83	59.92
98°	66.07	62.05	139°	107.24	61.39	173°	141.48	60.70	207°	175.84	59.89
100°	68.08	62.02	140°	108.25	61.37	174°	142.49	60.68	208°	176.85	59.87
102°	70.09	62.	141°	109.25	61.36	175°	143.50	60.66	209°	177.86	59.84
104°	72.09	61.97	142°	110.26	61.34	176°	144.51	60.64	210°	178.87	59.82
106°	74.10	61.95	143°	111.26	61.32	177°	145.52	60.62	211°	179.89	59.79
108°	76.10	61.92	144°	112.27	61.30	178°	146.52	60.59	212°	180.90	59.76

MISCELLANEOUS DATA.

GRAVITY or gravitation is downward pressure or weight. All bodies possess this property proportionate to their various degrees of density.

The force of gravity is an accelerated velocity which heavy bodies acquire in falling freely from a state of rest.

The velocity that a body will acquire in one second of time is equal to 32.2 feet, the distance fallen being 16.1 feet; therefore the velocity in feet that a body will acquire is equal to 32.2 feet multiplied by the number of seconds occupied in falling; or it is equal to the square root of the product of the distance in feet multiplied by 32.2×2.

TABLE XXXV.—PRESSURE OF WATER IN POUNDS PER SQUARE INCH FOR EACH FOOT IN HEIGHT.

Feet in height.	Pressure per square inch.	Feet in height.	Pressure per square inch.	Feet in height.	Pressure per square inch.	Feet in height.	Pressure per square inch.	Feet in height.	Pressure per square inch.	Feet in height.	Pressure per square inch.	Feet in height.	Pressure per square inch.
1	.43	21	9.09	41	17.75	61	26.42	81	35.08	101	43.75	121	52.41
2	.86	22	9.53	42	18.19	62	26.85	82	35.52	102	44.18	122	52.84
3	1.3	23	9.96	43	16.62	63	27.29	83	35.95	103	44.61	123	53.28
4	1.73	24	10.39	44	19.05	64	27.72	84	36.39	104	45.05	124	53.71
5	2.16	25	10.82	45	19.49	65	28.15	85	36.82	105	45.48	125	54.15
6	2.59	26	11.26	46	19.92	66	28.58	86	37.25	106	45.91	126	54.58
7	3.03	27	11.69	47	20.35	67	29.02	87	37.68	107	46.34	127	55.01
8	3.46	28	12.12	48	20.79	68	29.45	88	38.12	108	46.78	128	55.44
9	3.89	29	12.55	49	21.22	69	29.88	89	38.55	109	47.21	129	55.88
10	4.33	30	12.99	50	21.65	70	30.32	90	38.98	110	47.64	130	56.31
11	4.76	31	13.42	51	22.09	71	30.75	91	39.42	111	48.08	131	56.74
12	5.2	32	13.86	52	22.52	72	31.18	92	39.85	112	48.51	132	57.18
13	5.63	33	14.29	53	22.95	73	31.62	93	40.28	113	48.94	133	57.61
14	6.06	34	14.72	54	23.39	74	32.05	94	40.72	114	49.38	134	58.04
15	6.49	35	15.16	55	23.82	75	32.48	95	41.15	115	49.81	135	58.48
16	6.93	36	15.59	56	24.26	76	32.92	96	41.58	116	50.24	136	58.91
17	7.36	37	16.02	57	24.69	77	33.35	97	42.01	117	50.68	137	59.34
18	7.79	38	16.45	58	25.12	78	33.78	98	42.45	118	51.11	138	59.77
19	8.22	39	16.89	59	25.55	79	34.21	99	42.88	119	51.54	139	60.21
20	8.66	40	17.32	60	25.99	80	34.65	100	43.31	120	51.98	140	60.64

The space in feet fallen through is equal to 16.1 multiplied by the square of the number of seconds.

The force of gravity is a cause of retarded and of accelerated motion: ascending an inclined plane, the force of gravity retards the motion; descending an incline plane, the force of gravity accelerates the motion.

