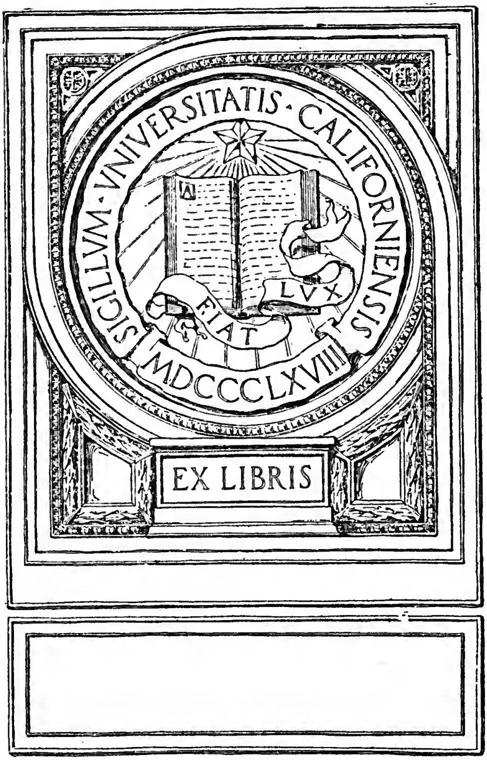
WARMING BUILDINGS BY HOT WATER

FREDERICK DYE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WARMING BUILDINGS BY HOT WATER

WARMING BUILDINGS BY HOT WATER

A PRACTICAL TREATISE

UPON

Warming Industrial and Residential Buildings,
Places of Worship and Horticultural Glass-
houses; Heating Drying-Rooms, also
Warming by Direct-Indirect and
Indirect Methods

EMBRACING

ALL LOW-PRESSURE GRAVITY AND ACCELERATED
SYSTEMS AND THE HIGH-PRESSURE SYSTEMS

BY

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PREFACE

The aim of this book is to provide a practical treatise on the subject of Warming Buildings by Hot Water; describing all recognized "systems" of piping, all methods adapted for particular purposes—such as residence work, the treatment of larger buildings, of places of worship, factories, horticultural glass-houses, etc.—and, added to these, a description of the fittings and appliances required. Although included in the foregoing general terms it may be separately mentioned that the High-Pressure system, with or without auto-control valve, is fully treated—more so than hitherto. In addition a new and full chapter is devoted to describing—and illustrating—all the present known Accelerated Systems, those relying on steam produced either by hot water boilers or steam boilers, also the means adopted to produce or accelerate a circulation mechanically. The newer method of warming open factories or warehouses by overhead pipes is explained, while the special requirements of church heating are described.

New information and tables are devoted to Quantities, with co-efficients for heat losses through various building materials; while, corresponding with this, is a chapter with table relating to Heat-emission from pipes and radiators. Calculations, with table, for finding pipe sizes is also newly treated.

One of the early chapters will be found to deal with the advantages of warming buildings, particularly residences, by hot water. This cannot be considered a practical part of the book, but is given in the belief that it may be helpful to those who follow this calling. It will put into their mouths a catalogue of the many real benefits that this mode of warming affords, and may in season enable an engineer to secure a wavering customer. The author has lived for many years in houses warmed by hot water, which enables him to describe what really marked benefits hot water as a heating medium affords.

Another early chapter is devoted to a fully detailed description of the parts of a simple form of hot water apparatus, this being given with the view to enabling a student to read the matter up from its elementary beginning. Failing this the book might be considered as more suitable for fitters of some experience; but, as stated, the idea has been to include an elementary chapter for the beginner.

Amongst other details is included what is new in a treatise on this subject, viz., information, and a table, enabling heating installations to be tested in any winter temperature other than that which figures in the guarantee embodied in a contract. This was the substance of a paper read by the author before the Institution of Heating and Ventilating Engineers and which gained their medal.

Owing to the wide degree of misconception that exists regarding the effects of heat in Drying-Rooms, this subject is given a chapter with the view, not so much to show how heat can be afforded in such places, as to make it clear how it can be utilized with advantage. The chapter is largely devoted to showing that heat by itself has no drying qualities

—that to heat goods in a closed room will not dry them. There must be ventilation, for it is air that is the drying agent and the warmer the air can be made the more thirsty it will be. The best results are therefore obtained by heating air and causing this to pass through the rooms in a continuous stream, circulating past the moist goods and then (after absorbing moisture) to pass away.

A final chapter is devoted to Indirect Heating—warming by air heated by passing over radiators enclosed in chambers. This necessarily embraces some mention of direct-indirect or ventilating radiators, their use and the work they will do.

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WARMING BUILDINGS BY HOT WATER

CHAPTER I

THE ACTIONS OF HEAT, ETC.

THE sensation experienced when approaching or touching anything of a high temperature, was originally attributed to the action of some subtile material, matter or fluid, which pervaded all hot substances; this delicate material being impalpable to our vision, and all our senses except that of feeling. This was known as the Material Theory. Now it is quite decided and recognized that heat is only a peculiar manifestation of motion—a minute but rapid movement of the particles (molecules) of which all descriptions of matter are composed. The rapidity with which the particles move is the index to the temperature; the more rapid the movement, the greater the heat, while a less rapid action manifests a less degree of warmth. This is known as the Kinetic (motion) Theory. Put briefly, we may say that this theory is based on the fact that by motion heat may be produced (the friction of a machine-bearing, if not oiled, proving this), while by heat we may produce motion or energy, both directly and indirectly.

Heat transmits or manifests itself in three ways, viz., by—

1. CONDUCTION.
2. RADIATION.
3. CONVECTION.

All three actions intimately concern the heating engineer and a knowledge of them is essential for the proper understanding of heating works of all kinds.

I. The Conduction of Heat

This action may be said to be confined to solid materials. Fluids, both liquids and gases, possess conductive powers in a degree; but it will be seen, by studying the subject of Convection, that fluids cannot successfully utilize any conductive properties they may have. Air, in fact, ranks as a poor or bad conductor.

Materials are said to be good conductors or poor conductors according to their heat-conducting powers; and these terms have the plainest of meanings when it is known that no two materials, of the vast number that exist, have exactly the same powers in this respect. The term "non-conductor" is a misleading one, as nothing exists that is totally devoid of the conductive property, and it would be well if this term had no existence in the heating engineer's mind.

The Conduction of Heat is that action which causes heat to travel along, or through, a solid substance which is not exposed to heat at all parts. A familiar example may be quoted in noticing what happens to a length of rod iron or a poker when it has one end thrust into a fire. It may have been icy cold when put in, but in a brief time the end which is outside the fire is unbearably hot, even though it may be shielded so that the fire does not shine on it. The heat has travelled up the rod, from the end in the fire, by conduction. A more interesting example may be seen in an ordinary heating boiler. If the metal of which it is composed was not a conductor of heat, it is obvious that the heat from the fire would not be transferred to the water. In the same way if the heat contained in the water within a radiator found a barrier in the iron of the radiator, then no warmth could escape or be distributed into the room or place where the radiator might be situated.

The transmission of heat by conduction varies in different materials, as stated; but fortunately iron, a cheap metal, is a good conductor, sufficiently so to make iron boilers and heating appliances highly successful. The table most usually relied upon for the comparative values of materials in heat conduction is that of Despretz, which is as follows :—

Silver	97·3
Copper	89·8
Brass	75·2
Cast iron	57·0
Lead	18·0
Marble	2·3
Firebrick	1·1
Water	0·9

A better known authority in England is Thomas Box, whose treatise on "Heat" is a recognized standard work and his table (abbreviated) is as follows :—

Copper	515·0
Iron	233·0
Zinc	225·0
Lead	113·0
Marble	28·0
Brickwork	4·8
Indiarubber	1·8
Coke dust	1·3
Woods (average)	1·0
Chopped straw	0·6
Ashes	0·5
Sawdust	0·5
Cotton and sheep wool	0·3
Eiderdown	0·3

This table, it will be noticed, affords information as to the comparative values of poor conductors, showing what a high resistance to heat-transference (which means heat-loss in certain cases) some materials exert. Silicate cotton, which is a material largely used for covering pipes and surfaces with a view to preventing loss of heat, would rank as 0·3 in the table just given ; while hair felt, which is made of cow and horse hair, would rank as 0·3 also. In other words, these two materials are the best known materials we have, easily obtainable, to prevent loss of heat from hot surfaces.

It will be recognized that while a hot-water heating apparatus is specially designed and erected to lose heat in rooms, yet if it loses heat anywhere else the loss must mean wasted fuel. In other words, every effort is made to make the apparatus part with its heat in the rooms and places to be heated, but nowhere else; and this makes information relating to poor heat-conducting materials useful. Pipes and similar hot surfaces which are not required to emit heat can, by being suitably covered, have their heat emission reduced by 75 per cent. or three-fourths.

There is a peculiar property relating to the conductivity of iron now to be considered, as its application is somewhat common. This property has been termed "diffusivity," meaning the power that metals have of diffusing heat over or through a large area of their substance. It is only another name for conduction, but the action bears a different application. If we take a hot-water pipe and fill it with water at, say 160° F., the heat of its outer surface will be practically the same temperature. But if we add a number of solid gills to the pipe, as Fig. 1, the heat will quickly travel into these plates and so become diffused over a much greater area. It must not be thought, however, that the whole will become of a temperature of 160° F., and it will be found that with the increased area there is a decrease of temperature. In other words, we get a large surface area at a moderate temperature, instead of a much smaller area of surface at a high temperature. The total number of heat units that could be emitted from the heated surfaces in either case might be considered as the same, but with the larger surface a greater volume of air can be warmed, as the small intensely hot surface is made into a larger surface at a more usefully effective temperature.

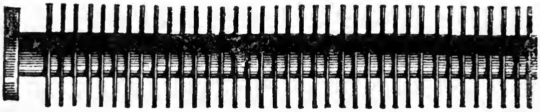

FIG. 1.—Hot water pipe with solid gills cast on.

A familiar instance of the utility of gills or feathers attached to hot surfaces may be cited in what is usually called the Gill-Stove. This is a cast-iron stove built up of sections, but forming in reality an arched-top shell stove with gills about $\frac{3}{4}$ inch apart all along the exterior. It has no firebrick lining, so that the part nearest the fire—the shell—would quickly be at a red heat ; but the gills take up the heat, and by diffusing it throughout their large surface (they project about 6 inches from the shell) the temperature is not dangerously high, while the surface for warming the air and surroundings is possibly six times as great as a plain stove could have.

The gilled pipe shown in Fig. 1 is largely used in some continental countries for hot water and steam work, but it is a little difficult to see the advantage when hot water is the heating medium, for the temperature of a plain hot-water pipe is not high, and to reduce it at all materially is not necessary. The heat of steam will bear reducing with some advantage. Gills, or similar solid projecting parts, are of service on pipes, and what are termed indirect radiators, when it is required to stack them closely, expressly for air to pass through rather swiftly, yet to receive heat. The spaces between the heating surfaces must not be large if air is to pass through rapidly and yet be warmed. Indirect radiators are used for fixing in boxes, or other enclosed spaces ; these boxes having cold air inlets and warm air outlets, the latter leading into the rooms or places to be warmed. The warmth is thus obtained wholly by warmed air ; and to ensure the air being warmed, the radiators are so constructed as to compel the incoming cold air to rub against the hot surfaces. Fig. 2 shows such a radiator, and it will be seen that, enclosed in a moderately close-fitting box, it would be difficult for air to get through without being raised in temperature.[1] Therefore, it may be considered that gilled pipes or surfaces in hot-water works are intended, not to reduce temperature, but to break up and

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[1] The projecting parts are not always gills. In some cases they are pins, or other shaped projections, but all are intended to serve the same end.

reduce air passages between otherwise plain and open heating surfaces.

It will be understood that these remarks relating to diffusivity only apply to solid gills or projecting parts. If gills were made hollow, so that the heated water (or gases from a fire) could enter and work through them, they would then be of the fullest temperature throughout, and no diffusive action would have to be considered.

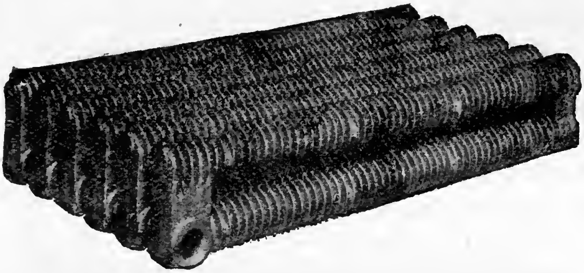

FIG. 2.—Indirect radiator stack, of tubular sections with solid gills cast on.

II. THE RADIATION OF HEAT

The radiation of heat is an action that entirely differs from that of conduction, in that it is the projection of heat rays through the air from the outer surface of the heated object. It would be more correct to say that the rays pass between the particles (molecules) of which air is composed, for radiant heat has the peculiar property of passing through the air without warming it. This heat travels from every hot object in rays or beams, these travelling in straight lines, and their heat is only manifested when they strike on a body or object. Thus, if we stand in front of a fire, we become warm by radiant rays striking us, but they only strike on the side facing the fire. If a screen is interposed, the rays are no longer felt; nor are they if the body or object is in any part of a room out of sight of the fire. A further familiar example can be given in pointing out how the shade of a tree prevents the sun's heat being directly felt, and the same example exists in the use of a lady's sun-shade. These show that the rays have to actually strike against an object to warm it, also that these rays travel in straight lines, not bending or travelling round any obstacle coming in their path.

It may be further explained that radiant heat-rays diverge or open out as they leave their source, or, more correctly stated, their intensity diminishes as they reach further from their source. This loss of intensity is inversely as the square of the distance, and Fig. 3 will make this clear. It will be seen that as the rays leave their source they affect a larger area, but this area is of a less intensity as to temperature. It is this action that accounts for our feeling the heat increase in intensity as we move nearer to a fire, or of less intensity over a larger surface as we get away from it.

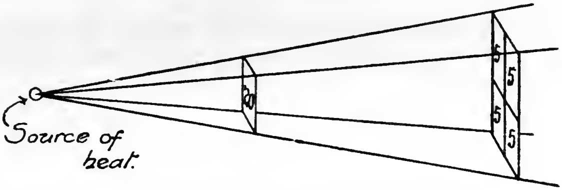

Fig. 3.—Illustrating the increase of area affected, with decreased intensity, as radiant rays travel from their source.

It might naturally be thought that if radiant heat fails to warm the air, then the air of a house (heated by fire-grates only) would always be extremely cold in winter weather; whereas we know by experience that, in an hour or so, the air in the rooms of such a house becomes comfortably warm, or even too warm. This is due to the radiant rays striking against the walls, floor, articles of furniture, etc., and these, when warm, cause the air which has contact with them to be warmed. In such a house, therefore, the warmth in the air is derived from its having touched objects which have been heated by radiant rays. The action of air on becoming warm is the subject of the third division of heating—viz. Convection (see page 10).

Although the radiation of heat from red-hot bodies interests the heating engineer in its relation to boilers and furnaces, the radiation from hot-water pipes and radiators proceeds from much cooler surfaces, and has no luminous source. With non-luminous bodies the outer surfaces have much to do with the results, and it is usual, with these, to say that the rays of heat proceed from the skin of the object. On this account the nature of the outer surface of a pipe or radiator can make a marked difference in the amount of heat radiated, but, fortunately, practically all paints give a suitable skin.

The following table will serve to show how radio-activity varies with different substances and surfaces :—

RADIATING AND ABSORBING POWERS OF SUBSTANCES

(The heat-radiating and heat-absorbing powers of materials are equal, but their reflecting powers are in inverse ratio.)

Lampblack	100
White lead	100
Water	100
Glass	90
Cast iron (natural surface)	60
Oil (film)	59
Tarnished lead	45
Cast iron (polished)	25
Wrought iron (polished)	23
Zinc (polished)	19
Silver and copper (natural surface)	12
,, ,, (highly polished)	3

Metallic oxides and earths, which go to form paint, rank as good radiators, therefore, as stated, there is no colouring matter that has to be condemned. Varnish is also a successful radiator of heat. What has to be guarded against is a polished surface ; and, although the writer has no test figures before him, yet everything points to bronze powders being poor radiators of heat. In conducting some experiments, however, it was found that a coating of lacquer or varnish completely altered the radiating qualities of a polished surface, making it rank but little below a painted surface.

The painting and general decoration of radiators will be found treated in a later chapter ; but it will be seen that, while plain cast iron is a good radiator, it can be actually improved by being painted.

Having devoted space to the description of radiant heat and its qualities, it is now necessary to point out that this subject is of much less importance than it appears. Perhaps it should be said that radiant heat does good and active work from the glowing fuel in boilers, but the amount of heat it gives into rooms heated by hot-water pipes and radiators is comparatively small. The term " Radiator," which is given to the heating appliance bearing this name, has the advantage of sounding well, and it also does something towards making hot-water work appear very hygienic and health-giving (as it really is) ; but if we had to rely wholly on the radiant heat given off by hot-water radiators (or pipes), then this mode of heating would be expensive and objectionable, on account of the size of the radiators required for even fair results.

Let it be clearly understood, that a hot-water apparatus affords warmth chiefly by warming the air. It is doubtful if any authority has been able to state what proportion the radiant heat bears to convected heat (see page 10) in the total warmth afforded by radiators or pipes ; but if radiant heat is credited with one-fifth of the whole (warmed air four-fifths), it is giving the radiant heat the best possible value. It is practically impossible to obtain radiant heat from these surfaces without heating the air of the room, otherwise a test could easily be made, but a thermometer fixed 24 inches in front of a radiator, and one fixed 24 inches above (in the stream of heated air rising from it), show very different results. Again, quite a marked decrease in the warmth of a room is experienced if a very loose-fitting shallow open box is inverted and placed over the top of a radiator, to retard the rising current of warmed air from it. Or, if a radiator is carefully surrounded at sides and top with a wood casing, and a strip about 4 inches high fastened across the lower part in front, thus leaving only the front of the tubular part of the radiator exposed, it will prove a very inefficient heater. As will be seen, this device prevents, as far as possible, a flow of air up through the radiator, though it makes but little difference to the heat radiated from it.

The average engineer considers that this information should not be too freely discussed, as there is a strange prejudice in the public mind against warmed air. Radiant heat is more in demand, the public not knowing that this form of heat does not offer the same degree of uniformity and comfort. Take the evening of a summer day, and note what it is that makes the temperature—the atmosphere, everything that our senses experience—so very agreeable. It is not the sun, for that has set. There is some radiant heat from warmed objects, but no greater proportion than that given by a hot-water radiator. It is warmed air that is so agreeable; it pervades all space, the source of heat not being from one point but from all points, for the earth, walls and all things the sun has shone upon during the day are now acting as low-temperature radiators. It is by no means an exaggerated analogy to consider the hot-water boiler as acting the part of the sun, for both afford the ultimate heat—the warmth we feel—by the same means when the sun is not visible. Both cause objects to distribute warmth, a little by radiation, but mostly by warming the air. The air is not warmed by the sun, but by the objects heated by the sun. If we relied on radiant rays alone, then we should be bitterly cold. If people ascend to a great height in a balloon, they are approaching a little nearer to the sun than those on the earth, yet the nearer they get the more likely they are to be frost-bitten by the intense cold, even though the sun be shining brightly all the time.

III. The Convection of Heat

The subject of Convection (*convcho*, to carry up) deals wholly with the action of heat upon fluids—air, gases, and liquids. The action of convection largely ceases, however, when liquids boil, that is, it is interfered with; but of course the water in a hot-water heating apparatus is not required to reach boiling point, therefore this detail does not require special consideration.

To understand this action, which is a peculiar one, and of chief importance to the hot-water engineer, it is necessary to inquire into the physical properties of liquids and gases. First, it must be explained that all fluids exist in the state of a mass of exceedingly minute particles, which are termed molecules. These are said to possess the property of mobility to a very perfect extent, as they are able to move up, down, or around one another, absolutely without resistance or friction. No one has seen a molecule of water or air; but from the property just stated it might be assumed that they are round, like minute ball-bearings. Even with polished steel balls it is possible, with care, to pile them up a little, yet no one can get a pile of water, however small. Some authorities have argued that a repelling influence must exist amongst the particles, as both water and gases, if free to move and spread out, always cover the utmost possible space, and readily separate into distinct globules. This scarcely interests the heating engineer, except that it shows what an absence of friction there is amongst the molecules of which water and air are composed.