TABLE XXXVI.—CAPACITIES OF ROUND AND SQUARE TANKS.

Diameter of Round Tank and side of Square Tank in feet and inches.	CIRCULAR TANK.		SQUARE TANK.	
	Cubic feet.	Gallons.	Cubic feet.	Gallons.
1	.7845	5.8735	1	7.4805
1–6	1.7671	13.215	2.25	16.8311
2	3.1416	23.494	4	29.922
2–6	4.9087	36.7092	6.25	46.7531
3	7.0686	52.8618	9	67.3245
3–6	9.6211	73.1504	12.25	91.63
4	12.5664	93.9754	16	119.68
4–6	15.9043	118.9386	20.25	151.47
5	19.635	146.8384	25	187.
5–6	23.7583	177.6740	30.25	226.27
6	28.2744	211.4472	36	269.28
6–6	33.1831	248.1564	42.25	316.03
7	38.4846	287.8032	49	367.52
7–6	44.1787	330.3859	56.25	420.75
8	50.2656	375.9062	64	478.72
8–6	56.7451	424.362	72.25	540.43
9	63.6174	475.756	81	605.88
9–6	70.8823	530.086	90.25	675.07
10	78.54	587.353	100	748.05
11	95.0334	710.697	121	955.08
12	113.0976	848.189	144	1077.12
13	132.7326	992.627	169	1264.12
14	153.9384	1151.212	196	1466.08
15	176.7150	1321.545	225	1683.
16	201.0624	1503.625	256	1914.88
17	226.9806	1697.451	289	2161.72
18	254.4696	1903.025	324	2423.52
19	283.5294	2120.346	361	2700.28
20	314.16	2349.414	400	2992.
21	346.3614	2590.229	441	3298.68

COMPARATIVE VALUE OF BOILER AND PIPE COVERINGS.

(From the *Metal Worker.*)

A mass of each material to be experimented upon, 1 inch thick, was carefully prepared and placed on a perfectly flat iron plate or tray, which was then carefully maintained at a constant temperature of 310° Fahr. The heat transmitted through each non-conducting mass was calculated in pounds of water heated 10° Fahr. per hour. The author summarized his results in two convenient tables, which are given below:

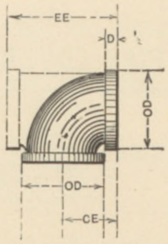
TABLE XXXVII.—BOILER AND PIPE COVERINGS: VARIOUS SUBSTANCES.

Number.	Substance 1 inch thick (in mass); heat applied, 310° F.	Pounds of water heated 10° F. per hour through 1 square foot.	Solid matter in 1 square foot 1 inch thick, parts 1000.	Air included, parts 1000.
1	Hair felt	11.4	189	957
2	Cotton felt	10.6	75	930
3	Jute felt	13.2	162	921
4	Linen felt	11.7	64	753
5	Loose cotton felt	9.3	17	990
6	Carded cotton	8.1	16	987
7	Rabbit-hair "wool"	7.1	43	912
8	Poultry feathers	6.2	44	976
9	Cork powder	13.6	66	931
10	Sawdust powder	14.2	141	793
11	Asbestos powder	47.9	67	961
12	Fossil meal	52.1	78	910
13	Plaster of Paris	36.2	371	598
14	Calcined magnesia	14.7	24	979
15	Compressed calcined magnesia	53.4	291	711
16	Fine sand	66.3	533	473

TABLE XXXVIII.—BOILER AND PIPE COVERINGS: PREPARED MIXTURES.