Assuming, therefore, that a vessel of water is in reality a vessel containing a vast number of minute liquid particles, let it next be seen what happens to these particles when heat is applied. In this the student is strongly recommended to make the simple experiment here described. Take an ordinary glass jar, place this on a stand, or suspend it by a string, so that there is room to place some kind of lamp beneath it. Nearly fill this jar with water into which has been stirred some amber-dust—or the fine dust (obtained by filing) of a hard wood, such as walnut, mahogany or box-wood will do. If much of the dust collects at the top, skim it off, as there will be plenty left suspended in the water to show any movement that occurs.[1] Place a spirit lamp or an oil lamp, as Fig. 4, beneath the jar at one side, and watch the water. It will be found that a move-

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[1] It must be explained that water in glass vessels or pipes is invisible, and any movement in the water equally so. The particles of amber or wood enable any movement that occurs in the water to be readily seen.

ment occurs almost immediately, the particles over the lamp ascending, while those on the more distant side descend; and a constant circulatory movement is set up, and continues as long as the lamp is alight. If the lamp is shifted to the other side the movement will gradually, yet swiftly, reverse itself. If the lamp is placed centrally under the jar, the ascending movement will be in the middle and the descending movement round all sides.

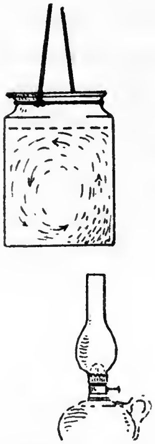

FIG. 4.—Simple means of making visible the circulatory movement of water when heated.

Several things may be noticed from this simple experiment. One is, that the water commences to move at almost the same instant as the lamp is placed beneath. Considering that the bottom of a jar is thick, and that glass is an exceedingly poor conductor of heat,[1] it is remarkable how soon the water commences to move. It goes to show very clearly that quite a minute difference in temperature is sufficient to set up the circulatory movement—the action of convection. This should be particularly noted, for there is a common impression that this movement cannot always be obtained. A man says he cannot get a circulation in his pipes, and supposes that the boiler is not powerful enough. This must be wrong, as quite a trifling difference in temperature will set up a strong movement; and it may be said that a real difficulty should be experienced in preventing the water circulating, once it is warmed. It may be taken for granted that a very little heat will cause a good and free circulation to set up if the general conditions are correct and favourable. A few minutes expended in the simple experiment suggested will prove this.

The theoretical explanation of the action of convection is this: when heat is applied to the bottom of a vessel con-

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[1] If a strip of glass, only four inches long, is taken in the fingers by one end, while the other end is held in a gas flame until it is red-hot, the fingers will experience no disagreeable degree of heat.

taining water (or any fluid), those particles nearest the bottom of the vessel absorb heat, i.e. they become warm. Practically everything in nature expands and becomes of greater bulk when warmed, and the particles of water are no exception to this rule. Therefore, when heat is applied to the bottom of a vessel of water we may imagine the particles nearest to the bottom increasing in size. This increase in size is not accompanied by any increase in weight, consequently the expanded particles become lighter, bulk for bulk, than the colder ones above. So soon as this happens it follows that the warmed particles must rise, for no substance lighter, bulk for bulk, than cold water can remain at the bottom of a vessel when cold water is above. Supposing a piece of cork were plunged to the bottom of a vessel of water, would it remain there ? it could not, because, bulk for bulk, it is lighter than water ; and the particles of warmed water may be likened to particles of cork, for they must, on account of their lessened weight (compared with their bulk), rise to the top.

It is most important that the true action that occurs should be recognized. There is a too common impression that heated water rises of its own accord ; that the heat gives it some power to rise. It is nothing of the kind. If heated water is put into a glass, it does not rise and flow over the sides. *The only cause of heated particles of water taking an ascending course is the superior weight of the cooler particles.* These cause the heated particles to ascend, and were this cause absent the hot water would rest quietly where it was heated.

To prove this explanation to be correct the action can be reversed if desired. Fill a glass vessel with warm or hot water, having amber or wood-dust in it to make any movement visible, then apply a piece of cold iron or ice to the top of the water and note the results. There will be a circulatory movement much the same as with the previous experiment, but it will be due to the cooling of the top water,[1] and not the heating of the bottom water. If

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[1] The falling of cool air at windows is due to warmed air coming in contact with a cool surface, the particles becoming contracted and heavier, bulk for bulk, than the warm air and, in consequence, falling.

the source of heat or cold is applied in a reverse way—that is, heat to the top of cold water, or cold to the bottom of heated water—no circulation will occur.

Air acts in precisely the same way as water when it is heated, except that it moves even more rapidly. As stated when dealing with the subject of RADIATION, it is the warming of the air by radiators or pipes that accounts for the pleasant degree of warmth obtained. Radiant heat, though good to talk of, does little work from radiators or pipes. It does some of the best work from incandescent fuel in boilers, but from comparatively low-temperature surfaces it does little. As stated, radiators warm rooms by radiant heat and convected heat (the heating of air), but the proportion is at the best only about 1 of the former to 4 of the latter. It is therefore highly important that the circulatory movement of warmed air from radiators and pipes should be assisted and made effectual by every possible means.

What has to be aimed at is the quickest and most even distribution of the air that is warmed; and no mechanical aid is required to effect this if the warmed air is allowed to circulate freely (as it readily will) and no obstacles to the movement are allowed to exist. To obtain this, it is requisite that air shall have free admission to the hot surfaces, particularly beneath them, and that the air when warmed shall be allowed to rise freely from the top. Radiators are best without ornamental tops, marble or iron, on this account. The heated surfaces give the quickest results if they are vertical, and this is obtained in all modern radiators. They must also be clean, and the sections not too closely packed. With these conditions the warmth will be so well distributed that a person occupying a chair at B, on one side of a room, will experience quite as good a temperature as a person at A. Fig. 5 shows the position of the chairs, the movement of the warmed air from the radiator on the right being indicated by broken lines.

The study of air-movement when the air is heated can be profitably undertaken, as it often influences results. It gives a correct idea as to where radiators or pipes should be fixed to afford the best and most uniform results. It will be found referred to more generally under the descriptions of example works.

THE COMBINED ACTIONS OF CONDUCTION, RADIATION, AND CONVECTION IN A HOT-WATER HEATING APPARATUS

In perusing the separate descriptions of the actions of Conduction, Radiation, and Convection, it will have been noticed that all three take important parts in transferring heat from the burning fuel to the rooms which are to be warmed, and the absence of either action would bring about failure.

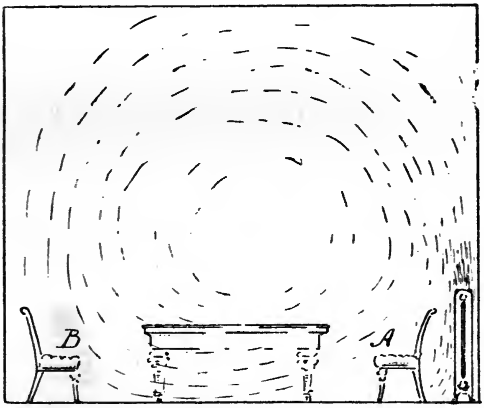

FIG. 5.—Illustrating the movement of air in a room when warmed by a radiator.

Starting at the firebox, there is radiant heat performing an active part when the fuel is in an incandescent state; and, were it possible to keep the fuel in this condition, many boilers would be much more effective than they are. This, however, is not practicable, as the boiler of a heating apparatus commonly—usually, in fact—has to take a charge of fuel that will last some time without attention, and this keeps the top of the fire covered, or in a dull state, for a considerable period after each occasion that stoking is done. In large buildings and institutions, where an engineer is kept, the fires may be kept in better condition, and boilers are worked closer up to their actual power, but with the majority of heating works the stoking is of an unskilled kind, and radiant heat in the boiler only does work intermittently. As stated, when describing the action of Radiation, radiant heat from glowing fuel is a very effective form of heat-transference, but from dark low-temperature objects the radiant rays do comparatively little.

In a boiler, heat transfers itself from the fire to the plate in two ways: one is by radiation, as described, this affording heat to the surfaces upon which the fire shines; while the other is by contact. There is contact of the hot fuel, and contact of the flames (if any) and heated gases. In the case of heat from flames and heated products of combustion, it has to be remembered that neither of these can be considered to afford much heat unless they actually touch the surfaces to be heated. They certainly give off some radiant rays, but these are of little value compared with the heat obtained by contact. Any simple experiment will show this: a piece of thin wire held close to a flame will become fairly hot, but nothing more; but if held in the flame it becomes red and then straw-colour in a few seconds.

This peculiarity of flame (and hot gases) requires consideration in flue making, for bad results are still more easily obtained by the fact that flame has a tendency to float between surfaces—to avoid touching them, if it can. Flame and gaseous heat must be *made* to touch the surfaces, and this is effected by making the flues as narrow as possible, and with as little bottom surface as can be had. A flue of this section **O** is more desirable than this **o**. Vertical heating surfaces are not the best, but they are much superior to a surface beneath the source of heat when the latter is a flame.

Assuming that the best has been done to cause the heat from the fuel to come in contact with the boiler plates, it has next to pass through the metal. This degree of transference readily occurs by Conduction, as will have been understood (see page 2), and it may now be supposed that the heat is on the water side of the plates. Water is a good absorber of heat (see page 8), so good that it is considered to be able to take up heat from a boiler plate two and a half times as fast as the plate can receive and conduct it. It is the action of Convection that accounts for this, for as fast as the heat comes the molecules of water receive it, and are as immediately replaced by others greedy for heat. If the heated molecules did not move, then the absorbing power of water would bear a different figure in the table.

As soon as the heat is felt, and absorbed by the water, Convection is set up, and the heated water is soon in swift movement through the pipes (see Chapter II., THE CIRCULATION OF HEATED WATER), and in a short time the heat is against the inside walls of the radiators or pipes, which are fixed with a view to distribute the heat. Here the heat finds itself enclosed in a space composed of a material (iron) which allows of its readily reaching the outside by the action of Conduction. From the outside it is distributed, partly by Radiation but chiefly by Convection, in warming the air (see page 10).

Between the furnace and the radiators,[1] however, these actions can occur to the prejudice of the apparatus, and this should always have the careful consideration of the engineer. An ideal apparatus would be one in which the fullest possible proportion of the heat evolved from the fuel was delivered from the radiators or pipes in the rooms (or whatever place is being heated), and the engineer has to arrive at this ideal state as nearly as he can. It is loss of heat that he has to guard against, for this means waste of fuel, less heat in the radiators, much slower results, and sometimes an inefficient circulation. The distributing pipes between the boiler and radiators, also the outer surface of the boiler itself, are all heat losers, and as they are nearer to the source of heat than the radiators, they are of a higher temperature and lose heat faster. These pipes and surfaces should always be covered (as described in a later chapter), and heat emission should be restricted to those places where the heat is wanted.

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[1] In speaking of radiators it will be understood that any description of radiating appliance is meant, including coils, plain pipes, or whatever may be used.

The Unit of Heat

Although in the past the average heating engineer has made but small use of the Heat Unit when calculating the area of radiation required, or when making other calculations necessary to the proportioning of a proposed heating installation, yet but little consideration will show that only by this means can any exactness in results be ensured. This is necessarily dealt with more fully in the later chapter on calculations for radiating surface (Quantities), and it is only necessary to say here that the heating engineer in future, whatever private rules or practices he may follow, must, at least, be prepared to make his calculations in British Thermal Units. A common practice is to adopt more than one means of finding quantities, an exact and a quicker means, one to check the other. Both means are dealt with in the chapter devoted to "Quantities."

The British Thermal Unit, or B.Th.U. as it is usually written, is the unit of heat employed in calculations in this country, and commonly spoken of as the "heat unit."[1] It is that amount of heat required to heat one pound of water one degree Fahrenheit. The degree is from 32° to 33°, and for very precise work this would have to be borne in mind; but for general purposes the unit is given the same working value at all temperatures.

The unit of heat, or B.Th.U., which will heat a pound of water one degree will heat 52 cubic feet, or 4$\frac{1}{5}$lb., of air one degree also, and no engineer is long in discovering that air is more readily warmed than water. In fact, gases and most solids require less heat for a given rise in temperature than water (this being termed specific heat). With water as 1·000, iron is 0·130, copper 0·095, mercury 0·033 and

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[1] As will be seen in the Appendix it has been proposed by the Institution of Heating and Ventilating Engineers that the term British Thermal Unit, or even B.Th.U., being rather cumbersome, shall be abandoned and the word "Therm" substituted, this in writing being represented, when desired, by the symbol θ. At present the proposal is only at the recommendation stage, it being proposed to circularize the different engineering institutions for their approval so that the change may have general acceptance. See Appendix.

lead 0·031. Even ice stands at 0·504, alcohol 0·622, petroleum 0·434.[1]

It follows that if one heat unit will raise a pound of water one degree, it will require fifty units to raise it fifty degrees, and so on. In the same way if a gallon of water, which weighs ten pounds, has to be raised in temperature one hundred degrees, then it will take a thousand units to do it; or perhaps it should be said that the water will have absorbed one thousand units in attaining this heat.

It is estimated that high quality coal can yield 14,000 heat units per pound, while coke is given a heat value averaging 12,000 units. As to what number of these units are absorbed by the water in a hot-water boiler, must rest with the boiler-maker, the pattern of the boiler, the draught in the chimney, and the person who attends to the fire. For practical purposes it is not safe to estimate on obtaining more than three-fifths (60 per cent.) in the water.

In regard to the number of heat units given off by heated surfaces, if a radiator is considered to be at full heat at 160°, and the air around it to be 60°, then the loss per square foot of surface per hour is about 150 units (depending on the kind of radiator). If a room has 1000 cubic feet of space (air) in it, and 1 unit will heat 52 feet of air 1°, it will require 20 units to heat the room 1°, or 560 units to heat it from 32° to 60°. According to this, 4 square feet of radiator surface would suffice to afford a 28° rise of temperature in this room, *but this it will not do.* If there were no changes of air and no heat-loss, this calculation might be correct, but under actual conditions this area of radiation must be multiplied about four to five times. With a room having a normally effective chimney in it the air is being continually changed; then there is the loss of heat by glass (windows), and a certain loss through the walls, etc. The area of glass influences results greatly, as will be found under the chapters entitled QUANTITIES. It will be seen, in the chapters just referred to, that a lean-to conservatory, having a brick

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[1] It should be stated that any substance taking a small amount of heat to raise its temperature has only a correspondingly small amount to be given out in cooling.

wall forming its highest side, and brickwork all around to about 30 inches high, requires about four times as much radiating surface (for a given size and given temperature) as a brick-built room, although the room may have a good sized window in it, and have a much more active air movement for ventilation.

The Calorie is a standard of heat measurement used in most Continental countries. It is the amount of heat required to heat 1 kilogramme of water 1° Centigrade, viz., from 15° to 16° C. The Calorie is equivalent to 3·9672 B.Th.U., or practically 4 British Thermal Units. This unit of heat is always coupled with metrical measurements and quantities, and these are given in the APPENDIX at the end of the book.

The comparative thermometric scales of Fahrenheit, Centigrade and Réaumur are given in the APPENDIX at the end of this book.

CHAPTER II

THE CIRCULATION OF HEATED WATER IN PIPES, ETC.

THE actual cause of the circulatory movement that occurs with water when it is heated, is described in the previous chapter, under the heading of CONVECTION, on page 10. There the movement was shown confined to a single vessel; and when heating by hot water was first attempted, the circulation was also confined to single pipes. A boiler, much like an inverted large-sized basin, had a furnace beneath it, and from this boiler extended one or more sloping pipes, as in Fig. 6. These pipes could not extend far, but would serve to heat a glasshouse of moderate size. It will be readily found that heated water will circulate in a single pipe from a boiler. If the pipe is vertical the circulation is quite free, up the centre and down the walls or sides of the pipe; if it is sloping (upwards from the boiler) the water ascends along the top and back along the bottom. About twenty degrees is the least slope, and then it requires to

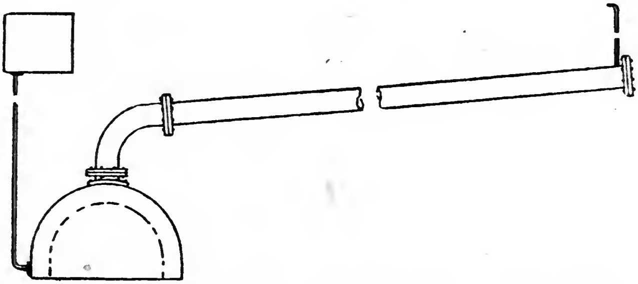

FIG. 6.—The oldest form of hot water heating apparatus with single "circulating" pipe.

be a full-sized pipe. The single pipe circulation, however, had a comparatively short existence, as it was soon found that two pipes could be used to greater advantage.

Nothing can give a better illustration of the circulatory movement of heated water in pipes than a few simple experiments with an apparatus of glass tubes, and it is strongly recommended that every student practise this. On page 12 was shown an extremely simple method of *seeing* the circulation of water heated in a vessel, and but little extra trouble is required to get a valuable experience of the movement in an apparatus of pipes.

In Fig. 7 is shown such an experimental apparatus in its

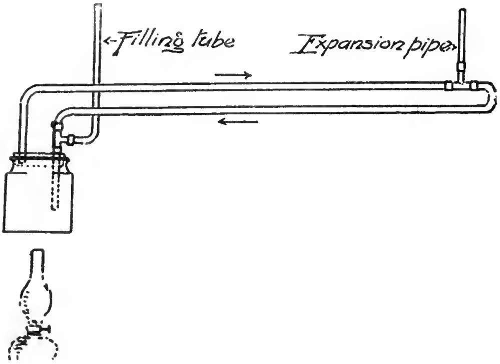

FIG. 7.—An inexpensive model to make visible the circulation of water in pipes.

most simple form. A small glass jar, securely corked, a few feet of $\frac{3}{8}$ inch glass tube (obtainable at most chemists for a few pence), and the expenditure is nearly ended. The joints are made with short pieces of rubber tube, a size smaller and stretched on, while tee pieces can be formed of zinc or copper tube. The model is filled with water, in which has previously been stirred some amber or wood dust (see page 12), and a lamp beneath will immediately start the circulation.

Of course such a simple arrangement as that just illustrated will do no more than show the action of the circulation out of and into the boiler, but the materials used admit of arranging the apparatus to suit anything that requires investigation. Not only is instruction to be gained, but many are the problems the writer has solved by this means. A student or engineer, interested in this work, will find this simple model of glass tubes a source of much instruction and gain. The effects of dips in pipes, the causes of retarded circulation, the best (or otherwise) methods of branching, the peculiar actions of air in horizontal pipes (a highly important but neglected subject), and scores of other instructive things, are all made plain, and the reasons easily ascertained. One detail, little known, will be made very clear, this being that the circulatory movement commences practically everywhere at once. There is a common idea that after lighting the fire the circulation must be confined to the boiler for a time, then to the nearest circuits, and so on. Instead of this, the instant a movement occurs in the boiler, there will be found an almost immediate movement everywhere.

In constructing this model, every detail of an ordinary hot-water apparatus must be included. The filling tube is equivalent to the cold-supply service, and a tin tank can be put at the top of this if desired. The expansion pipe must also be put to allow for air escaping, particularly when charging or filling with water. It must be admitted, though, that considerable instruction can be obtained by omitting or temporarily stopping either of these pipes—or trying to make one serve both purposes—for more can be learned from a faulty detail than from a perfectly working apparatus.