Number.	Prepared mixtures for covering steam pipes, etc.	Pounds of water heated 10° F. per hour by 1 square foot.
1	Clay, dung, and vegetable fiber paste	39.6
2	Fossil meal and hair paste	10.4
3	Fossil meal and asbestos powder	26.3
4	Paper pulp, clay, and vegetable fiber	44.6
5	Paper pulp alone	14.7
6	Stag wool, hair, and clay paste	10.0
7	Asbestos fiber, wrapped tightly	17.9
8	Coal ashes and clay paste wrapped with straw	29.9

TABLE XXXIX.—DIMENSIONS OF ELBOWS AND COUPLINGS FOR WROUGHT-IRON PIPE.*



Nominal inside diameter of pipe in inches.	ELBOWS. Center to end in inches. CE	External diameter of end in inches. OD	Depth of end in inches. D	COUPLINGS. External diameter in inches.	Length in inches.
$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$	$1\frac{11}{32}$	$1\frac{1}{2}$
1	$1\frac{5}{8}$	$1\frac{7}{8}$	$\frac{9}{16}$	$1\frac{2}{3}^{1}$	$1\frac{3}{4}$
$1\frac{1}{4}$	$1\frac{7}{8}$	$2\frac{1}{2}$	$\frac{5}{8}$	2	$1\frac{15}{16}$
$1\frac{1}{2}$	2	$2\frac{3}{4}$	$\frac{5}{8}$	$2\frac{9}{32}$	$2\frac{3}{16}$
2	$2\frac{3}{8}$	$3\frac{1}{4}$	$\frac{5}{8}$	$2\frac{13}{16}$	$2\frac{5}{16}$
$2\frac{1}{2}$	3	4	1	$3\frac{9}{32}$	$2\frac{23}{32}$
3	$3\frac{7}{16}$	$4\frac{3}{4}$	$1\frac{1}{16}$	$4\frac{1}{32}$	3
$3\frac{1}{2}$	$3\frac{3}{4}$	$5\frac{1}{4}$	$1\frac{1}{8}$	$4\frac{1}{2}$	$3\frac{1}{8}$
4	$4\frac{1}{8}$	6	$1\frac{1}{8}$	$5\frac{7}{64}$	$3\frac{1}{8}$
$4\frac{1}{2}$	$4\frac{3}{8}$	$6\frac{1}{2}$	$1\frac{1}{8}$	$5\frac{17}{32}$	$3\frac{1}{8}$
5	$4\frac{3}{4}$	$7\frac{1}{4}$	$1\frac{1}{8}$	$6\frac{1}{4}$	$3\frac{23}{32}$
6	$5\frac{1}{2}$	$8\frac{3}{4}$	$1\frac{1}{8}$	$7\frac{11}{32}$	$3\frac{23}{32}$
7	$6\frac{1}{8}$	10	$1\frac{1}{8}$	$8\frac{11}{32}$	$4\frac{5}{16}$
8	$6\frac{3}{4}$	11	$1\frac{1}{4}$	$9\frac{7}{16}$	$4\frac{9}{16}$
9				$10\frac{15}{32}$	$5\frac{3}{4}$
10				$11\frac{1}{2}$	$6\frac{1}{4}$
11				$13\frac{25}{32}$	$6\frac{1}{4}$
12					

TABLE XL.—DIMENSIONS OF STANDARD WROUGHT-IRON PIPE.