One peculiar result that can be obtained with this model is that of a regular circulation occurring when the pipes in the jar or boiler neither project down inside and are quite level at top. It might be thought that no circulation would occur, but instead of this the movement commences as quickly and continues to flow as freely, as if the pipes were one high and one low, as customary. The different heights at which the pipes join a boiler, or terminate in it, are quite unnecessary so far as obtaining a circulation is concerned, but with the ends level there is no certainty as to which pipe will constitute itself the flow pipe and which the return. It is, therefore, a proper practice to connect the flow pipe at the extreme top of the boiler, and the return at the bottom or near the bottom. The pipes can then be described by their respective names before the apparatus is tested, as there is a certainty of the highest pipe acting as the flow and the lower one as the return. With level pipes there would be a decided uncertainty, and, strange to say, the writer has found that at separate tests one pipe will act as the flow on one occasion and be the return at another time.

It will be seen from the description given as to the cause of the circulatory movement of heated water, on pages 12-13, that the action must be strongest when the water has to travel straight up and down; and the height of the two columns of water must also govern results. Perhaps the chief factor in varying the speed of the circulation is the amount of heat lost by the water. The greater the difference of temperature of the water in the flow and return pipes, the greater must be the difference in weight of the two columns—for temperature is equivalent to weight in this respect; but it is only in vertical height that this counts, as the water in horizontal pipes does nothing to cause a movement. Therefore a high apparatus, consisting chiefly of vertical pipes, must have the strongest circulatory movement, provided it is constructed in a correct manner.

It is seldom, however, that an apparatus, even when high, does not have a considerable amount of pipe running in horizontal directions; but, happily, water is so ready to move and circulate when it receives heat, that the amount of vertical pipe may be quite small compared to that running in other directions, and yet make a perfect working apparatus. By referring to Chapter IX., in which hot-water works devoted to horticultural buildings are described, it will be found that an apparatus may consist of hundreds of feet of pipes, yet the total amount of vertical pipe in it may be no more than six to ten feet. Such an apparatus will work well in all respects and give no trouble. All pipes in such an apparatus (and all others) are given a gentle rise from the boiler to their most distant points, but this is to facilitate the escape and discharge of air more than anything.[1]

The engineer has to use judgment, and exercise his best skill, when an apparatus has to consist partly of vertical and partly of horizontal pipes. Most works are of this kind, but this fact does not make the difficulty any less. It is not a trouble when the upright and horizontal pipes are merely a continuation of one another. It is when the pipes are branched, as they have to be. Take Fig. 8 as an example. This shows a vertical branch from low horizontal mains, and, without the aid of a regulating stop-valve in the vertical branch it would be difficult to get a good circulation through the horizontal work which is beyond this branch. The vertical circulation will be much the stronger, and this tends to decrease and retard what would otherwise be a normal circulation along the distant horizontal piece. This is one of the instances in which the difference in strength of circulation must be considered ; it is not that the horizontal part of the work would not ordinarily have sufficient movement, but that branches may interfere with it. In the instance just given the vertical flow could be checked by

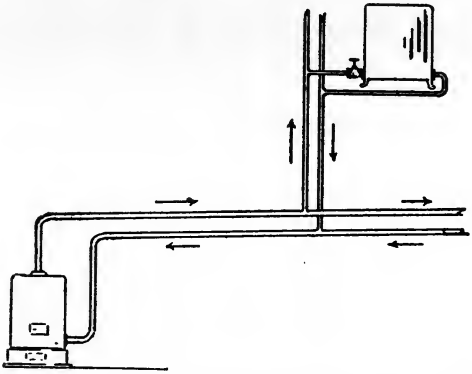

FIG. 8.—A vertical branch circulation which can prejudice the more distant horizontal piece.

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[1] The subject of Air in Pipes will be found treated fully in a later chapter. It is a subject of considerable importance.

using a small pipe for part of it, or inserting a stop-valve (which should have a key that can be removed when the valve is set); but the better plan would be to commence this branch horizontally for a few feet, or by running a distinct circulation from the boiler, if it should be at all near; or there will be found other ways of overcoming the difficulty, according to the conditions.

One of the best plans that can be adopted in hot-water heating works is to get separate circulations from the boiler, rather than branches from a pair of main pipes, where this is possible. More uniform results are obtained in this way, and, considering that uniform working in all parts of a hot-water apparatus (when it extends in different directions and to different heights) is difficult to get, every reasonable means should be adopted to this end. Whether there are separate circulations or branch circulations, it is usually necessary to have stop-valves to control the circulation through those circuits which are either short or have much vertical pipe, or possess some detail which favours them; for what is to their advantage is nearly always at the expense of the more difficult working circuits.

In Box's standard work on "Heat," a very simple method is adopted of showing what constitutes the motive power in a hot-water apparatus, sketches being given something like Figs. 9 and 10. In these, regular spaces are marked off, it being supposed that the water in travelling loses five degrees of heat between each point. What amount of heat it would actually lose in practice depends on various conditions, as the pipes of each job must lose heat more in some buildings or situations than others. But they all lose some heat, and the instruction contained in the diagrams remains sound. In Fig. 9 there is a mean temperature of 160° in the flow pipe, with 117° in the return, a difference of 45° to furnish the motive power. This 45° represents a distinct weight or pressure, and with a vertical circulation as shown the movement would be very rapid. In Fig. 10 the mean temperature is 135° in both columns, so that theoretically there would be no movement. In practice, as may be ascertained by a model, as suggested at the beginning of this chapter, there will be a movement, but it cannot be counted on as a useful one for practical purposes.

What Fig. 10 shows us is that a dip in the circulation, even to some part of it extending below the boiler, is possible. Take Fig. 11, for example; a model erected to this pattern will quickly show a positive and good circulation.

Another instructive illustration may be given in Figs. 12 and 13. The first shows what may be termed the typical method of connecting up a horticultural apparatus of cast pipes, and it will be seen that, in adopting this plan, the greatest difference of temperature is obtained in the two pieces of vertical pipe, where the motive power of the circulation may be said to exist. In the second figure the difference is less, owing to the vertical piece of the return being at a point where the return water could not ordinarily be at its coolest temperature. This last illustration does not show an impossible apparatus, as occasionally in some

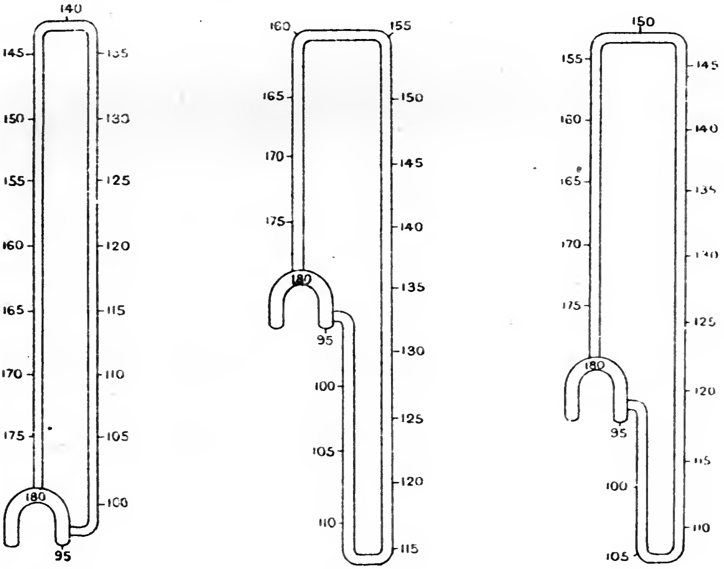

FIG. 9. FIG. 10. FIG 11.

Means of showing what constitutes the motive power in circulating pipes.

works the upper or flow pipe of an apparatus has to be carried along a ceiling, then descend and return along the floor. The purpose of the illustrations, however, is to make clear how the circulation can be improved or favoured—or otherwise—under certain conditions.

With either of the examples just given the circulation would be strong enough to be considered quite satisfactory, although the small proportion of vertical pipe to that which is horizontal is very marked. Such horizontal works usually appear in horticultural buildings, and in these the pipes are always of large size, 3 inches or 4 inches, and this detail assists good results materially by reducing the element of friction. There now, however, arises a more difficult point to be settled, this being the possibility or otherwise of introducing dips into circulations. It was shown at Fig. 11 that a considerable dip was possible, provided the loop or circulation above the boiler was sufficient, but in works consisting almost wholly of horizontal pipes this does not so well apply.

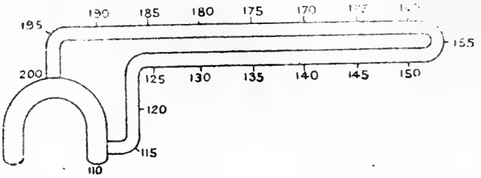

Fig. 12.—With low-lying works a drop return near the boiler ensures the more effective circulation.

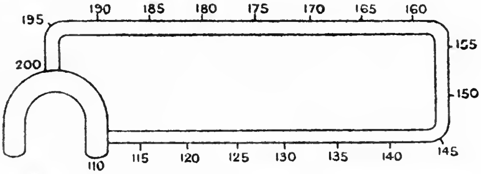

Fig. 13.—A drop return remote from the boiler results in a somewhat slower circulation than when near the boiler.

Let Fig. 14 serve to explain this. From A to B there is a mean temperature of 179°, while from J to K the mean is 141°, a difference of 38° in favour of the circulation. At the dip the two upright pieces of pipe are in favour of a retrograde circulation, the falling column E to F being lighter than the ascending column G H. These spaced off show a difference of 7°, which is opposed to the normal direction of the circulation, and which must be deducted from the 38° last mentioned. This, however, leaves ample margin for satisfactory results, and such a dip can be put in successfully. Of course if the space between F and G should be much increased, there must be greater resistance caused; and, in the same way, if the space anywhere from F to H was subjected to a greater cooling influence, the normal circulation must be prejudiced.

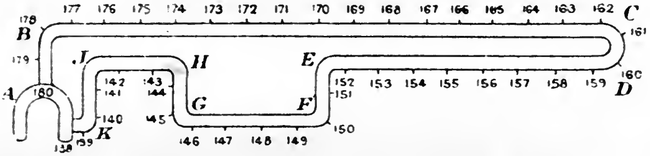

FIG. 14.—A means of showing the resistance caused by a dipped pipe.

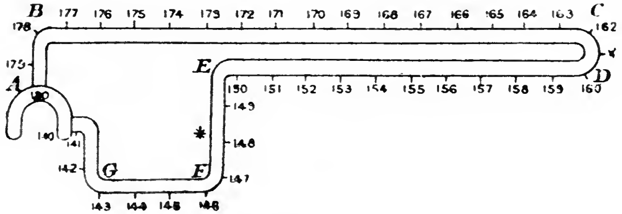

FIG. 15.—Showing the resistance offered by a return dipped beneath boiler level.

In Fig. 15 a further and final example is given, this showing a dip below the boiler. It will be seen that the apparatus presents no unusual features from A to the point marked with an asterisk, and only the dip below this level has to be considered. A glance at the figures will show that this dip, in an apparatus as shown, is permissible.[1]

Dips in horizontal circulating pipes are, of course, objectionable at all times. As a rule they are considered necessary when an above-floor pipe has to pass a doorway and, while the circulation may be strong enough to permit of this, special care is necessary in venting the pipes and thought should always be given to avoiding dips when possible. It is not sufficiently known that if the pipe is looped over a doorway this actually favours the circulation and a series of loops over a series of doorways (or other obstacles to the straight horizontal run) offers no resistance to the circulation and has some advantages except, perhaps, that of appearance. The subject of Dips or Loops to negotiate doorways is dealt with in Chapter XI, page 130.

FIG. 16.—A means of obtaining a circulation through pipes wholly below boiler level.

With horticultural works (and occasionally in other instances) a simple plan can be adopted to overcome the resistance of a dip—or of a length of circulating pipe which has to run at a low level—this plan being to introduce a small cistern or tank, as Fig. 16. This needs no explanation beyond saying that the cistern is put as high as it can reasonably be got, for the higher it is the more successful it must be in overcoming the retrograde force that exists

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[1] It is of the highest importance, when dipping a circulation, that the effects of air in the pipes have the fullest consideration. This will be found clearly explained in the chapter dealing with this subject.

in the low section of piping. The cistern can be fed by hand—as is usual with small installations—or it may have a small supply cistern, with ball-valve, at its side.

As previously stated, a good circulation can be obtained if the pipes both start level from the top of the boiler, but there will be no certainty as to which pipe will act as the flow and which the return ; and the reason, therefore, for connecting the intended flow pipe high and the return low is to ensure, when the apparatus is used, that both pipes shall act up to the work assigned them.[1]

As to the distance the flow and return connections at the boiler should be apart, it was once thought that 12 inches should be considered the minimum. This distance can be readily got on most boilers, but it will be found that a much less distance will serve quite well should it be desirable or necessary. It is certainly preferable to have the distance as great as possible, for, with the majority of boilers, to reduce the distance would mean making the return connection high up, and there is no gain, either in effect or cost, in this.

The flow connection is, or should be, always at the extreme highest point of the boiler, while the return joins the side or back of the boiler at as low a point as can be conveniently arranged. This is usually within 3 inches of the bottom of the water-way, or that part of the boiler which has water in it.

An exception to this rule occurs in what is now usually termed the "Loughborough" type of boiler. This is described in the Chapter on BOILERS, and will be found to consist of a boiler which can be fixed in a greenhouse wall, with its back part projecting inside the greenhouse, the

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[1] There is nothing to be gained by connecting both pipes level at the top of the boiler. If there was, then the direction of the circulation could be ensured by two means. One would be to arrange that the greatest amount of pipe and radiating surface be on the return pipe or pipes ; or, should the work be about equally divided between flow and return, then by arranging that the greatest heat be felt below the flow connection. This can be easily tried with the model suggested on page 22 ; but, except as a study of the subject, it conveys no instruction, as boiler connections can be so readily made high and low in the usual way.

pipes being there connected and run horizontally[1] as required. To allow of the pipes running one close beneath the other, the connections at the boiler have sometimes but 4 inches space between them, yet, although the pipes run horizontally (with the usual slight rise from the boiler), at no point the flow or highest pipe being more than about 6 inches above the boiler, the circulation is sufficiently effective. The fact of a rapid circulation occurring with two vertical pipes starting level from the top of a boiler, and being apparently alike in all respects, shows plainly that some trifling inequality, not noticeable to the eye, will bring about the circulatory movement up one pipe and down the other. The recommendation still remains, however, that the flow and return be, the former at the top, the latter near the bottom of the boiler whenever possible.

If the foregoing particulars appear to refer more to glass-house than other works, it is only because this kind of apparatus lends itself best to the discussion of the subject, and it will be found in the later pages that works suited for all conditions and purposes are treated about equally.

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[1] It should be noted that when speaking of horizontal pipes in this work it means pipes run in a horizontal direction with more or less rise or fall to them. Hot water circulating pipes should never be run quite horizontally, as, apart from whether this would prejudice the circulation, it would not allow air to get away. The least rise or fall is 1 inch in 10 feet. See the subject of AIR IN PIPES, Chapter XI., page 126.

CHAPTER III

THE ADVANTAGES OF WARMING BUILDINGS BY HOT WATER

This short chapter includes no practical instruction in hot-water work, but is introduced with a view to describing clearly and without exaggeration—or prejudice—what advantages are to be gained by this mode of heating. Every hot-water heating engineer has to argue in favour of his speciality occasionally, in fact, often; and not infrequently, has to overcome unfounded objection. It is rather remarkable how much prejudice exists, but in practically every case it proves to be associated with complete ignorance and inexperience. The most prejudiced person is nearly always the one that has never been in a house or place properly warmed by hot water. It must be unhealthy, they say, stuffy, unbearable; they consider the sight of a fire something they cannot do without—and so on. This latter argument is easily overcome by asking if the sight of a fire is welcome and cheering on a summer day, and it is admitted that it is not. A house properly warmed by hot water has perpetual summer in it; not the heat and glare of mid-day, but the temperature and atmosphere of the evening, the time when the sun is not visible and everything is so particularly agreeable.

The writer may explain that for many years he has lived only in houses warmed by hot water, the work being superintended by himself, and although a technical treatise is not supposed to deal with domestic matters, yet in the warming of residences the lady of the house must influence things. In the writer's own case, on first introducing the heating apparatus, there was the customary doubt (amounting to marked prejudice, as it usually does), and dissatisfaction was anticipated. It is necessary to mention this to show what a complete change of opinion came with subsequent experience. It was afterwards admitted that no idea had been formed or imagined as to what agreeable results the apparatus would afford; and, briefly, a distinctly prejudiced woman was converted, without argument or persuasion, into a really enthusiastic votary of this mode of heating.

In a recent instance there were 13 radiators, heating approximately 30,000 cubic feet of space. The fire was kept alight night and day, and the consumption of ordinary gas coke was slightly over 1 ton per month in the coldest weather, but less than 1 ton at other times, or say about 7 tons per winter season (extending from about October 1 to middle of May). This is a very economical outlay to warm 9 full-sized rooms and a hall and corridor, for 24 hours every day.[1] The boiler was of sufficient size to take a charge of fuel that would last through a night of 9 hours, and although the temperature would fall at night (as it does in summer, and as it is desirable for it to do), no need for any change in the summer bed-clothing was experienced.

In addition to the economy in fuel, there is a pronounced economy in labour. The attention to the *one* fire may be four times daily, this attendance being of a very brief duration. Each morning there is no stove cleaning, nor fire lighting, nor the dust and dirt that accompanies this. Should it be a country house, set well back from a road, the dust trouble almost disappears.

Perhaps the greatest advantage is that of uniform temperature. In the writer's case it is believed a record has been established—a household of eight (all ages) passing two successive winters without a single cough or cold. No care is needed in this respect, no anxiety with children as to draughts and the like. It was the regular practice for young children to walk in their night-dresses from a bedroom along a corridor to a bath room, at 7.30 a.m. each day; and

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[1] It is probable that to get the same resulting warmth in these rooms for the period and night and day hours named, at least three times as much fuel would be required if fires in open grates were the source of heat.

whatever the weather might be outside it made no difference, for winter was the same as summer as regards warmth and salubrity of atmosphere. It may sound a trifling detail to some, though it is not to the housewife, that servants find less difficulty in staying in a house well and efficiently warmed by hot water. A house has to be kept clean, and to effect this there is a room being "turned out" almost every day. It is difficult to imagine a more miserable task than this on a really cold day (in the average house): but in a warmed house it is, as just stated, the same in winter as in summer—perhaps more agreeable, for the full heat of summer is not always agreeable. It takes a woman, however, to give a proper value to the benefits that an agreeable warmth affords when house-cleaning, or housework of any kind, is being done in the winter.

One agreeable detail soon noticed in a house properly warmed by hot water, is that there are no draughts. A draught may be correctly defined as a current or movement of air that is cold enough to produce a disagreeable sensation to the body, or, it might be said, is cold enough to be perceived. Currents of temperate air are not perceivable, and the ideal warmed house that is being described appears to have a soft, still atmosphere, such as is experienced on a few summer evenings. The air appears to be more silent (if it may be so described), which would perhaps be due to its conveying sound waves less sharply. It could easily be thought that the air was still, and the ventilation (change of air) insufficient for healthful results, but any simple test will show that the air movement is as active as could possibly be desired, the chimneys of the rooms still performing their duties as extractors. Chimneys exist in practically every house; but should a house be newly built, and the heating is to be done by hot water, without any provision for fires then air flues must be provided in the walls and there will act as extractors as chimneys do.

It is about the only thing that can be said in favour of the fire-grate, that its chimney provides an automatic air-extractor to cause the air of the room to be changed, but, as stated, it induces cold draughts if the grate fire is the only source of heat. Many houses are fitted with a hot-water apparatus as an auxiliary to the warmth afforded by fire-grates. It is a good plan so far (though the writer finds the grate fire unnecessary, and affording no pleasure to those who otherwise favour the visible fire), and those who insist on seeing a fire can thus have large rooms properly warmed, also their halls and corridors, while preserving the cheerful effect that an open fire is thought to afford.[1] In such cases as these the area of radiation is reduced one-fourth, and this (without the fires) will be found to afford a nice temperature when the outer air is above say 40° Fahr., the fires not being required until the air is nearer freezing point.