Nominal inside diameter. Inches.	Actual diameter. Inches.		Thickness. Inches.	Circumference. Inches.		Length of pipe in feet per square foot of surface.		Area. Square inches.	
	Inside.	Outside.		Internal.	External.	Inside.	Outside.	Internal.	External.
1/8	.27	.4	.07	.84	1.27	14.15	9.44	.06	.12
1/4	.36	.54	.08	1.14	1.69	10.50	7.07	.1	.22
3/8	.49	.67	.09	1.55	2.12	7.67	5.65	.19	.35
1/2	.62	.84	.10	1.95	2.65	6.13	4.5	.3	.55
3/4	.82	1.05	.11	2.58	3.29	4.63	3.63	.53	.86
1	1.04	1.31	.13	3.29	4.13	3.67	2.9	.86	1.35
1 1/4	1.38	1.66	.14	4.33	5.21	2.76	2.3	1.49	2.16
1 1/2	1.61	1.9	.14	5.06	5.96	2.37	2.01	2.03	3.83
2	2.06	2.37	.15	6.49	7.46	1.84	1.61	3.35	4.43
2 1/2	2.46	2.87	.20	7.75	9.03	1.54	1.32	4.78	6.49
3	3.06	3.5	.21	9.63	10.96	1.24	1.09	7.38	9.62
3 1/2	3.56	4.	.22	11.14	12.56	1.07	.95	9.83	12.56
4	4.02	4.5	.23	12.64	14.13	.94	.84	12.73	15.9
4 1/2	4.5	5.	.24	14.15	15.7	.84	.76	15.93	19.63
5	5.04	5.56	.25	15.84	17.47	.75	.62	19.99	24.29
6	6.06	6.62	.28	19.05	20.81	.63	.57	28.88	34.47
7	7.02	7.62	.30	22.06	23.95	.54	.5	38.73	45.66
8	7.98	8.62	.32	25.07	27.09	.47	.44	50.03	58.42
9	9.	9.68	.34	28.27	30.43	.42	.4	63.63	73.71
10	10.01	10.75	.36	31.47	33.77	.38	.35	78.83	90.79
11	11.	11.75	.37	34.55	36.91	.34	.32	95.03	108.43
12	12.	12.75	.37	37.7	40.05	.32	.3	113.09	127.67
13	13.25	14.	.37	41.62	43.98	.29	.27	137.88	153.94
14	14.25	15.	.37	44.76	47.12	.27	.25	159.48	176.71
15	15.4	16.	.28	48.48	50.26	.25	.24	187.04	201.06
16	16.4	17.	.30	51.52	53.41	.23	.23	211.24	226.98
17	17.3	18.	.34	54.41	56.55	.22	.21	235.61	254.47

TABLE XLI.—WEIGHTS, CAPACITIES, AND THREADS OF STANDARD WROUGHT-IRON PIPE.*

Nominal inside diameter. INCHES.	Nominal weight per lineal foot. POUNDS.	Number of threads per inch.	Size to drill for thread. INCHES.	Length to thread. INCHES.	Length of pipe containing one cubic foot. FEET.	Length of pipe containing one gallon. FEET.	Contained gallons per lineal foot.	Contained cubic inches per lineal foot.	Continued pounds of water per lineal foot.
1/8	.24	27	21/64	9/32	2500.	336.6	.0029	.686	.024
1/4	.42	18	29/64	3/8	1385.	184.8	.0054	1.249	.044
3/8	.56	18	19/32	7/16	751.5	100.8	.0099	2.299	.082
1/2	.84	14	23/32	1/2	472.4	63.2	.0158	3.657	.132
3/4	1.12	14	15/16	9/16	270.	36.1	.0277	6.399	.23
1	1.67	11 1/2	1 3/16	5/8	166.9	22.3	.0448	10.352	.373
1 1/4	2.64	11 1/2	1 15/32	11/16	96.25	12.8	.0777	17.952	.648
1 1/2	2.68	11 1/2	1 23/32	13/16	70.65	9.4	.1058	24.456	.883
2	3.61	11 1/2	2 3/16	7/8	42.36	5.7	.1742	40.26	1.454
2 1/2	5.74	8	2 5/8	1	30.11	4.02	.2484	57.396	2.072
3	7.54	8	3 1/4	1	19.49	2.6	.3837	88.656	3.202
3 1/2	9.	8	3 3/4	1 1/16	14.56	1.95	.5136	118.644	4.285
4	10.66	8	4 1/4	1 1/8	11.31	1.51	.6612	152.76	5.517
4 1/2	12.34	8	4 3/4	1 1/4	9.03	1.2	.828	191.268	6.908
5	14.5	8	5 5/16	1 1/4	7.2	.96	1.0388	239.988	8.668
6	18.76	8	6 5/16	1 3/8	4.98	.66	1.5007	346.668	12.521
7	23.27	8	7 3/8	1 1/2	3.72	.49	2.0123	464.844	16.79
8	28.18	8	8 3/8	1 5/8	2.88	.38	2.5998	600.468	21.688
9	33.7	8	9 19/32	1 5/8	2.26	.3	3.3056	763.596	27.58
10	40.06	8	10 13/16	1 3/4	1.8	.24	4.0954	946.056	34.171
11	45.	8			1.5	.2	4.9366	1140.36	41.189
12	49.	8			1.27	.17	5.8748	1357.08	49.017
13	54.	8			1.04	.139	7.1625	1645.56	59.762
14	58.	8			.9	.12	8.2933	1913.76	69.125
15	62.	8			.77	.102	9.7163	2244.48	81.07
16		8			.68	.091	10.9734	2534.88	91.559
17		8			.61	.081	12.2394	2827.32	102.122