Another point in favour of hot-water warmth relates to the question of dampness in houses. Any one who has lived in a country house (however dry the district may be considered to be) will be perfectly familiar with this subject ; and as so many of the heating engineers' works are in rural districts the subject is, so far, important. Town dwellers have no idea how damp a really good and well built country house is, even when built in a situation that is favourable as to dryness and a bracing air. There are no objections whatever to the humidity of the air from a healthful or hygienic point of view, but as leather shoes and boots have a vigorous growth of blue mould on them in a week, and even dresses hung in a wardrobe become mouldy in a brief time, the subject assumes considerable importance in the housekeeper's eyes. Spare bedrooms, too, are a source of anxiety. Hot-water heat—meaning a fairly uniform summer temperature day and night through the winter — will remedy this as far as possible, and reduce the trouble to reasonable bounds. It may not prevent it entirely, for it is not a thing that can be wholly prevented by any ordinary means—and perhaps it is as well that it should be so—but it reduces a real source of trouble and anxiety to one only needing ordinary care or thought.

As to the gain effected in a household generally, this,

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[1] There is no desire to condemn the open fire, but in a house well warmed by hot water the visible fire is scarcely agreeable, and is never sought for.

while made up of many details, represents a large total. The inconveniences of winter, in an ordinary residence, are many and varied. This everyone knows, and needless to say the whole are due to the want of warmth and salubrity that the summer air has. A person's nature and feelings, their ability and inclination to work, the quality of their work, and a number of things, are distinctly influenced by their comfort.

As to health, let it most clearly and emphatically be stated—and it is beyond dispute by any experienced person—that the health is benefited. It is not that the health is not prejudiced; it is more than this, for a real benefit is had, both to young and old. Appetites are as keen as could be wished, there is no lassitude nor anything that is associated with high temperatures. As already stated, the temperature, the atmosphere, and the general effect is that experienced on a summer evening, when the temperature has dropped to 65°, a temperature that is found to stimulate the mind, the body, and the appetite.

A question is often raised as to whether a cold is not the usual result of walking from a house at 65° into the winter air. The writer can answer this beyond dispute by saying it never is so. In the first place no one goes out without clothing themselves suitably, but, apart from this, what does nature inspire us to do? The average person thoroughly warms him or herself at a fire before they go out, or they take a warm meal or beverage, and everything points to the body requiring to be warm—as warm as possible and warmed through—before going into the cold air. Only under stress of circumstances does any one go into the cold air while they themselves are in a cold condition. A previous statement in this chapter, too, disproves the "cold-catching" idea, for a household of eight, of all ages, passed two whole consecutive winters in such a house without once catching cold; and, needless to say, all went into the outer air one or more times every day. It should perhaps be added that the members of this household were not particularly vigorous either physically or constitutionally, two were rather the reverse but showed great and permanent improvement very soon. The winter is a trying time with many people, of all ages, but only because they live in houses the atmosphere of which is inclement and distressing to the human body.

CHAPTER IV

THE DETAILS OF A HOT-WATER HEATING APPARATUS FULLY EXPLAINED

Before giving illustrations and particulars of example works (which form the subject of the next chapter), it is thought best to describe the detailed parts of an apparatus so as to make the reader familiar with the reasons for their existence, their uses, etc. This can be done by describing a small and simple apparatus, and it will be found that the general information afforded will apply generally to works of all sizes and on all "systems." A further use for this chapter is that it will make the examples in the next ones (Chapters V., VI., VII., VIII.) readily understood without tiresome description and repetition in each case.

It is assumed that the action of convection—the circulation—is understood from the description given in Chapter II., and that the general results to be expected when erecting a heating system are understood; if not, then the description afforded in Chapter II. must be referred to. For the purposes of this present chapter, therefore, Figs. 17 and 18 are given, these representing a simple apparatus on what is known as the "Two-pipe" System.[1]

It is supposed that a dining-room and a drawing-room of a residence—both large rooms—require some warmth, as the fires in the grates are not enough when the outdoor temperature is at or below freezing point. This quite frequently happens, for the fire in a fire-grate of the best and most modern make is seldom quite sufficient when a room exceeds 20 feet by 18 feet. In the case of a drawing-room it is often required, when the help of hot water warmth is

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[1] The different systems are described in Chapters V., VI., VII.

decided on, that this be fully heated without the aid of a fire, as the room is thus kept cleaner and is ready for use of visitors at any time without the servants having to run in and out.

In Fig. 17 there are three radiators, one in the dining-room as an auxiliary to the grate fire, and two in the drawing-room; and it is supposed that the boiler is in a scullery or kitchen office in the basement, while the pipes run along beneath the basement ceiling.[1]

From the highest position on the boiler [2] the *flow pipe* proceeds by the most direct or convenient route to the point where the radiators are to be situated,[3] and it will

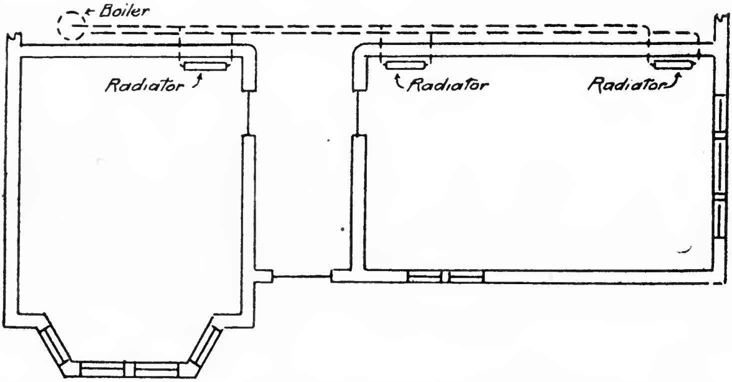

FIG. 17.—Plan of two rooms warmed by radiators, two-pipe system.

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[1] The sketches are made to form a simple example, otherwise it would have been desirable, while doing the work, to put a radiator in the entrance-hall; where, as is usually the case, nearly all the cold air first enters the house. It will be found mentioned more fully in later chapters, but may be stated here, that in many residences a full degree of warmth in the front and back halls is of great assistance in the efficient heating of the house.

[2] Fig. 18 shows the flow-pipe leaving the side of the boiler close to the top. It is probable, in a small job like this, that an inexpensive boiler of this make would be used; but where possible, boilers should always have the water-way extend over the top or crown (see BOILERS) in which case the flow always leaves the extreme top of the boiler by a vertical pipe.

[3] Should cast pipes ever be used instead of radiators, as in a conservatory attached to a residence, the general work and connections remain the same. The way in which cast pipes are joined up will be seen in the chapter on HORTICULTURAL WORK.

be seen that the *return pipe* takes the same course, but it joins the boiler near the bottom. It is important that both pipes are given a rise or slightly ascending course (where they run in a horizontal direction) from the boiler, and the least rise allowed is 1 inch in 10 feet. This should always be exceeded if possible, though it is not necessary to give a greater rise than, say, 4 inches in 10 feet if it makes the run of pipes unsightly on the wall. The chief purpose of this rise to the pipes is to allow of air escaping (getting away by itself) freely. Air in the pipes is a source of real trouble to the heating engineer until he is conversant with what it can and does do, and on no account must a student ever consider it a detail of minor importance. It is air that usually makes all the difficulty when a flow or return pipe has to be dipped or made to descend (lose its rise) in any way. The strength of the circulation may be fully powerful to allow of the dip, and when done it may be quite successful, but success will lie chiefly with the skill displayed in disposing of the air that has to be displaced or given freedom of escape. (See AIR IN PIPES.)

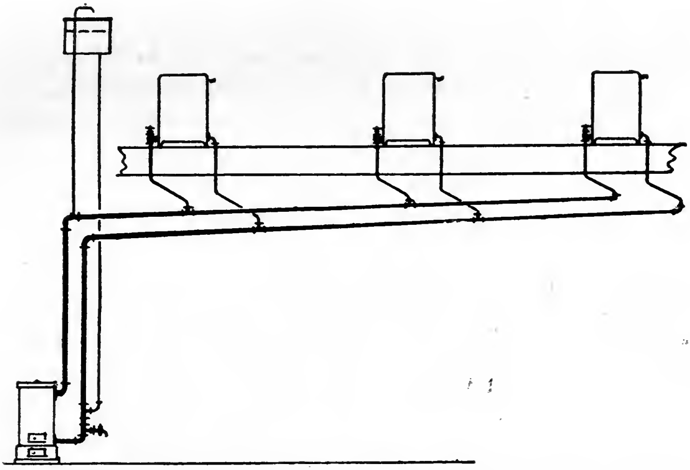

FIG. 18.—Elevation of apparatus serving radiators shown in Fig 17.

The flow pipe (Fig. 18) proceeds from the highest point of the boiler (so that no air may be caused to collect there), and then proceeds along past near the positions given to the radiators, and, with this system, it may end in the last radiator as shown. The return follows the same route, either by the side of the flow or beneath it; it might be carried above the flow if desired, but in practice the lower pipe of any pair is usually considered the return.

The radiators (or coils, or other heat-distributing devices) are connected by branches from the main flow and return as shown. It is not a good plan to let the main pipes come directly beneath the radiators, so that the branches are merely short pieces of vertical pipe. It is better to keep them from one to three feet away; for, although this entails more labour and using at least two more bends, it allows of the main pipes expanding and contracting (as they heat and cool) without straining the joints. Perhaps this may not be of such importance in a small apparatus as Fig. 18, but it is the rule, and it is very necessary in large works where the push and pull of the main pipes, when heating and cooling, is considerable. Joints may be strained, leaks started, and injury done to cement and decorative work. In long, straight runs of pipe special provision for expansion has to be made, apart from the effect on the branches, but this detail is treated separately. (See EXPANSION JOINTS.) The same rise is given to branch pipes and connections as is given to main circulations, viz., 1 inch in 10 feet as the least; double this, or more, when possible.

The reason that the last radiator may have the main circulation end in it (as shown in Fig. 18) is that each of the other radiators forms a by-pass between the main flow and return. Thus, if the stop-valve on the end radiator was closed, and the circulation through it quite stopped, it would not interfere with the circulation through and the proper working of the others. It may be thought that the end radiator should be connected as Fig. 19, so as not to stop the main circulation past it, but there is no gain in doing this with an end radiator when on a two-pipe system of apparatus. With the one-pipe system, which is described in Chapter VI., the argument applies differently, as the radiators nearer the boiler have no connection with the return pipe, and any valve regulation affecting the main circulation at its extremity would affect all and be a fault.

It is a failing laid to the door of the two-pipe system, that, as every radiator, and every branch circulation, is more or less a by-pass between the main flow and return pipes, it favours what is termed "short circuit." This means the possibility of the circulation occurring up to and through a certain branch, and returning from there without moving the water in whatever part of the apparatus extends beyond that point. Take Fig. 18 for example (though as a rule the trouble only occurs with larger and more complicated works). In this let it be supposed that the circulation occurs normally through the first and second radiators, while the third one remains cold and apparently has not warm water working through it. This would be considered as a case of short circuit. The "one-pipe" system which is described in Chapter VI. cannot have this trouble, but the fact is that all systems give trouble if they are not properly carried out, and short circuit is only an instance of this. Its chief cause is want of boiler power, or using pipes of too small a size. It might be supposed that with either of these mistakes the result would be a general failure, but it is not so; and the rule is, in such cases, for part of the apparatus to work fairly well and part to fail entirely. This peculiar result is always puzzling until it is understood, for the part that fails sometimes acts as if it was quite cut off from the rest by a stoppage of some kind; and until the fault is remedied it is an almost dead part of the apparatus.

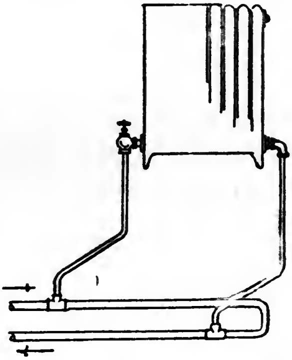

FIG. 19.—Unnecessary by-pass at extremity of circulation, two-pipe system.

Short circuit, stated briefly, means faulty construction, boiler or pipes under size. There may be exceptions, as in the case of badly dipped pipes, or pipes that get air locked, but these are not so permanent or regular in their failure, and can usually be distinguished both by their action and by inspection.

Referring again to the description of the apparatus illustrated by Figs. 17 and 18, a detail of some importance is the "expansion pipe." This often bears other names, such as "exhaust pipe," "vent pipe," etc. The pipe would certainly allow of steam escaping should the water boil, and would do good service in this respect, and it also allows of air escaping. The customary point at which it exists is on the highest point of the circulation, but in Fig. 18 it is shown nearer to the boiler, to allow of discussion, and to show that the highest point, though considered best, is not essential.

When the expansion pipe is at the highest point it allows of air passing out freely, either at the time of charging the pipes with water, or afterwards.[1] If it is not convenient to put the expansion pipe there, then it may be placed anywhere on the flow pipe, *provided* some other means exists for the air to get out of the circulating pipes. In the illustration referred to it will be seen that a radiator comes at the highest point, and this will take the air satisfactorily. When charging the apparatus with water the radiator air-cocks are (or should be) open, therefore the air at the highest point is disposed of quite perfectly. Afterwards, when the apparatus is in normal use, the air that works to the highest point will collect in the radiator; and all radiators are made so that they will take a reasonable volume of air at the top without interfering with their work or heating. In an apparatus like that now being discussed (Fig. 18), the air-cock on the radiator on the highest point might not require to be opened more than once or twice during the whole winter season.

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[1] Air must be expected to collect in a hot water apparatus, not always in great quantity but sufficient to cause trouble if provision for its free exit is not made. This is one excellent reason for giving the circulating pipes the rise stipulated.

If, therefore, the expansion pipe is not of primary importance in giving free vent to the air in an apparatus, and may never be called upon to act as a steam pipe,[1] the question may arise, what is it for? Is it to provide for expansion? Water, when heated, expands in a regular manner, and it might be thought that this could be provided for in the size of the cold supply cistern. As a matter of fact this is done, and has to be done, in every case (see SUPPLY CISTERNS, sizes of) yet this provision does not obviate the necessity of the expansion pipe. Let an experience of the writer's confirm this (and nearly every engineer has had the experience). An apparatus of moderate size, with eight radiators, was erected in quite an ordinary manner, but it was not easy to get an expansion pipe in. It was omitted, and, as usual, the cold supply cistern was made of full size, and had only about 3 inches of water in it when the apparatus was cold. Soon after lighting the fire, and before the radiators were really hot it was noticed that the water in the supply cistern was rising at quite a rapid rate. In a very brief time it overflowed, although it was fully large for the mere expansion of the water. On testing again it was found that the water appeared to swell back in an unaccountable way, and no care in stoking or attention to other parts of the apparatus would prevent it. The provision of a $\frac{1}{2}$-inch expansion pipe proved to be a perfect remedy for this; and the writer has to acknowledge that he cannot, nor has he found any one who can, give a very clear reason for this phenomenon, which is now known as the "swelling back" of water in a supply cistern.

A further detail of the apparatus, Fig. 18, to be explained is the cold supply service. This is an important pipe, and must be correct in connection and detail. In the first place the supply cistern must be of suitable size. As already explained, water when heated expands, that is increases in bulk, to a recognized extent, and this being so, some provision for the increased bulk must exist in

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[1] Supposing no expansion pipe existed, and the water boiled, the steam pressure could relieve itself by way of the cold supply pipe. Apart from this, every boiler, without exception, should have a safety valve on it.

every heating apparatus. Failing this provision, there would probably be an overflow and other troublesome happenings. Water heated from its point of greatest density (which is near freezing) to boiling point, expands one twenty-fourth—that is, 25 gallons of water just on boiling point would be but 24 gallons at near freezing point, and the weight of the two would be the same.

In heating works a provision for expansion of 1 in 24 is not usually made, yet when starting an apparatus in winter, with a good boiler, there may be a rise in the temperature of the water of very nearly 150°, so that 1 in 24 is scarcely too much to allow. This means that the supply cistern, which has about 3 inches of water in it when the apparatus is charged cold, must have sufficient space above (below the overflow pipe) to take quite 1 gallon for every 20 to 24 gallons of water that is in the boiler, pipes, and other parts of the apparatus which the cistern supplies. Supposing the cistern to be fitted with a ball-valve, then this comes near the bottom of the cistern, and when the apparatus is cold it appears as Fig. 20. The dotted line near the top shows where the water may rise to when the apparatus is at its fullest heat, this line being just below the overflow pipe.

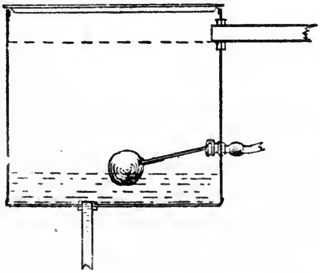

FIG. 20.—Supply cistern of heating apparatus, showing the low water level when all is cold. The water may rise to the upper dotted line when heated.

In the APPENDIX will be found a table that gives the quantities of water that pipes of different sizes hold per foot-run, and in regard to radiators it may be taken that their water capacity averages about $\frac{1}{5}$th gallon per square foot of surface. It is rather a troublesome calculation, and it is probable that the majority of engineers guess the sizes of the cisterns, allowing a margin to the good, as the moderate cost of cisterns readily allows them to do.

The ball-valve is not favoured as a means of automatically supplying these cisterns, chiefly because it is likely to become stuck through want of use, this result being made more certain by the valve being submerged—covered with water—when the apparatus is heated. It must be admitted, however, that nothing better is known if an automatic supply is required; but if the conditions will admit, then a cistern without valve, and fed by hand, should be used. As a rule, there is little objection to this, as it may not require to be replenished more than once a month, and should it be forgotten there is no danger to be feared.

The plan that usually works out best of all is to take the cold supply service directly, or indirectly, from the house cistern. This is supposing there is a house cistern, and that taking the supply from this will not involve any special extra expense. It may be assumed that the house cistern is too large to have any appreciable rise in its water level due to the expansion of the water in the heating apparatus, and it is needless to add that this cistern provides a constant automatic supply to the boiler. It is not always necessary to take the cold supply service, as a separate pipe, all the way down from the house cistern. There probably is a domestic or other cold service already down to a point near to the boiler, and a branch may be taken from this. It may be argued that this is a doubtful practice, owing to the likelihood of the service being shut off for repairs, which would deprive the boiler of its supply, and the reply is that this does not matter, as a heating apparatus as ordinarily constructed, will usually work quite well for several days with the cold water supply cut off, and at the worst there could be no danger and little or no inconvenience. The cold service down to a w.c. flushing cistern could be utilized quite well if of suitable size.

A peculiar form of supply cistern that has been introduced from America is known as the Expansion Tank. This is merely a galvanized wrought-iron cylindrical tank, with a water-gauge on it, as Fig. 21, about ten different sizes being made to suit apparatus from small to large undertakings. With this, as with other methods employed, the cold supply pipe to the apparatus is carried into the boiler, or into a return pipe near the boiler, the object being to feed into the boiler as direct as possible, this being the only certain means of avoiding trouble from air collection when the apparatus is filled. (This will be spoken of again.) The cold supply pipe, however, is not taken from this tank, but is usually a branch from a main or other convenient service nearest to the boiler. The expansion tank therefore answers well where no house cistern exists, and may often be used instead of putting in a hand-fed supply cistern. If a house cistern should exist, however, it is best to utilize it, for it will probably save expense, and, more important, it will feed the apparatus automatically without giving trouble.

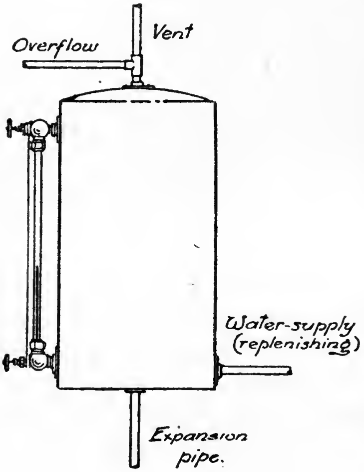

FIG 21.—Expansion tank and its connections.