TABLE XLII.—EQUALIZATION OF PIPE AREAS.

Sizes of pipes.	½ inch.	¾ inch.	1 inch.	1¼ inch.	1½ inch	2 inch.	2½ inch.	3 inch.	3½ inch.	4 inch.	4½ inch.	5 inch.	6 inch.	7 inch.	8 inch.
½ inch	1.	1.7	2.8	4.9	6.6	11.	15.6	24.	32.	41.	52.	65.	94.	123.	167.
¾ inch	....	1.	1.6	2.6	3.8	6.2	8.9	13.8	18.	23.	30.	37.	54.	72.	93.
1 inch	....	....	1.	1.7	2.3	3.8	5.5	8.5	11.	14.	18.	23.	33.	44.	57.
1¼ inch	....	....	....	1.	1.3	2.2	3.1	4.9	6.6	8.	10.	13.	19.	25.	33.
1½ inch	....	....	....	....	1.	1.6	2.3	3.6	4.8	6.2	7.7	9.7	14.	19.	24.
2 inch	....	....	....	....	....	1.	1.4	2.2	2.9	3.8	4.7	5.3	8.6	11.	14.
2½ inch	....	....	....	....	....	....	1.	1.5	2.	2.6	3.3	4.1	6.	8.	10.
3 inch	....	....	....	....	....	....	....	1.	1.3	1.7	2.1	2.7	3.9	5.2	6.7
3½ inch	....	....	....	....	....	....	....	....	1.	1.2	1.6	2.	2.9	3.9	5.
4 inch	....	....	....	....	....	....	....	....	....	1.	1.2	1.5	2.2	3.	3.9
4½ inch	....	....	....	....	....	....	....	....	....	....	1.	1.2	1.8	2.4	3.1
5 inch	....	....	....	....	....	....	....	....	....	....	....	1.	1.4	1.9	2.5
6 inch	....	....	....	....	....	....	....	....	....	....	....	....	1.	1.3	1.7
7 inch	....	....	....	....	....	....	....	....	....	....	....	....	....	1.	1.2
8 inch	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.
Internal areas of pipes.	.3048	.5333	.8627	1.496	2.038	3.355	4.783	7.388	9.887	12.73	15.93	19.99	28.88	38.73	50.03

TABLE XLIII.—INCHES IN FRACTIONAL AND DECIMAL PARTS OF A FOOT.

Inches.	Fraction of foot.	Decimal part of foot.	Inches.	Fraction of foot.	Decimal part of foot.
1	1/12	.0833	6½	13/24	.5417
1½	1/8	.125	7	7/12	.5833
2	1/6	.1667	7½	5/8	.625
2½	5/24	.2083	8	2/3	.6667
3	1/4	.25	8½	17/24	.7083
3½	7/24	.2917	9	3/4	.75
4	1/3	.3333	9½	19/24	.7917
4½	3/8	.375	10	5/6	.8333
5	5/12	.4167	10½	7/8	.875
5½	11/24	.4583	11	11/12	.9167
6	1/2	.5	11½	23/24	.9583

TABLE XLIV.—DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH.