Assuming the expansion tank to be connected to an expansion pipe at the highest point of an apparatus, the water supply is then turned on ; and, after it has filled the boiler, pipes and radiators, it will mount up and appear in the water gauge of the expansion tank. When it is about 3 inches up the supply must be stopped, and the fire can then be lighted. As the water heats so the water-line in the gauge attached to the expansion tank will rise, and from this time it will only be necessary to glance at the water-gauge to see if replenishment is necessary. The addition of water, as will be understood, is effected by opening the stopcock in the cold supply down by the boiler.

A little difficulty arises in the detail just explained in the fact that whoever opens the cock in the cold supply cannot watch the water gauge at the same time, and in consequence of this a second cold water connection is sometimes made, this one being to the expansion tank itself. It will be seen that once the apparatus is full, and all air lifted out of it by the water rising from below, there is no objection to the regular replenishment being effected at the top. Therefore a cold connection to the expansion tank will readily supply the little water needed periodically, and when doing this the attendant has the water gauge in sight to regulate the replenishment correctly.

As previously stated, the cold service pipe is connected either directly into the boiler or into a return pipe quite near to the boiler, i.e. as near as possible, say, within about 1 to 3 feet. This applies whether the pipe comes down direct from a feed cistern, or whether it comes as a branch from a domestic water service (see page 47) or from the main, the object always to be attained being *a direct feed to the lowest part of the apparatus.* In the few instances in which a return pipe runs below the bottom of the boiler, then it is a good plan, the best plan in fact, to feed into this return pipe instead of into the boiler. *It is of considerable importance in the filling of an apparatus that the water enter at the lowest possible point, and rise from there.* This ensures the most perfect possible expulsion of air. Previous to an apparatus being filled, or charged as it is called, it is, of course, full of air, and if this air is not all driven out by the water as it flows in, then there will be ill results occur afterwards. With a very simple apparatus it might be possible to fill by a cold service connected to a high part of the return pipe, quite away from the boiler, but it needs mature judgment to say when this can be done, and then it is only possible occasionally. The rule is to connect the cold service to the lowest point of the apparatus, so that the inflowing water *lifts all air above it* as it rises. With many works having branch circulations, and complicated details, to connect the cold water at a point far from the boiler would cause air to be locked in some of the pipes, and small as this trouble may sound, it will be found to be a very real cause of vexation and expense before it is put right.

It is the custom to put a dip—or syphon as it is wrongly called—in the cold service pipe, the purpose of this dip being to prevent heated water working up the service pipe to the supply cistern. Heated water, it will be found, will circulate up a single pipe when it runs vertically (see page 21), but if the pipe, where it first receives the hot water, is dipped a little, i.e. descends a little, this proves a barrier to the circulation that can occur wholly in a single pipe. In very many cases the fact of some warm water circulating up the cold pipe is no fault. It comes either from the bottom of the boiler or from a return pipe, but it seldom does harm. Should a dip be needed, however, then it should not exceed 6 inches in depth, and it must be made at the lower end of the cold supply pipe, as either of the examples in Fig. 22. This shows the cold pipe joining a return near to the boiler. *The dip should never be made as Fig.* 23, for it costs more unnecessarily and may get air-locked. On no account should this double bend, or any form of dip or syphon, be put high up the pipe near the cold cistern. This is a practice that will almost certainly cause trouble. Fig. 22 should be considered the only correct methods of making a dip (either into a return as shown or direct into the boiler).

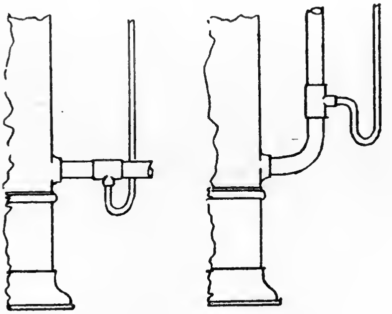

FIG. 22.

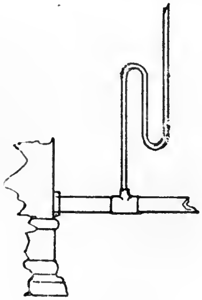

FIG. 23.

Cold supply connections. Good and bad practice.

It is the rule to run the cold supply service by the most direct or easiest route to the boiler, but some care should be exercised to see that no dips or sags occur in its run. As a rule it is run in iron tube, but should lead pipe be used it must be run on wood fillets, where necessary, and precautions taken to let it have a slight fall all the way towards the boiler. Air is quite an enemy to the heating engineer, and, with the novice, it sometimes seems to lie in wait to trip him up. It must be remembered that if air cannot get away easily it will, of course, stay and collect. If the apparatus had large taps on it that were opened occasionally (as with the domestic hot water supply to baths, etc.) the air would be swept out with the rush of water through the pipes, but there is no such assistance here, and a little collection of air will stop even the water passing through the cold service pipe after the apparatus is charged and in use. An apparatus loses such a little water by evaporation that there is no rush to dislodge the air. There may be only a quarter of a gill, or even less, pass down the cold supply per day, and any place where air can collect will lock this pipe as readily as it will stop a circulation. This is explained more fully under AIR IN PIPES.

The size pipe best suited for the cold service is generally left to the engineer's judgment, but there should be some rule to work to. The last paragraph will show that an ⅛-inch pipe would serve quite well as regards supplying the small quantity of water a medium size apparatus requires, but ½-inch is the smallest size that should ever be used. It is the fact of a small pipe being readily choked, or stopped by dirt or rust, that precludes its use; and the following is a rule that may be worked to (unless larger is preferred or specified) :—

For works having this radiating surface	The cold supply service should **not** be less than
Up to 250 sq. ft.	½ inch.
250 ,, 500 ,, ...	¾ inch.
500 ,, 1000 ,, ...	1 inch.
Above 1000 ,, . .	1 inch or 1¼ inch, according to conditions.

When a stop-cock is put into the cold supply service, it is put near to the boiler, and it should be of a pattern that has a full way or bore through it. A gate or Peet's valve is generally used, but in certain cases it may appear best to use a valve with a removable key; but whatever kind is used, it should have a clear straight way through it equal in size to the pipe it is attached to.

A near neighbour to this stop-cock—when it exists—is an emptying cock. This has always to be put. There is no rule as to size, but one or two shillings spent in an extra size is often saved if an apparatus has to be emptied once or twice before the job is finished. If the apparatus is anything but a small one, it is an economical plan to have the nose of the cock provided with a hose union. A piece of hose is then attached, and taken to the nearest open gulley or other convenient spot. It saves the carrying of, possibly, scores of gallons of water in pails. From ½-inch to 1 inch (full-way, if possible) are the sizes of cocks ordinarily used, but there is no limit in largeness.

Every radiator, or run of radiating pipe, has an air-vent at its highest point. In horticultural works it may be said that this always takes the form of a piece of ¼-inch or ⅜-inch pipe, as this needs no attention at any time. But this is seldom possible in brick buildings, and the air-cock is in general use. These will be found described in the chapter devoted to FITTINGS.

Every heating boiler, small and large, should have a Safety-valve. These are also described under FITTINGS, but a rule may be suggested here as to sizes.

A boiler having a catalogue heating power as under	Should have a safety valve of this nominal size
Up to 400 ft.	¾ inch.
400 ,, 600 ,, ...	1 inch.
600 ,, 1000 ,, ...	1¼ inch.
1000 ,, 2000 ,, ...	1½ inch to 2 inch.

In giving the nominal size of safety-valve this means that, for instance, a 1-inch valve has not always a 1-inch clear way through. Nominal size, therefore, means catalogue size. Reference to safety-valves in the chapter on FITTINGS will show that the lever safety-valve is recommended. It is simple and, rather importantly, its price does not rise out of all proportion in the larger sizes.

The last detail that may be explained is that of charging the apparatus with water when its construction is finished. As mentioned more than once, the chief object to be attained is to fill the whole of the pipes and parts with water ; and, to effect this, all air must be expelled by the water as it enters. The expansion pipe is the chief air-pipe, but this may not give vent to the air that is in the branch circulations. A very important thing to remember, therefore, is to *have all air-cocks on radiators, or pipes, open when the water is coming in.* This means of course that a little extra help may be needed for part of an hour, as a man and mate cannot watch several radiators in different rooms at once, so as to shut the air-cocks when the water appears. It should however be managed somehow ; for, to charge an apparatus with the air-cocks closed will, in a number of cases, result in air-lockage at some point or other. (See AIR IN PIPES.

Further general details will be found in the succeeding chapters, details which appear in the more advanced work described there, and which cannot be referred to so well here. The reader is recommended to peruse the particulars given with the example works illustrated there, particularly with the first example which, in a large measure, forms a continuation to this chapter.

CHAPTER V

EXAMPLES OF LOW-PRESSURE HOT-WATER HEATING APPARATUS FOR BRICK BUILDINGS

In stating that these example works are for *brick* buildings, it is intended to convey that the buildings are not glass-houses or similar horticultural structures. Brick buildings, therefore, include everything from a residence or a workshop, to a factory or block of flats, or any large building. The limited number of examples that can be given are as representative as possible, and, although not meeting every requirement, will serve to guide the student when planning works for practically any kind of building. It is probable that none of the following schemes of work can ever be copied exactly, for every engineer knows that two installations are rarely alike; therefore, the principles of the different systems is all that can be suggested or taught, and these have to be adapted to the works that the student has put before him.

There are three systems of piping work in general use—viz., the two-pipe system, the one-pipe system, and the overhead system. There occur modifications of these, as an engineer will find—conditions which require the strict rule of the system to be modified. It will also be found that an apparatus may easily have all three systems embraced in it, the conditions, again, making this desirable. There is nothing confusing about this, as any one practising the work quickly finds. There are also "Accelerated" systems in which the contained water has its movement accelerated or hastened by mechanical aid or by steam, this being needed when the conditions are opposed to the ordinary gravity apparatus working properly. These systems are the subject of a separate chapter, and while the means of obtaining and the effect obtained by the "acceleration" are a subject in themselves, the piping connections with which this present chapter is chiefly concerned, will be found to closely follow the ordinary systems about to be described. In addition to the methods named, there is the high-pressure, small-bore or Perkins' system, but this is quite different, and as it does not form part of a low-pressure system, it is treated separately, and forms the subject of a later chapter. What is termed indirect or direct-indirect work only relates to a special kind of radiator used, and description will be found under RADIATORS and in other places. Horticultural work is treated separately, but has its connections nearly always on the two-pipe system.

For the general description of the parts of an apparatus, the reader is referred to Chapter IV., which is wholly devoted to this.

THE TWO-PIPE SYSTEM

This is the oldest method of carrying out these works, and its name is derived from the fact that the radiators (or coils or rows of pipes)[1] are connected to both flow and return pipes of the main circulation. It may be explained here that in all systems the main circulation has a complete main flow and return circuit, and as regards the two-pipe and one-pipe systems, the difference is chiefly in the method of connecting the radiator branches. This difference, however, introduces others, as will be seen later.

Figs. 17 and 18 (pages 40, 41) illustrate a two-pipe system of apparatus in a simple form, while Figs. 24 and 25 give a somewhat larger example in which more detail appears. In this the flow pipes appear as solid lines, while the returns are broken, i.e. dotted. This shows the ground floor of a residence which is to be fully heated, except in the dining-room where auxiliary heat to the fire only is required. This means

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[1] It will be found that most of the following suggested example works show radiators as the heat-distributing surfaces. This is because so few works are now carried out wholly with pipes (except in horticultural buildings, which form the subject of a separate chapter).

that one radiator is fixed in that room instead of two, the radiator being of about two-thirds to three-fourths the total surface that would be required if the room had no fire.

The main circulation is carried beneath the floors of these rooms, which means that the boiler must be in the basement, or sunk below the floor level by some means. Effort should always be made to effect this, as it facilitates the work so greatly; and so far as the two-pipe system is concerned it is absolutely necessary. If the boiler is not below the ground floor, then only a one-pipe system is possible, and an example of this (the writer's own house) will be found given later.

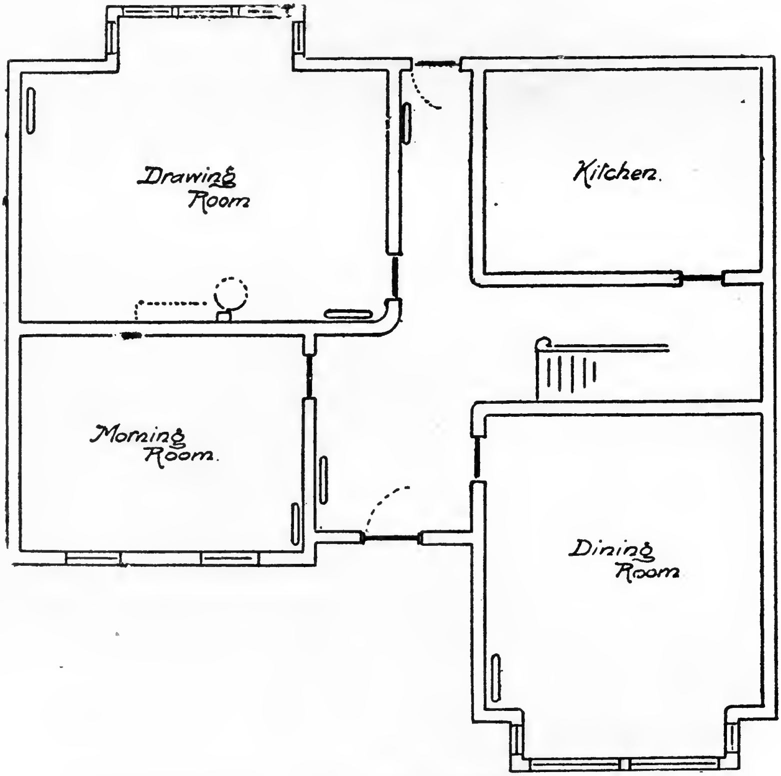

FIG. 24.—Plan of villa showing disposition of radiators.

Assuming the pipes are below the ground floor, then all radiators can be connected without any pipes being visible above the ground floor. This is an excellent feature, as visible pipes have done much to prejudice this mode of heating, particularly in residences and buildings of this kind. People are quite commonly heard to say that they dislike hot-water heating works " because of the ugly pipes." Students—and engineers—should therefore consider it an essential in good work that no pipes are made visible. There may be three inches of small pipe to be seen—but only by looking for it—where the connection to the radiator comes through the floor, but nowhere else. When pipes have necessarily to go up angles, or along a wall, then the lines must be carefully chosen, and the piping afterwards encased. Visible pipes are always objectionable, and this should never be forgotten. Of course in factory, warehouse, or similar work, visible

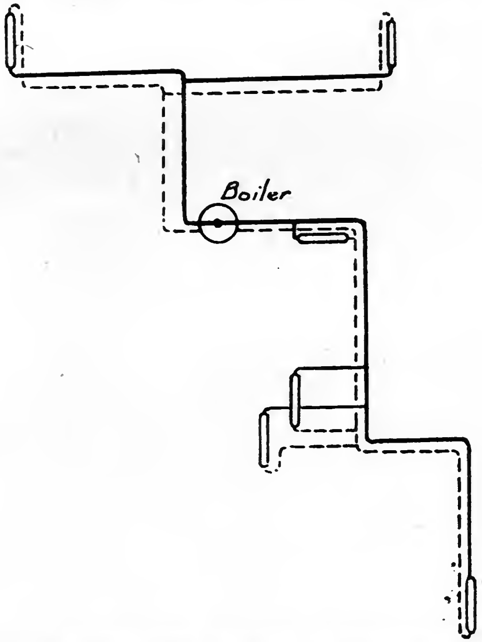

FIG 25.—Plan of piping scheme to serve the radiators shown in Fig. 24.

pipes are not objected to, and in such cases the circulating pipes are often counted on to represent so much heating surface, but in residences, and all good class work, the pipes must be hidden, and also covered to prevent loss of heat. (See COVERING PIPES.)

The question of visible pipes has an important bearing on the method of connecting up radiators. Where pipes come through a floor to a radiator, the generally practised good method of connecting up is by means of an Angle Valve at one end, and a Union Elbow at the other end. These valves and elbows are illustrated in the chapter on fittings, while Fig. 26 will show their application as now described. It will be seen, also, that if the valve has a union upon it, the disconnection of the radiator is simplified.

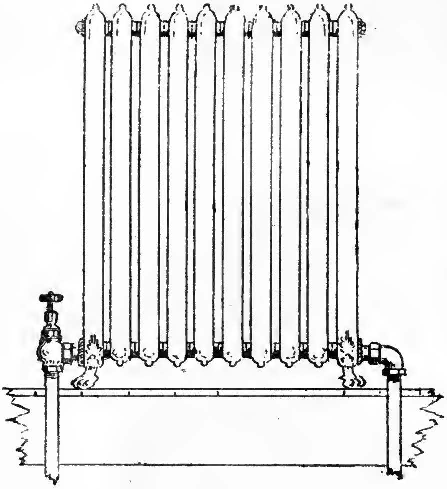

FIG. 26.—Best method of connecting a radiator without the connecting pipes being visible in the room.

A later method designed by the writer, firstly to make the pipe connections still less visible, secondly to bring the regulating valve up where it can be used without stooping, is illustrated in Figs. 27 and 28. It will be seen that the pipe connections are between the feet of the radiator, while the valve (which is desirably quick-opening and closing) shows as a neat and not over-large disc handle only. Fig. 28 will give a sufficient idea how the regulating effect is obtained, there being no water-way between the first two sections at the bottom, while at the top the valve uses the water-way as its seating. It thus makes the first section of the radiator serve the same purpose as an outside pipe, reaching to the top of the radiator, would do.

An engineer does not practise this work long before he finds that his pipes and radiators have to be in and tested before a house, or other building, is decorated. He is then asked to take his radiators down, that the walls behind may be papered or coloured, the skirtings painted, and the back of the radiator itself given at least one coat of paint. After this, at a suitable moment, the engineer is asked to put the radiators back. This alone will show how convenient union connections are, and how much labour and injury they save. As practically all these

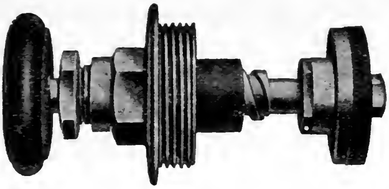

FIG. 27.

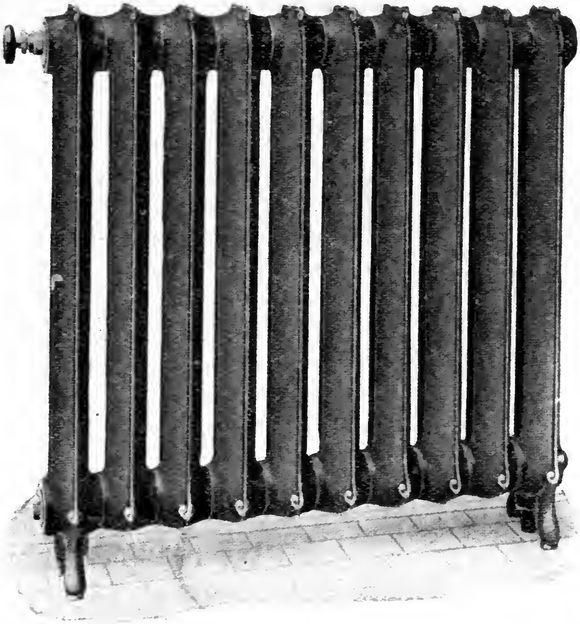

FIG. 28.—Invisible connections to radiator, made possible by the special form of valve shown at Fig 27.

union fittings have coned faces, the desirability of a branch service not being rigid (see page 42) will be understood, as one of the pipes must be sprung back about a quarter of an inch to get the radiator free after the nut of the union is undone.