$\frac{1}{64}$	of an inch		=	.015625
$\frac{1}{32}$	"	"	=	.03125
$\frac{1}{16}$	"	"	=	.0625
$\frac{3}{32}$	"	"	=	.09375
$\frac{1}{8}$	"	"	=	.125
$\frac{1}{8}+\frac{1}{32}$	"	"	=	.15625
$\frac{1}{8}+\frac{1}{16}$	"	"	=	.1875
$\frac{1}{8}+\frac{3}{32}$	"	"	=	.21875
$\frac{1}{4}$	"	"	=	.25
$\frac{1}{4}+\frac{1}{32}$	"	"	=	.28125
$\frac{1}{4}+\frac{1}{16}$	"	"	=	.3125
$\frac{1}{4}+\frac{3}{32}$	"	"	=	.34375
$\frac{3}{8}$	"	"	=	.375
$\frac{3}{8}+\frac{1}{32}$	"	"	=	.40625
$\frac{3}{8}+\frac{1}{16}$	"	"	=	.4375
$\frac{3}{8}+\frac{3}{32}$	"	"	=	.46875
$\frac{1}{2}$	"	"	=	.5
$\frac{1}{2}+\frac{1}{32}$	"	"	=	.53125
$\frac{1}{2}+\frac{1}{16}$	"	"	=	.5625
$\frac{1}{2}+\frac{3}{32}$	"	"	=	.59375
$\frac{5}{8}$	"	"	=	.625
$\frac{5}{8}+\frac{1}{32}$	"	"	=	.65625
$\frac{5}{8}+\frac{1}{16}$	"	"	=	.6875
$\frac{5}{8}+\frac{3}{32}$	"	"	=	.71875
$\frac{3}{4}$	"	"	=	.75
$\frac{3}{4}+\frac{1}{32}$	"	"	=	.78125
$\frac{3}{4}+\frac{1}{16}$	"	"	=	.8125
$\frac{3}{4}+\frac{3}{32}$	"	"	=	.84375
$\frac{7}{8}$	"	"	=	.875
$\frac{7}{8}+\frac{1}{32}$	"	"	=	.90625
$\frac{7}{8}+\frac{1}{16}$	"	"	=	.9375
$\frac{7}{8}+\frac{3}{32}$	"	"	=	.96875
1 inch			=	1.

TABLE XLV.—RECORDED TEMPERATURES.

STATION.	No. of months fire is required.	Mean temp. of fire mos.	Avreage No. of degrees temp. to be raised.	Max. No. of degrees temp. to be raised.	Min. temp. of fire mos.
Albany, N. Y.	7	35°	35°	87°	—17°
Baltimore, Md.	6	39°	31°	72°	— 2°
Boston, Mass.	7	37°	33°	81°	—11°
Buffalo, N. Y.	8	35°	35°	83°	—13°
Burlington, Vt.	7	32°	38°	90°	—20°
Chicago, Ill.	7	35°	35°	90°	—20°
Charleston, S. C.	3	52°	18°	47°	+23°
Cincinnati, O.	7	42°	28°	77°	— 7°
Cleveland, O.	7	38°	32°	83°	—13°
Detroit, Mich.	7	35°	35°	90°	—20°
Duluth, Minn.	8	28°	42°	108°	—38°
Indianapolis, Ind.	7	41°	29°	88°	—18°
Key West, Fla.				26°	+44°
Leavenworth, Kan.	6	37°	33°	90°	—20°
Louisville, Ky.	6	42°	28°	80°	—10°
Memphis, Tenn.	5	39°	31°	68°	+ 2°
Milwaukee, Wis.	8	37°	33°	95°	—25°
New Orleans, La.				44°	+26°
New York, N. Y.	7	40°	30°	76°	— 6°
Philadelphia, Pa.	7	40°	30°	75°	— 5°
Pittsburgh, Pa.	7	39°	31°	82°	—12°
Portland, Me.	8	33°	37°	82°	—12°
Portland, Ore.	6	43°	27°	67°	+ 3°
San Francisco, Cal.	4	53°	17°	34°	+36°
St. Louis, Mo.	5	37°	33°	86°	—16°
St. Paul, Minn.	7	25°	45°	102°	—32°
Washington, D. C.	5	40°	30°	73°	— 5°
Wilmington, N. C.	4	50°	20°	55°	+15°

WEIGHTS AND VOLUMES.