Referring again to Figs. 24 and 25, assuming that the first floor (the floor above the ground floor)[1] requires warmth in addition to the ground floor, then the best plan, whenever possible, is to carry branches up to the radiators from the mains in the basement rather than attempt running mains under the boards of the upper floor. What is suggested would be done as Fig. 29 the ascending pipes being carried up in a chase in the wall, or up in an angle and cased in. If two or three radiators can be properly served by one rising branch service, as Fig. 30, without seriously cutting the joists, then it might be done with advantage; but attempts to run a pair of fair-sized mains, probably 2-inch, beneath the boards of a first floor are seldom possible, and more seldom allowed by an architect if the joists have to be notched.

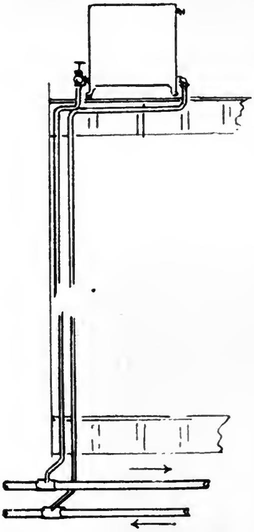

FIG. 29.—Serving a radiator two floors above the main horizontal circulation.

A detail in house warming which requires full consideration is the disposition of the radiators. As previously explained the radiator, notwithstanding its name, affords most heat by warming the air; and this, although there may be a general idea to the contrary, is how it does excellent work, and makes hot-water heating the source of real comfort that

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[1] American readers may be informed that in England the floor which is level with the ground, or thereabouts, is called the ground floor, while the floor above it is termed the first floor and so on. In America the first floor is that which is at the ground level, the second floor being the next above it, while the floor beneath the ground level is the basement. They have none termed the ground floor.

it is. (See Chap III. page 33.) It is therefore necessary that whatever cold air enters the house shall be dealt with at the earliest moment, for, failing this, the space occupied by unwarmed air will be disagreeable to the occupants, and a source of complaint.

Where does the cold air enter a house? All houses have chimneys built in them, one to each important room, and these, although the fire-grates are unused, have draughts in them which keep up a full change of air. Ventilation, i.e. a change of vitiated air for new good air, is highly important in all buildings; and, as stated, chimneys make excellent extractors. But where does the new air enter the house—very cold air in winter—and which is usually described as cold draughts? As residences are but rarely ventilated on any good principle, it will, in almost every case, be found that the new air which makes good the volume extracted by the chimneys enters through the crevices around the front and back outer doors, also around ill-fitting windows or other places which may afford a passage for air from outside to inside the building. It scarcely matters where an opening exists in the outer wall of a house, or its size or shape, but what an in-current of outer air occurs through it. This is due to the extracting qualities of the chimneys.

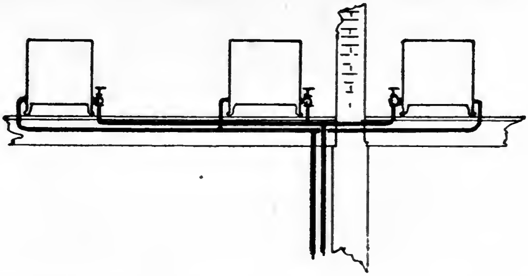

FIG. 30.—Serving three radiators by one vertical branch circulation.

Having realized that cold air enters in considerable volume by the routes named, radiators should be disposed to deal with it and take its coldness, and its ill quality as a "draught," from it. In the illustration Fig. 24, it will be seen that a radiator is placed near the front and back entrance doors. These are very important situations, if the house is to be properly warmed. There are houses in which it would appear possible to almost warm the whole building if the ground-floor halls or entrances were equipped with sufficient heating surface. In all cases there has to be extra surface here, and even then they are the coolest places in the building. By referring to the chapter entitled QUANTITIES, it will be found that the highest figure for a given space is against outer entrance-ways, and it may be explained here that the special quantity is needed because it does two services, viz., warming the hall to a reasonable temperature, and partially warming the air that goes to the rooms and other parts of the house. It is particularly recommended that full surface be used in those places, for, failing this, the whole undertaking may be in a sense unsatisfactory, affording a feeling that all is not quite right, or that an improvement is possible somewhere. It need never be thought that entrance-halls or corridors can be overheated. This might not be an impossible task, but it is doubtful if any one has done it yet.

In the different rooms the radiators are placed where they are supposed to do best service. It will be seen at once that the writer does not favour placing radiators under windows. They doubtless do good work there, but they waste much heat and give diminished results elsewhere. In good houses the windows are not very draughty; in fact, their yield of cold air through crevices around them is trifling. What little air does enter may come mostly between the middle rails and this does not produce any uncomfortable feeling. There is, however, always a downward fall of cool air from a window, this being due to the cooling influence of the glass—the rapid cooling and making heavier of the warm air that comes against the glass. This is remedied by placing a radiator beneath the window, but the writer considers the remedy the reverse of economical in heat, for most of the warm air rising from the radiator must come against the glass, and this is, to some degree, like trying to heat the air outside. In rooms properly—i.e. sufficiently, and efficiently—warmed by radiators placed in other positions, no inconvenience is experienced by the cool air of the windows, for it is then possible to sit near a window without discomfort.

The practice of putting radiators beneath window seats is a bad one. The seat stifles the work of the radiator (for it is like putting it in a box) ; the warm air cannot rise freely from it ; it is doubtful if the falling of cold air at the window is neutralized, and, lastly, it is not agreeable to occupy a seat with a hot radiator beneath it sending out warmed air in front.

While on the subject of disposing the radiators, it may be mentioned that the not uncommon practice of heating a billiard room by placing a radiator beneath the table must be condemned. If the radiator is powerful enough to heat the room, it is powerful enough to injure the table ; but apart from this, it will be found that players, as they lean on the table, feel an irritating current of warmed air rising beneath their faces. Briefly, billiard rooms should be heated as other rooms, and although the exercise of the players makes less radiation necessary for them, yet it is customary to put in sufficient for 60°, as there are usually lookers-on who need this temperature for comfort.

In disposing the radiators it is not important to put them near the doorways inside the rooms (to intercept the entering air), if the halls are properly warmed. In the halls, as already stated, the cold outer air that enters there should receive warmth as soon as possible ; but when this is done the positions of the radiators in the rooms should be chosen with the knowledge that they warm the air, and send this circulating across or about the rooms. If no other currents disturb the air movement, it will be found that the cooler air will always be moving towards a radiator at a low level, while warmed air ascends from the top of the radiator, and travels more or less horizontally at and above head level Fig. 31 will give an idea of this, the broken lines indicating air movement.

As stated in another part of this book, the writer has for some years lived in houses heated by hot water, and has, naturally, been able to note any good or poor results, that is, any noticeable difference in results, obtained with radiators fixed in different positions. The outcome of this is that some certainty is felt that the best work is done by radiators placed against a solid or blank wall (a wall without a window or opening in it), and facing a similar wall. It is not requisite that the radiators be placed in the centre of the wall, and experience shows that they are best put at that part which comes nearest to a wall with a window in it. The radiators in the Dining-Room and the Morning-Room of Fig. 24 will show what is meant, these radiators being on blank walls and facing blank walls, but moderately close to those walls which have windows in them. The writer has no theoretical argument to back up his conviction, but experience has shown it to be so reliable that he always adopts this plan when possible and feels that it may be recorded here.[1] Of course all this is based on the understanding that the halls, or entrance-ways from which the rooms open, are properly warmed.

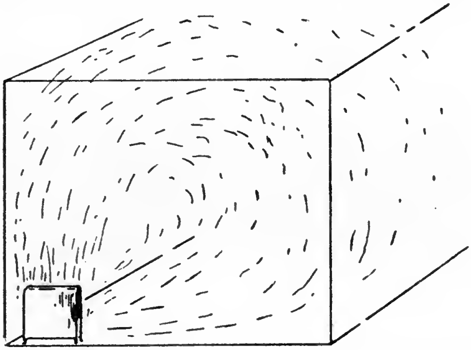

FIG. 31.—Movement of air in a room warmed by a radiator.

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[1] A reasoning that may be offered for a radiator giving good results when placed as described is, that the warmed air from it is largely devoted to counteracting the cooling effect of the window and the outer wall in which the window is. Windows and outside walls are the chief cooling factors if entrance-ways and surrounding rooms are warmed.

A final detail of Fig. 25 that may be discussed is the boiler connections. It will be seen that the main flow pipe leaves one central point at the top of the boiler, that is, starts as a single vertical pipe which is branched just above, while the returns do not join one another, but enter the boiler separately one on each side. Fig. 32 will give an idea of this.[1] The lesson to be learned from this is, that while a main flow pipe may be branched (as many times as its size and the general circumstances will permit), every effort should be made to bring returns home separately to the boiler. Of course this is not always possible; but when it is, the circulation will be found to proceed more uniformly in each, and make regulating valves less necessary. An even better plan with Fig. 25 would be to let the two main circulations have both flows and returns separate at the boiler.

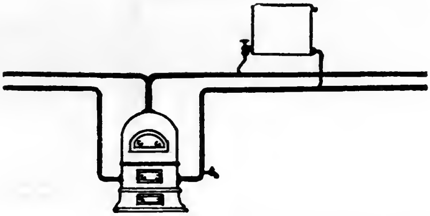

FIG 32.—Boiler with branched main flow and separate returns.

One well-known London engineer appears to try to get a separate circulation from the boiler to every two or three radiators, or as near to this as he can. In a large job it makes a maze of pipes, and much extra expense, but there need be little hesitation in saying that he gets the freest possible circulation to every point on every occasion. Opposed to this, the writer occasionally meets instances in which a man delights in getting all his work on one pair of pipes from the boiler, showing ingenuity in a multiplication of branch circulations. Very few such installations, when at work, fail to show that the engineer lacks experience.

Another example of work on the two-pipe system may be given in Fig. 33. In this it is supposed that the boiler faces the reader, and, while two separate flows leave it at the top,

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[1] It is not absolutely necessary, when two or more returns enter the boiler, that they should be as distant from one another as possible, but it is good practice, and should be arranged so when it can be done.

two returns will be seen entering separately near the bottom, one each side. It will be seen that the apparatus is incomplete, but sufficient is shown to indicate what may be done. It is an apparatus that might appear in a business or public building of several floors, the rising branch circulations (or sub-mains, as they are sometimes called) having the radiators on them, while the chief main circulations are in the basement just above the level of the boiler. There is practically no limit to the number of mains that might be run in the basement (according to the size of the building), and the apparatus lends itself to dealing with any number of radiators.[1]

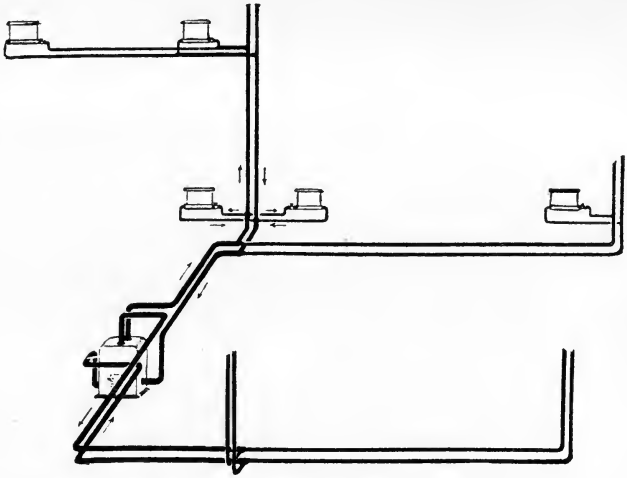

FIG. 33.—Arrangement of main and branch circulations of a large apparatus—two-pipe system.

A detail of importance is the plan adopted in connecting

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[1] It is not too early to state that while a large apparatus, on the two-pipe system, with boiler in basement or pit and mains beneath basement floor or ground floor, is common practice, often seen, and correct to describe as ordinary work, yet the writer always avoids it unless the conditions are particularly favourable or nothing else can be done. He much prefers the Overhead System as ensuring that the most distant radiators and all radiators be of a satisfactory temperature, with low fire or strong fire, all parts being better served than with the two-pipe system. This, of course, refers to extensive installations.

the rising branches to the basement mains. It is not desirable that they be connected by tees "looking upwards," as it is termed. If these branches start vertically, it will be found difficult to get the circulation past them in a satisfactory manner without the aid of stop-valves very nicely adjusted. In any case it is the custom to put valves in these branches, but every effort should be made to get the circulation to work as equally as possible at all points. The difficulty experienced when stop-valves have to be so carefully set to adjust the circulation is, that a variation in the firing will vary the results; and if the valves are accessible to servants, they regulate them according to their own ideas, and, needless to say, complaints quickly follow. Let it be repeated, every engineer should arrange his branches, set out and proportion his work, so that the apparatus will be as independent of regulating valves as an apparatus can be. What valves are used should have removable keys, if in a private residence, and only some one understanding hot water circulations, such as a gardener, be allowed to use them.

As stated, if vertical branches of any importance are taken from horizontal mains, much care and the best judgment should be used as to connections. It is not too much to say that the work past the branch will be wholly cut off and dead, if sufficient care is not shown. Therefore, let such branches start horizontally, as the illustration Fig. 32 shows, and only with branches which run horizontally should the outlets of the tees, which make the connection, look upwards. Of course, any angle between vertical and horizontal can be adopted with the tees, according to the engineer's judgment, but considerable practice is required to make a man skilled in this.

While on the subject of stop-valves (for regulating purposes) in branch circulations, a good plan when the branches carry much work, and the cost will admit, is to put two stop-valves [1] in the branch, one in each pipe, and just above the

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[1] It should be the practice with every engineer never to put any but gate or Peet's full-way valves in circulating pipes. These valves do not reduce the area of the water-way, and the water goes in a straight line through them.

valve in the return pipe insert an emptying cock. The idea is to be able to shut off and empty a branch—a section of the apparatus—and effect any needful repair without emptying the whole or putting the fire out. Whatever happens to a heating apparatus—whether the leaking of an air cock or something greater—always occurs when the apparatus is in use, and the suggestion just made enables any such trouble to be remedied with the least possible inconvenience and cost.

No cold supply service is shown to Figs 32 or 33. This would be connected into one of the returns near the boiler, or into the boiler itself. Full particulars, with suitable sizes of pipes, are given on pages 45–51.

In regard to the expansion pipe, it is a commendable plan to put more than one on an apparatus of large size. On that illustrated, Fig. 33, there might be two, while still larger works might have three or more. It might be roughly reckoned that one to each twenty radiators would be a good number, though more than one is seldom absolutely necessary.

SIZES OF MAIN AND BRANCH CIRCULATING PIPES

It is both necessary and important that the circulating pipes be of a correctly suitable size to serve the radiation, for not only must the radiators be supplied with hot water, coming to and passing through them, fast enough to keep the metal at full temperature, but they must also have pipes of *limited* size, so that the circulation to one radiator, one set of radiators, or one section of the apparatus shall not be so excessively free as to prejudice the supply to other radiators or parts. In other words the pipes can be too small and they can be too large, there being a proper correct size between these extremes.

Tables of pipe sizes are given in Chapter VIII., p. 94.

With the two-pipe system of apparatus just described it is possible to reduce the sizes of the main and branch circulating pipes as the work is passed; thus, if a 3-inch pipe is necessary at the boiler (to carry, say, 700 feet of work), it need not be carried in this size to the most distant point of the apparatus. As branches and work are passed, a size of pipe may be used which is suited for that beyond and no larger. A clear idea of this may be gained from Fig. 34.

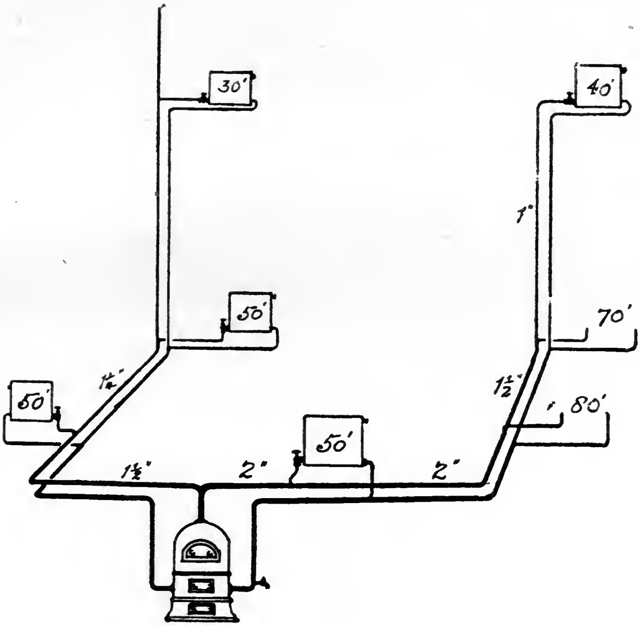

FIG. 34.—Illustrating how the main circulating pipes may be reduced in size as the branch circulations are passed—two-pipe system.

This does not apply to any "one-pipe" system, as will be seen in the following chapters, as the single main pipe then has to carry the flow and return waters of all the radiation on it.

CHAPTER VI

EXAMPLES OF LOW-PRESSURE HOT-WATER HEATING APPARATUS FOR BRICK BUILDINGS—continued.

THE ONE-PIPE SYSTEM

THE meaning of the term " brick buildings," used in the title of this chapter, is given at the beginning of Chapter V., on page 54, in which chapter the two-pipe system of apparatus is described. For the general elementary details of a hot-water apparatus, of any kind, see Chapter IV., page 39.

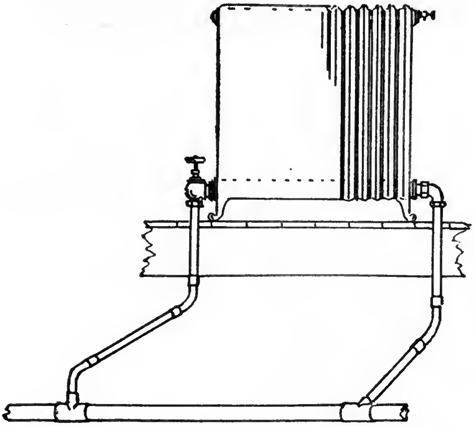

FIG. 35.—Typical correct radiator connection—one-pipe system.

THE ONE-PIPE SYSTEM of apparatus has a flow and return circulation in its mains and branches, much the same as the two-pipe system but as its radiators are connected to one main pipe only, much variation in the work and general planning is possible. It is, however, the fact of the radiators having both their service branches connected into one main pipe (instead of two) that gives this system its distinctive name. To make this clear, a sketch of a radiator, as ordinarily connected up, is given here (Fig. 35), but the description will be given later.

It is somewhat probable that now the one-pipe system has become universally understood, more work is carried out on this principle than any other. Its convenient details lead to this being done—as will be seen very clearly if this chapter is read through—and the convenient features which are so obvious are sometimes accompanied by reduced cost in the work as compared with a two-pipe apparatus.

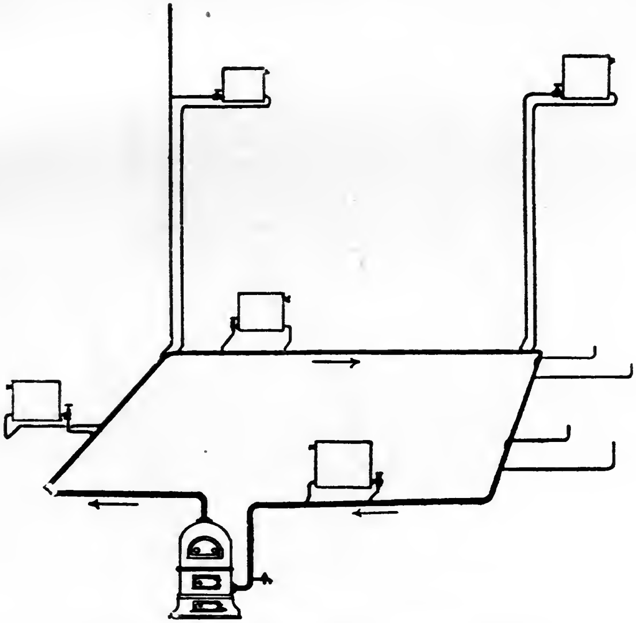

FIG. 36.—Typical apparatus—one-pipe system.