One United States gallon contains 231 cubic inches.

One United States gallon weighs 8.33 pounds.

United States gallons multiplied by .13367 equals cubic feet.

United States gallons multiplied by 231 equals cubic inches.

Cubic feet multiplied by 7.48 equals United States gallons.

Cubic inches multiplied by .04329 equals United States gallons.

One cubic foot of water at 62° weighs 62.321 pounds.

One cubic inch of water at 62° weighs .03606 pounds.

A column of water one foot or 12 inches high equals .433 pound pressure per square inch.

A column of water 2.3093 feet or 27.71 inches high equals one pound pressure per square inch.

A column of water 33.947 feet high equals 14.7 pounds pressure per square inch, which is the pressure of the atmosphere at the level of the sea.

A column of water 100 feet high produces a pressure on the base of 43.3 pounds per square inch.

One cubic foot of ice at 32° weighs 57.96 pounds.

Water is at its maximum density at 39.33° Fahr., or 4.107° cent.

Wrought-iron: One cubic foot = 480 pounds. One square foot 1 inch in thickness = 40 pounds. Square bar 1 inch by 1 inch 1 foot long = $3\frac{1}{3}$ pounds. 3.6 cubic inches = 1 pound.

Weight of wrought-iron × .92 = weight of zinc.

Weight of wrought-iron × .93 = weight of cast-iron.

Weight of wrought-iron × 1.01 = weight of steel.

Weight of wrought-iron × 1.15 = weight of copper.

Weight of wrought-iron × 1.47 = weight of lead.

Weight of wrought-iron × 1.08 = weight of brass.

Cubic inches × .26 = pounds of cast-iron.

Cubic inches × .278 = pounds of wrought-iron.

Cubic inches × .283 = pounds of cast-steel.

Cubic inches × .322 = pounds of copper.

Cubic inches × .410 = pounds of lead.

TABLE XLVI.—COMPARISON OF WEIGHTS AND MEASURES.

UNITED STATES AND BRITISH IMPERIAL GALLONS.

	Cubic inches in one gallon.	Weight of one gallon in pounds.	Gallons in one cubic foot.
United States	231.	8.3311	7.4805
British imperial	277.274	10.	6.2321

LIQUID MEASURES.

United States gallon.	British imperial gallon.	French litre.	Cubic metre.
1.	.83	3.77	.0038
1.19	1.	4.53	.0045
.26	.22	1.	.001
8.3311 lbs.	10 lbs.	2.204 lbs.	
231 cubic inches.	277.27 cubic inches.	61 cubic inches.	

LINEAR MEASURES.

Inches.	Decimals of inches.	Feet.	Metre.
1			2.54 centimetres.
12		1.	30.475 "
36		3.	91.425 "
$\frac{25}{64}$	.39	.0328	1 centimetre = .01
$3\frac{15}{16}$	3.9376	.328	1 decimetre = .1
$39\frac{3}{8}$	39.376	3.28	1 metre = 1

SQUARE OR SURFACE MEASURES.

Square inches.	Decimals of square inches.	Square feet.	Square metre.
$\frac{155}{1000}$	.155	.001076	1 square centimetre.
$15\frac{1}{2}$	15.5	.1076	1 square decimetre.
$1550\frac{47}{100}$	1550 47	10.76	1 square metre.
1 square inch.	1 square inch.	.00694	6.45 square centimetres.
		1 square foot.	9.3 square decimetres.

CUBIC OR SOLID MEASURES.

Cubic inches.	Decimals of cubic inches.	Cubic feet.	Cubic Metre.
$\frac{61}{1000}$	.061	.0000353	1 cubic centimetre.
$61\frac{1}{20}$	61.05	.0353	1 cubic decimetre.
$61061\frac{3}{10}$	61051.3	35.32	1 cubic metre.
1 cubic inch.	1 cubic inch.	.000578	16.38 cubic centimetres.
		1 cubic foot.	28.32 cubic decimetres.

1 pound avoirdupois = 0.45 kilogramme.
1 kilogramme = 2.204 pounds avoirdupois.

General Directions.

THE Circulator and all flow and return pipes which are not used for heating should be covered. The emptying or discharge-valve should be at the lowest point in the system; the outlet from it should be open to view and should not be connected to a sewer pipe.

The end of the overflow pipe from expansion tank should be open to view, and discharge into sink or other open receptacle. Where overflow pipe is connected to expansion tank, a tee, open on top end of vertical run, should be used instead of an elbow.

The expansion tank should be placed as high as possible above the Circulator.

An automatic supply of water to a system by means of a ball cock in expansion tank or other device is desirable.

As few valves as possible should be used on hot-water heating systems, and they should be of the gate or angle pattern.

Direct radiators may have one valve on either flow or return connection according to convenience.

Direct radiators should have an air cock or air valve where the pipes are not arranged to prevent air accumulations.

The flow and return pipes should be arranged so as to prevent air accumulations by being directly connected with main air pipe.

Main flow pipes are preferably inclined up from Circulator to radiators, but they may be inclined down toward radiators, dependent on the position of the air outlet pipe.

Main return pipes are inclined down toward Circulator or emptying or discharge-valve.

One main flow pipe and one main return pipe with short branches are preferable to numerous small flow and return pipes from Circulator to each radiator, as the latter method reduces the temperature of the water before entering the radiators, introduces an unnecessary number of joints, occupies much space with pipes, is more costly, and is not needed to assist circulation where a well-designed heater is used.

Indirect radiators should have air pipes in preference to air valves, or the pipes should be arranged so that the radiators can free themselves of air through the flow pipes without using air pipes, air cocks, or air valves.

Indirect radiators need no stop valve on either flow or return pipes, as the regulation of the heat from them is controlled by the register valve, and dampers in air-mixing flue and cold-air ducts.

Provision may be made for the application of thermometers on the main flow and return pipes near the Circulator by means of inserted copper or brass caps screwed into the pipes or fittings and in which the thermometers may be applied as desired. Fixed thermometers screwed into the pipes are not desirable.

Fittings, tees, elbows, etc., on flow pipes should not have their openings reduced by the use of bushings. Reducing fittings may be used, but it is preferable, especially with tees, to make the reduction with a nipple and reducing coupling.

The casings for indirect radiators may be of tin, wood, or galvanized iron. In all cases the casing should be made as tight as practicable. Galvanized iron by itself is not as desirable a material for a radiator casing as when used in combination with wood or other covering because it transmits heat too readily.

An indirect radiator and casing should be connected to only one warm-air flue or duct.

A single warm-air flue or duct should not supply registers on different floors.

Warm-air pipes should be of tin or galvanized iron.

Warm-air pipes in exposed positions or in external walls should be constructed double or protected so that there will be but little loss of temperature to the heated air in its passage to the apartment to be warmed.

The cold-air duct to each casing should be fitted with a damper and connected to a by-duct or air-mixing duct which should also have a tight-fitting damper.

These dampers should have levers attached by which they can be adjusted readily and held in any desired position.

Cold-air ducts are made of wood tongued and grooved, and also of galvanized iron; the latter material is preferable. These ducts should be made air-tight so that the air from the cellar or basement in which they are located will not be drawn into them and allowed to pass up into the apartments warmed.

The cold-air duct should be connected to an air chamber which should surround the cold-air inlet opening. In this chamber there should be a baffle or some device to prevent the velocity of the wind affecting the air in the ducts and casings.

The cold-air opening should be fitted with a damper easily adjusted and accessible; outside this damper the cold-air inlet opening should be fitted with a screen of wire mesh.

A separate ventilating flue should be provided for each apartment in dwellings.

One or more ventilating flues or shafts should be provided in all buildings that are occupied and required to be warmed.

No indirect heating system is complete or satisfactory without proper arrangements for ventilation.

Ventilation is the most important part of a well-designed indirect heating apparatus.

The circulation of air is as much needed as the circulation of water in an indirect heating system.

Ventilation is as necessary to health as heat.

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