Taking Fig. 36 as an example apparatus to describe the detail from, this, which is a perspective outline of the piping, shows a boiler in a basement or pit, and a single main circuit starting from the top of the boiler, extending around a basement ceiling (or beneath the joists of a ground floor), and returning to the boiler after making what might be a complete circuit of the building. The arrows indicate the direction of the circulation.

One thing that will be noticed is that there can be no short-circuit (see page 43), and no radiator can well be neglected. It must be acknowledged, however, that if the main pipe is too small the last radiators will not heat successfully, but this is a result to be expected with all systems.

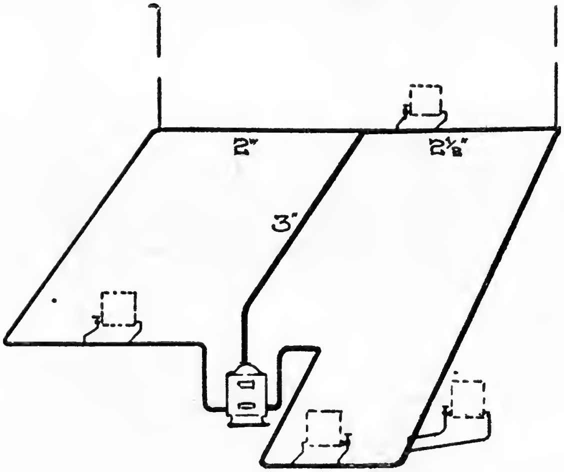

FIG. 37.—Branched main circulation—one-pipe system.

The main circulation is of one size of pipe at all points; that is to say, if it starts 3-inch from the boiler, it keeps this size all the way—and cannot be reduced as the work is passed, as it is with the two-pipe system (see page 68). Of course, if the main flow pipe is branched and returns home to the boiler from two or more different directions, then it would be reduced, as Fig. 37 will serve to show, but with one or more unbranched circuits (and there may be several from one boiler if desired) each one is carried round all the way in the size of pipe it starts with. The reason for this is easily explained, for it will be seen that the water from the radiators returns into the one main pipe, and the latter has, therefore, to act both as flow and return for a greater part of its length. If the temperature of the water could be taken at about half the distance round a circuit, it would be found that the upper part of the pipe contained the hottest water—to serve the radiators as yet unserved—while the lower part of the pipe contained cooler water, viz., that having been through the first radiators and lost some of its heat. Even the application of the hand to a one-pipe main, when it is a full-sized pipe, will show that, in parts, it contains two distinct strata of water, the hottest unused water at top, the cooler used water at bottom. With the two-pipe system the cooler used water at once returns to the boiler, and, therefore, the main service pipes may be reduced as the work is passed, but with the one-pipe system the used water travels on with that which is unused, and the bulk at all points remains the same. As stated, therefore, one-pipe main circuits are carried from beginning to end in the size of pipe they commence with, and are not reduced in size as the work is passed.

The particular kind of job in which the one-pipe system excels is when the work lies to a large extent round the sides of a building. It then means that a single pipe may be carried around the basement about four to six feet from the outer wall, and this one circuit will take all the work, in the way that Fig. 36 shows. Or, if more convenient or desirable, the circuit can be started as a single pipe, and then be branched and returned as two, or more, circuits, as Fig. 37, or, again, there can be two or more distinct circuits from the one boiler, not associated or connected in any way, except for the fact that the one boiler heats the water they contain. In certain cases there may be a circuit to serve a ground or lower floor, while another circuit around the ceiling of the latter will serve the radiators on the floor above. In such a case the higher of the two circuits will probably need a valve to control.

Unless, when two or more floors have to be heated, the conditions make it preferable to run a separate circuit to each, there are usually no objections to heating the radiators of the different floors from the one basement main, as Fig. 36. In that illustration it will be seen there are two radiators occupying much higher situations than the others, and these will be served quite as well as those at the lower level. It means, of course, carrying several pairs of pipes up the least conspicuous angles of some of the rooms, if there are several radiators upstairs, but this may be preferable to a main circuit around the ceiling, or beneath the floor boards above. In suites of offices, or business premises, there is less objection to pipe-casings in angles of rooms, and in such cases several radiators, one above the other, may have their connections, as Fig. 38.

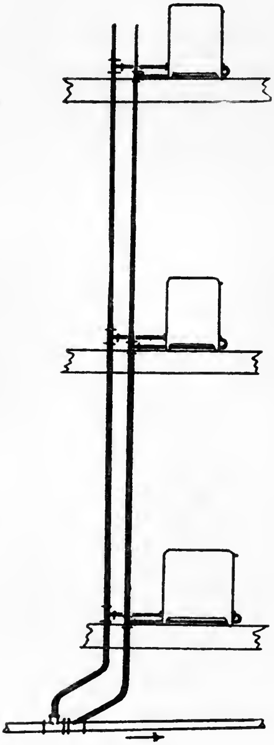

FIG. 38.—Vertical branch circulation serving radiators on three floors, from a one-pipe main in basement.

Referring again to the example apparatus, Fig. 36, it will be seen that the main circulation must have a highest point, that is, it starts from the top of the boiler, and proceeds around the basement with the customary rise of not less than one inch in ten feet, but it must commence to descend somewhere to reach the boiler again. The customary practice is, starting with the flow pipe from the top of the boiler, to give this a rise until it is about half-way round, and then to let it descend the rest of the way back to the boiler. The highest point then is somewhere about as ar from the boiler as it can be, and the pipe from the top of the boiler to the high point is known as the flow, while the continuation of it from that point is considered the return.

A good practice, and which should be considered essential, is to put only half, or less than half, the radiation on the flow, while the remainder is on the return. To do this it follows that the highest point cannot always be exactly half-way out from the boiler, and this is why it was stated it would be *about* half-way. As a matter of fact, however, the highest point is often much nearer to the boiler. What has to be considered is this : That both the theoretical and practical explanation of the action of convection proves that the movement, and the most effective movement, of the water is obtained by studying the return pipe. The actual motive power lies in the return, and this is owing to its carrying the coolest water. Therefore, to load the flow pipe (of the one-pipe system) with radiation more than the return is to lessen good results in a certain degree for the simple reason that all radiation is simply water-cooling surface. Radiators are fixed expressly to lose heat from the water they contain, therefore there should be at least half of them on the return main or more. Occasionally instances are met with in which this argument appears to be weak, as a greater surface on the flow of a circuit is found to work satisfactorily. The writer must admit he has risked it himself when conditions made it imperative, but the fact remains that however well such an apparatus worked, it might be expected to have done better had the greater share of work been on the return.

On the highest point of a horizontal one-pipe circuit (as Fig. 36) there must be provision for the escape of air that will collect there. Air is always collecting in pipes, quite apart from what may gather at high points when filling, and it must have free escape. On this account it is customary to put the expansion pipe on the high point ; and if the general conditions admit, the high point may be arranged to suit the expansion pipe. When, however, they cannot be brought together, the expansion pipe may be anywhere on the flow length of the circuit, but it is then necessary that a radiator be put on the highest point. A radiator allows of a fair volume of air collecting in it without impairing its efficacy, and may only require its air-cock to be opened a few times during the winter season, although it takes all the air of the main circulation. It will not do, however, to have neither expansion pipe nor radiator on the high point, and only trust to an air-cock there. The cock would require opening frequently, and would often be neglected. It is never impossible to arrange the high point to come convenient for a radiator or expansion pipe.

In connecting radiators it is considered best to let the flow or hot connection come vertically from the main by a tee, with its outlet looking upwards, while the return is best if connected by a tee with its outlet horizontal. Fig. 39 (which is a copy of that given on page 70) shows these connections, and their utility is based on the fact, already referred to, that in a one-pipe main the hottest water is carried along the top of the pipe, while the cooler water (which has passed through radiators) travels beneath it. This being so, the reason of the top connection for the flow branch is obvious, while the horizontal return branch delivers its used water in the best possible manner to prevent its mixing with or otherwise prejudicing the hottest water at the top of the pipe. Here again, however, arises the fact that many jobs have been done with both connections made by tees looking upwards, and good results have been obtained ; but it is certainly best to make the connections as first stated whenever possible.

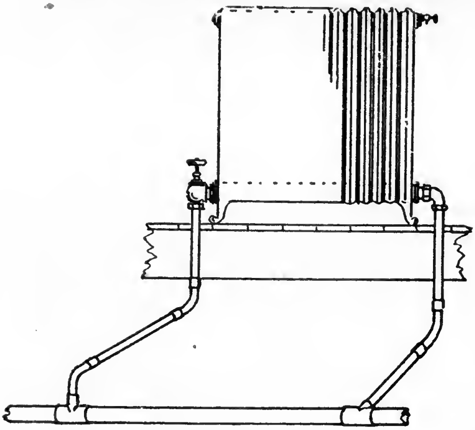

FIG. 39.—Correct method of connecting radiators from one-pipe horizontal mains, the radiators being on the floor above.

When an apparatus on the one-pipe system is being first or newly heated up, or the heat of its water increased, it will be noticed that much of the hottest water appears to enter the first radiator branch, and not work beyond this until the first radiator is quite hot. After this the section of main between the first and second radiators gets hot, but is checked for a time at the second radiator branch and so on. Each radiator branch acts as a temporary or partial check in the heating of the main circulation. This, as stated, only occurs to a noticeable extent when the apparatus is being heated up, yet it occurs to some extent at other times, particularly if only a moderate fire is being kept when, say, the outer air is 42° to 50° Fahr. At these times, although the apparatus is not being newly heated up, but is performing its normal and regular duty, there is often too great a difference in the temperature of the first and last radiators on a circuit.

The object of referring to this is to suggest that when the conditions appear to make it advisable the branch connections to the first, and sometimes the second and third, radiators may be made wholly with horizontal tees—neither the flow nor return tee looking upwards. Considering that the flow main, when it leaves the boiler, is full of the hottest water, there is no necessity for an extreme top connection for the flow branch of the first radiators, and by adopting this plan it will be found that the more distant radiators do better.

It must not be thought, however, that this detail amounts to being a fault of the one-pipe system, for when an apparatus is in full work in cold weather, all radiators are, or should be, thoroughly hot. Of course, with this system as with others, the best uniform results depend to some extent on regulating the radiator valves. If there were say eight 40 feet radiators on a circuit, the valves of the first three, however they might be connected, should be closed to some extent, so as to favour the more distant ones. The writer's common practice, whenever the conditions appear to admit of it, is to put smaller pipes and valves to the first radiators. Some care has to be exercised in this, but in the case of eight 40-feet radiators, it is probable that the two first would be given $\frac{3}{4}$-inch branches and valves instead of the 1-inch that is more customary for radiators of this size. It is astonishing how much the valve of a first radiator can be closed before the full efficient heating of the radiator is interfered with. In the writer's own house, the valve cannot be open more than $\frac{1}{16}$-inch, yet the first radiator, of 32 feet surface, heats most perfectly. It is only a $\frac{3}{4}$-inch valve, too.

Another method of carrying out the one-pipe system of work may be illustrated in Fig. 40. This is truly an example of the "overhead system" (to be next described), but as it is confined to one floor, it may be shown here. It represents the heating of one floor by a boiler which has to be fixed level with the floor that the radiators stand upon. This is not an infrequent demand, as it has often to be done in suites of offices, and in suites of rooms (flats), which are all situated on one floor of a building; and in the writer's own case it was adopted to heat a one-floor bungalow, which had no basement or cellar, and which was on soil that made a boiler pit impossible. There were eight radiators on the return pipe, which, in this case, was carried beneath the floor joists. In suites of offices, or rooms, the return has either to be carried above the floor, or in notched joists beneath the floor boards, when there are other offices or rooms below.

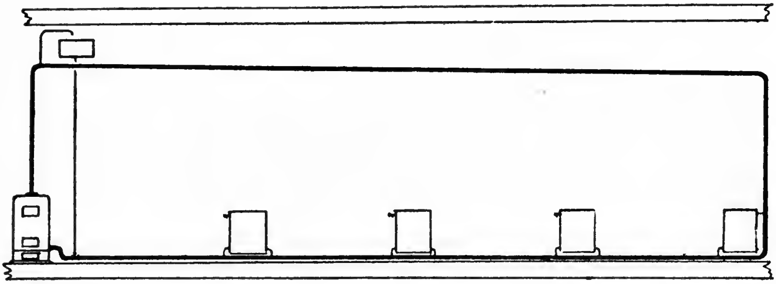

FIG. 40.—A one-pipe apparatus wholly confined to one floor.

It will be seen that the flow pipe is carried as high as possible immediately it leaves the boiler, and then proceeds in a horizontal direction until it is about over the furthest radiator. The flow pipe, having no work on it, can have its highest point either over the boiler or at its distant end, as may be most suitable; but wherever it is, it must carry the expansion pipe there.

A difficulty that arises is in the fact that when the offices or rooms are confined to one floor the flow pipe cannot be carried up to the ceiling and encased there, but must be some 12 inches down, so as to come below the necessary supply cistern, as shown. If it is possible to have the cistern above the ceiling, then the flow pipe can be carried higher; and, in the case of the bungalow just referred to, the flow was carried along on the ceiling joists in the roof. In a self-contained suite of rooms, however, the flow pipe must be carried along the wall, about a foot below the ceiling, unless some special condition allows of it being put higher.

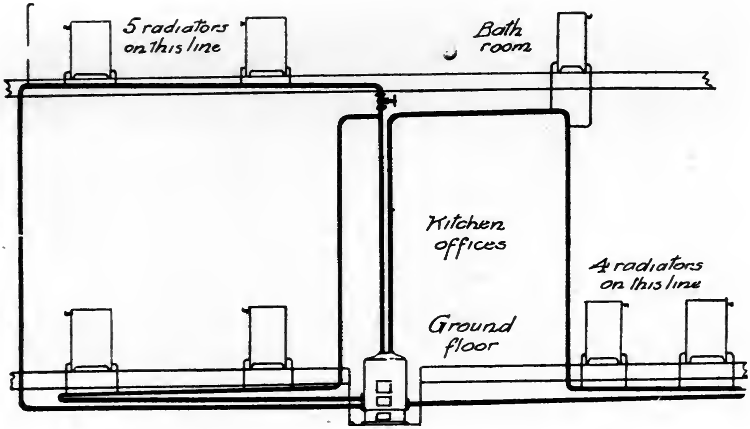

FIG. 41.—An example one-pipe apparatus with two distinct circuits from the boiler.

A final example of an apparatus on the one-pipe system may be given in Fig. 41, this being in the writer's present house, and presenting some unusual features. It is a house of two floors, but without a basement, or any convenience for getting the boiler below the ground floor. It was possible to get the boiler sunk in the floor of an outhouse sufficiently to let the returns be connected without rising, but it could not be sunk low enough to get the flow pipes beneath the ground floor without unusual expense.

In this it will be seen that two circulations start from the top of the boiler. That on the right was carried along the ceiling of the kitchen offices, and could, fortunately, be given an air vent on its highest point by the bathroom radiator coming there.[1] It then dropped in the angle of a lobby (between kitchen and dining-room), and was carried beneath dining and drawing rooms floor and home. The left-hand circulation was branched near the ceiling, and served the greater part of two floors. It is almost needless to say a valve had to be put to prevent the upper floor taking the lead.

In this case, and as has been so strongly recommended in an earlier chapter, the boiler, though having but two flows from it, had three return connections. A flow pipe, if of suitable size, may be branched to any reasonable extent; but the returns of these branches should, wherever possible, be returned to the boiler and connected directly and separately into it. To connect the ends of two or more branch circulations into one return, though permissible, is seldom, if ever, so satisfactory as returning each into the boiler.

The cold supply to the one-pipe system of apparatus should be connected into the boiler or into a return near the boiler. If there is a return which runs below the level of the boiler then it should always be connected into this. The great point to be remembered is that when an apparatus is being charged *or recharged*, the incoming water must enter below any point where air can rest or collect. The incoming water must lift all existing water (left in dips or low pipes), and all air, above it. Full details of the methods and rules to be observed in running the cold supply to a hot-water apparatus, also sizes of cisterns and pipes, are given on pages 45 to 51. All particulars are afforded there, particulars which apply to all systems of low pressure work.

An emptying cock must be put to every boiler, and particulars relating to this are given on page 52.

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[1] It should be mentioned that the work did not run directly to right and left as shown, but the pipes are straightened out on the illustration to make it clear. The levels are correct.

For particulars as to suitable positions for expansion pipes, see page 44 and those following.

SIZES OF MAIN AND BRANCH CIRCULATING PIPES

See note on page 72. Tables of pipe sizes are given in Chap. VIII., p. 94.

A TWO-PIPE CIRCUIT SYSTEM, WITH POSITIVE CIRCULATION

To the best of belief this system has no better title, and is but little practised as yet. The scheme of piping is really a combination of the one-pipe and two-pipe systems; for, while there can be no short circuit, there is a distinct and separate return pipe for the water that comes from the radiators, and the main pipes can be graduated in size.

This combined system, while costing a little more, is of advantage when the rising branches go up to several floors, and their returns bring down a considerable volume of water that is cooler than is usually returned into a one-pipe main. With an apparatus as ordinarily constructed the water that passes through a radiator and returns to the main is hot enough to do further service, or, in any case, it is not cool enough seriously to prejudice the temperature of the hot water the main carries; but when the return water is expected to be cool enough to be useless this duplicate arrangement of mains offers some advantage.

Fig. 42 illustrates the piping of mains as might be carried round a basement, the branches rising to supply the radiators on the floors above. The flow pipe starts out from the top of the boiler, and proceeds in its full size as far as the first branch. As this branch takes a fair proportion of the work, the flow pipe is reduced in size when the branch is passed, and until the next branch of importance is reached. As this is passed a further reduction occurs, and so it proceeds, exactly the same as with the two-pipe system (see page 6); but with the flow pipe the similarity ends.

The return pipe may be said to commence at the first flow branch, the return of which is the commencement of the main return, and, on its proceeding, and taking in the next branch return, its size is increased accordingly. This is continued, the return following the line of the flow, but the return increases in size as the flow decreases, the reason for which can be plainly seen. Ultimately the return pipe ends in the boiler in the same size as the flow ; and the pipes at the boiler, both in size and detail of connection, are the same as with any other system.

A peculiar detail in an apparatus erected in this manner is that the main pipes do not both preserve the same line. As is known, the flow pipe has to be given a rise from the boiler, while the return is given a fall towards the boiler—or, it might be said that both pipes rise from the boiler. It is equally correct with this apparatus ; but the unusual or opposite paths pursued by the pipes makes them diverge, or open out, as the illustration shows.

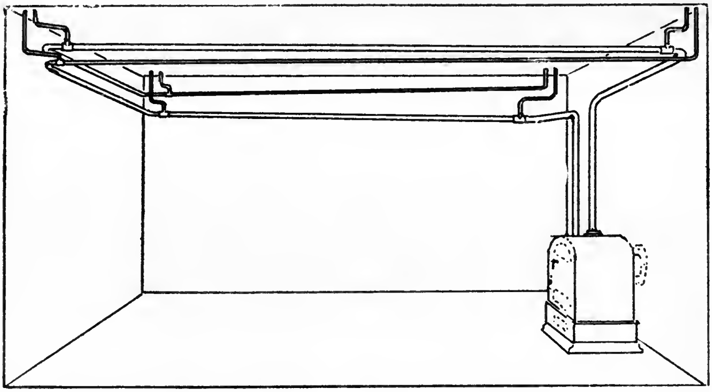

FIG. 42.—Illustrating the main circuit which ensures the positive circulation.

Details of sizes of mains and branches, cold supply and expansion pipes, would be the same as with the systems already explained.

CHAPTER VII

FURTHER EXAMPLES OF LOW-PRESSURE HOT-WATER HEATING APPARATUS FOR BRICK BUILDINGS

THE OVERHEAD SYSTEM AND METHODS OF WORK TO SUIT SPECIAL CONDITIONS

THE meaning of the term brick buildings, used in the title of this chapter, is given at the beginning of Chapter V., on page 54, in which the two-pipe system of apparatus is described. For the general elementary details of a hot-water apparatus, of any kind, see Chapter IV., page 39.

THE OVERHEAD SYSTEM of apparatus is really a one-pipe system, but in which the piping is largely run in a vertical direction.

Fig. 43 is an outline of an apparatus which may be supposed to be heating several floors of an apartment building (flats), or a warehouse, or block of offices. One building the writer heated by this plan was a furnishing establishment of four floors— the floors being constructed of iron and concrete, and no horizontal pipes were to be visible at floor or ceiling lines. The importance of this detail appears when it is stated that the boiler had to be on a level with the ground floor, where the chief show rooms and offices were, so that the usual horizontal mains around the lowest floor of the building just above the boiler were quite impossible.

It will be seen that in this apparatus the flow-pipe proceeds unbranched and by the most direct route to the top or a high part of the building. At this point it runs horizontally, perhaps as a single pipe, though more probably it is branched in different directions, until it can descend down the angles, or other convenient parts, of the rooms below.[1] The high horizontal part of the flow main must run along a floor or a ceiling, but it may be assumed that on a fourth floor this will be allowed, even if it has to be encased. Failing this, however, it must be run in the roof, and be well covered to prevent loss of heat. If it is run along the floor line of the highest floor that is to have radiators, then the radiators may be connected to it as shown. In the same way the horizontal main return, which is shown carried beneath the floor line of

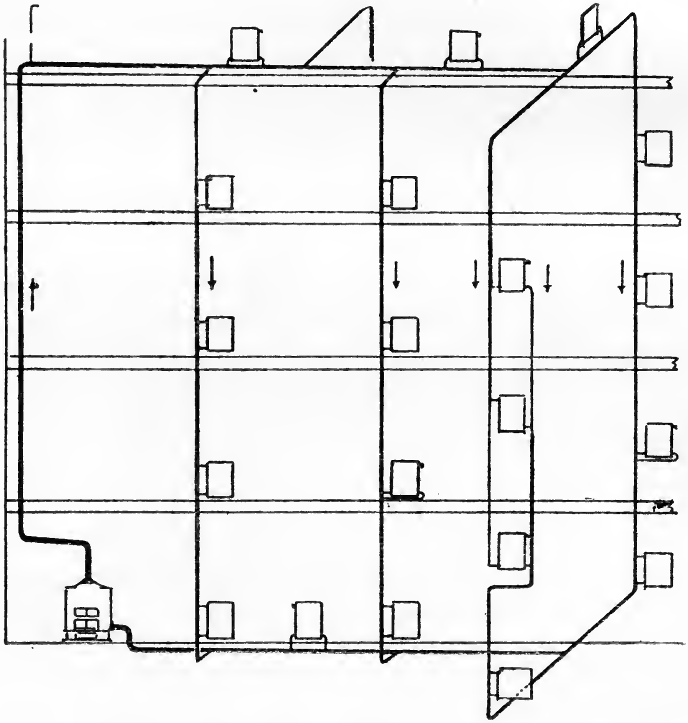

FIG. 43.—The Overhead System, as carried out with large installations.

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[1] The descending pipes in the angles of the rooms are probably inconspicuous, or they may be encased. The main flow-pipe should be cased and well packed to prevent loss of heat as this pipe carries the hottest water and can lose heat the fastest.

the lowest floor, can, and would, have radiators on it to warm that floor.

All the descending branches (they might be called branch mains) have the radiators connected on the one-pipe system—that is, the two branches to each radiator proceed from the same pipe, and the radiators may have two bottom connections, or one top and one bottom, as may appear best. Some of each are shown in the illustration. One branch main, however, is shown partly in duplicate—that is, it has an extra pipe for part of its length, this pipe being in the nature of a return to receive the water after it has passed through the radiators, thus keeping the cooled water from coming into the branch main, which is carrying the hot. The illustration makes the connections clear, which, in themselves, are like those described with the special apparatus shown on page 82, and the same result is obtained. It is a plan, however, which is seldom if ever necessary with the apparatus now under discussion, and it is only described because some engineers favour the practice.

Of course, when the main is branched in several places, as illustrated, it can be graduated in size according to the work it has to carry, but should the main circulation by any chance be unbranched, then it must remain the same size of pipe throughout. In this respect it exactly resembles the ordinary one-pipe system (see page 71).

It is claimed for this system of apparatus that, with ordinary care, it never fails to work well and uniformly. Theoretically it is a perfect arrangement, as the flow main carries no work, and is filled with the hottest and lightest water at all times. The returns, which carry cooler water, are all descending pipes and nearly all vertical, and under these conditions there can be no doubt the circulatory movement is the freest and swiftest of any apparatus. On this account the mains and branch mains can be of the least size.

Opposed, however, to the advantage of uniform working is the fact that the radiators on the lower floors are of a little less temperature than those on the top floor, and as a general rule the reverse of this is required. In the first place, a building that is warmed nearly always has warmed air gather towards its upper floors. This is so recognized that if a fourth floor was as important a place, and required the same warmth as a ground floor, it would not be necessary to put quite as much radiation up there. In the second place it is very unusual for a top floor to be needed as warm as a lower floor ; it is generally the least important part of a building, though requiring some warmth to keep stock in good condition or some similar purpose.

This need not, however, be considered a serious fault of the system, but provision must be made to equalize results. It should be noted (1), that it is important that the mains and branch (descending) mains be well covered, so that all possible waste of heat be prevented, remembering that the lower floor radiators are the last to be served. (2) The radiators of the upper floors must be of minimum size for the work and the valves must be regulated (closed), so as to give them only the water they actually need. Internally adjusted valves (Fig. 45) might well be used here. (3) The radiators on the lower floors must be of full size for the work to allow for their slightly lessened temperature, and the best heat nearly always being needed here.

A small example of an overhead system of apparatus is given in Fig. 40 page 78, and may be referred to. It was included in the chapter describing the one-pipe system, owing to its being confined to one floor of a building.

The cold supply to this apparatus would be run in the manner described on page 45, and following pages. The sizes of pipes and cisterns and all particulars are afforded there.

An emptying cock must be put to every boiler, and particulars relating to this are given on page 52.

For particulars as to positions for expansion pipes see page 44.

SIZES OF MAIN PIPES, BRANCH AND CIRCULATING, are the same as with other systems, see Chap. VIII., p. 94.

WARMING BY HOT-WATER PIPES OR RADIATORS *FIXED OVERHEAD*

For some time past a method of warming has been practised which would appear to be opposed to the general idea as to how pipes or radiators afford heat, until it is remembered that a circulation of air must occur when a hot body exists in a room, whether the body be placed high or low or midway. It must be said, however, that with the heated surfaces as near the floor as possible the best results are obtained, and the quickest, but with several installations carried out and a number of others inspected and tested the overhead heating surface has done excellent work ; perfect work it might be said.

One installation in particular was a tobacco factory, and all floors were heated by lines of pipe carried about 3 feet from the ceiling and about 9 feet from the floor. Taking a typical floor of the building, this was about 80 feet long by 40 feet wide, and was occupied by about 150 to 180 girls making cigarettes. These girls, also the forewomen, who had not the slightest interest in speaking favourably of the heating apparatus, and who would have been ready enough to complain if complaint could be made, said they were quite comfortable. When asked if they experienced more warmth at their heads than their feet, they said no in such a way that it could be seen that no discomfort or unusual feeling whatever had been experienced. There was no heating surface at the floor line, and although the pipes near one ceiling would afford warmth to the substance of the floor above, very little could be expected to go through, as the floors were of iron joist and concrete construction.

This method of work is particularly suited for factories and similar places, in which an extensive area has to be warmed ; probably too extensive for pipes or radiators on the floors, confined to the walls, to deal with. Furthermore, in the majority of factories the walls are utilized either for benches, machine tools, or other purposes. In very few such places is it the custom or wish to leave the walls unoccupied. If a factory consists of two or more floors, the light is obtained through windows around the side walls, in which case there are always benches or machines along the walls where the best or more delicate work requiring the best light is done. Even in single floor (bungalow) factories, with the light coming through sashes in the north side of each roof ridge, the walls are almost invariably occupied.

Taking for granted that the walls are practically never available for pipes or radiators, where can they be put? Any attempt to place them on the floor nearer the middle of the factory is quite out of the question, and the overhead pipe comes as a solution to the problem.

Fig. 44 will give an idea of how such a job might appear.

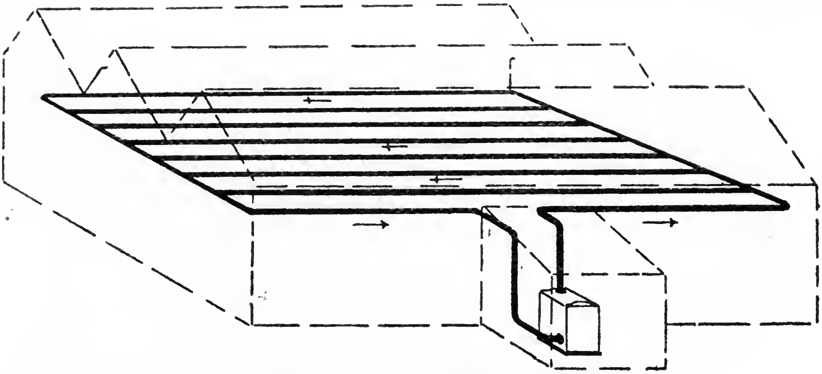

FIG. 44.—Factory warming by radiation wholly overhead.

The faint outline suggests a factory (a boot factory or a printing works, for instance) wholly on the ground level, and lighted by north lights in the ridges of the roof. The boiler is supposed to be in a small outhouse, and the thick lines show a main flow pipe proceeding from the boiler to one end of the building and along the wall there. From this flow a number of 2-inch, 2½-inch., or 3-inch pipes run the whole length of the place, descending as returns, and join a main return at the opposite end, whence it proceeds home to the boiler.

The general principles to be followed in this work are the same as with the ordinary one-pipe or two-pipe systems, according to which appears to be best to meet the conditions; and the sizes of mains and other details would remain the same.

CHURCH HEATING

There are two things which may be counted as difficulties when heating places of worship or public buildings of large area and lofty interiors. One is the down currents of cool or cold air that are usually experienced in cold weather; the other being the frequent difficulty of getting the heating surface distributed so as to give the best results.

Taking the latter difficulty first, the average church appears to be planned by an architect who has a disregard for the heating arrangements. Pews are carried to the walls on both sides (even under the windows, where a downward movement of cold air is sure to occur in cold weather), and the boiler pit is put anywhere. It would be far better if the seating accommodation could be arranged so as to leave the side walls clear, where pipes and radiators could come above the floor. The more customary plan, made necessary by the arrangement of seats, is to have pipes in trenches with gratings over, and, remembering that they are usually 4-inch pipes, nothing worse could possibly be devised.

The large pipes, 4-inch, hold so much water that of all heating arrangements they are the slowest to get hot and the slowest to cool. Both are good features in horticultural works, as may be learned by turning to that section of this book, but while the slow cooling is no gain in a church, the slowness in heating up is a distinct fault. If low-pressure heating is adopted, every effort should be made to use radiators, with the smallest main pipes that will do the work well, as, by keeping down the bulk of water in an apparatus, the quickest heating is assured. It is the fact of a church (or public place) not being heated every day, with the fire constantly alight, that makes quick heating essential. In one case heard of, the fire of a church heating apparatus had to be lighted on Friday evening to afford sufficient warmth for Sunday morning service. If the consumption of fuel was proportionate to the time it was excessive for the duty performed.

Every effort should be made to erect an apparatus that will heat up quickly, and to do this to best advantage the whole of the radiating surface should be above the floor and uncovered. Four-inch pipes should be avoided, and if pipes must be used (as radiating surface), let them be 3-inch and 2-inch. A 2-inch pipe has half the surface of a 4-inch one, but it holds only one-fourth the water. In the ordinary way an apparatus is made up almost wholly of 4-inch pipe, mostly in grated trenches, with some built up in coils and covered with coil cases. Supposing the apparatus to be quite new, the loss of heat due to trenches is at least one-fifth, but after a few months or a year the loss of heat is far greater. The passage of numbers of people over the trench gratings, the dusting and cleaning of the place, and other things, literally load the trench pipes with dirt; in fact, they are sometimes found to be loaded on top and half buried beneath with dust and what is termed " flue "; and the coils in the coil cases are little better. Now, remembering that this dirt is composed almost wholly of poor conductors of heat—hair, fibre, cotton, wool, grit (silica), etc., the loss of heat, or rather the prevention of heat emission, is equivalent to wrapping the pipes in a blanket. It must not be thought that church attendants clean the pipes, for it is beyond their power. There may be a ton or more of gratings to be removed, and by the time the dirt was got away and the pipes well cleaned, the rest of the church would be in a terrible state.

Briefly stated, use every means to get the heating surface above the floor. Put radiators (or pipes) along the walls if possible, get radiators against the front and back risers of each block of centre or side pews and against the chancel and the transept walls. Make a special effort to heat all lobbies and entrance ways as, notwithstanding the ventilating arrangements, these places are usually the source of insupportable draughts.

The other difficulty referred to is that of the down-currents of cold air. Let it first be explained that this has nothing to do with the downfall of cold air at the windows. The latter, if it has to be treated, must be considered separately; but the best plan, if it lies in the engineer's power, is to persuade the architect to keep seats away from immediately beneath the windows.

The downward movement of cold air, commonly felt over the whole body of a church, or nearly so, is due to the height of the place. Reliable experiments have shown that the heat—heated air really—from pipes or radiators placed on or near the floor has little or no effect in warming the air above 15 feet height. At about this height the heated current turns in a lateral direction and presently descends, and in doing so is either cooled by the upper stratum of air, or mixes and brings some down with it. This unpleasant effect is doubtless made worse by the common use of inlet ventilators of the Tobin-tube pattern, which discharge cold air a few feet over the heads of the congregation, but it is a fact that the cold downward movement of air referred to occurs when the Tobin's tubes are either closed or do not exist.

The outcome of this is to show that to deal with the upper air of churches there should be another set of pipes or radiators at just about the 15 feet level, or a little above it. This has been done as far as is possible, and has proved a success, so much so that our best engineers, when designing this work, always arrange for one or two pipes to come around the wall at about the height named, or as near to it as possible.

In one instance, of the writer's experience, not only was the customary amount of radiation provided at floor level and a pair of pipes also run about 16 feet high, just beneath the clerestory windows, but an additional four pipes were run along the horizontal beams in the apex of the roof. This made an excellent job, and considering the money spent in erecting churches—which are not a cheap type of building—the comparatively small extra cost of these upper pipes should always be willingly borne. It certainly should be so, remembering that they obviate an unpleasantness which is little short of a danger to many.

In the instance just recorded, the roof pipes formed a distinct apparatus on the high pressure principle, with its filling cap and expansion pipe in the tower. The chief idea in this was to enable the roof to be heated in summer, if desired, to promote ventilation.

Another mode of dealing with the upper air in high interiors lies in discharging warmed air there. A large coil or battery of 1½ or 2 inch low-pressure, or ⅞-inch high-pressure, pipe is made, and suitably connected up for heating, and through this a supply of fresh air is propelled by a fan or blower. This affords the needed warmth to the air, which is then carried by tubes or ducts, and discharged through openings, around the church interior walls, at a suitable height. This quite defeats any down currents of cool air that might set in in cold weather. The chief objection is the first cost; but it can be run quite economically when once the arrangement is installed, and could be used for ventilating purposes, without heat, in the summer.

In any case, it is highly desirable, in church work, that no inlet ventilators of the Tobin's tube design exist to bring in and discharge air above the heads of the congregation, unless provision is made for warming the air in winter. This is sometimes done by putting two or three small radiator sections in the base of each air tube, the tube being specially made for the purpose. By this plan sufficient ventilation can be obtained for cold weather without any disagreeable effects; but to discharge cold air, at from 12 to 16 points, at about a 7 feet or 8 feet level, into a building warmed by hot water is unreasonable.

An ever present weakness in a low-pressure hot-water apparatus, when installed in a church, is the liability of its water freezing at some point or points in very cold weather, when the fire is not alight. Certain churches have services three or four times a week, and can afford to keep a fire in the boiler the whole of the winter season; but a great number, probably the majority, have no heat for three or four consecutive days each week, and unless great care is used and the conditions are favourable, a severe frost may prove destructive. On this account the apparatus that is being somewhat favoured for this and similar purposes is that of the high-pressure principle, the reason being that the pipes of this can be charged with a non-freezing solution. This makes all parts frost-proof, but, in addition to this, a high-pressure apparatus, if properly erected, is quicker in heating up than one on any low-pressure system ; and, again, a high-pressure installation will, as a rule, be found to be the cheapest to erect. Unfortunately, the London Building Act, which most surveyors and authorities recognize, will not allow a high-pressure pipe to be run nearer than 3 inches to wood-work or any inflammable material, but this and all details relating to the high-pressure system will be found in a later chapter of this book.

CHAPTER VIII

SIZES OF CIRCULATING PIPES, MAINS AND BRANCHES, FOR TWO-PIPE, ONE-PIPE AND OVERHEAD GRAVITY SYSTEMS

THE circulating pipes are the means provided to convey the heated water from the boiler to the radiators or radiating pipes. It follows, therefore, that they must be of a size that will best serve this purpose, firstly, by ensuring that the radiation is sufficiently supplied to keep it at full temperature and, secondly, by serving all radiators, sets of radiators or sections of the apparatus as uniformly as possible. In simple words, and in general practice, this means that the pipes must be large enough to permit of the full needed amount of hot water coming to the radiation, while, on the other hand, they must not be so large that one section of work will have such an excessive supply that other parts will be more or less starved. Briefly pipes can be too small and they can be too large.

As has been shown the circulating movement of water is due to the difference in temperature (meaning weight in this case) of the two columns of water, so that the hotter the flow-pipe and the cooler the return pipe the swifter the circulation must be. Consequently the greater the difference in this respect the smaller the pipes might be to bring the needed amount of hot water from boiler to radiation, but there has to be a limit in this respect, as the heated water in the radiators must not be held there until it is cool. The following tables are therefore based on an average difference of 30° Fahr. in the main flows and returns, which is a common difference in an apparatus working under normal conditions.

It must always be understood that when "Radiation" is spoken of in determining pipe sizes, or in determining boiler power, the surfaces of the main or branch circulating pipes must be counted in, as they all lose heat as much or even more than radiators, unless they are well covered to prevent heat-loss. But even covered pipes lose some heat, the amount varying with the kind of covering and its thickness, it usually being safe to allow that well covered pipes lose only one-fourth as much as uncovered pipes, this being a 75 per cent. reduction by the covering.

Special Note.—In the following Tables are given the amounts of radiation that pipes of certain sizes will serve under certain conditions, the amounts being shown in British Thermal Units and in Square (superficial) feet of surface. The more correct figures are those given in B.Th.U. because radidiators of different kinds (one, two, three and four column) and different heights (13 inches to 42 inches), also those intended to be run at different temperatures, emit different amounts of heat per square foot, per hour. Again, when the radiation takes the form of wrought or cast pipe, as it does in some buildings and nearly all glass-houses, the heat emission per square foot differs again (being greater), so that to say a certain size of circulating pipe will serve a certain number of square feet of radiation of any kind must be wrong. Tables in Chap. XII, pp. 146–149. give quite clearly the heat emission from different kinds of radiators and radiation so that when what may be termed ordinary radiators are not used the B.Th.U. figures should be worked to.

It now remains to be said that although the subject of pipe sizes has been most carefully considered and worked out by several capable authorities the fact remains that conditions vary to such an extent, even in two installations of same height and horizontal distance, that figures have to be given to suit the worst instances, these figures being more or less incorrect when the conditions are the best obtainable. To some it might be thought that giving pipe-sizes of full diameter for poor conditions is only erring on the side of

In the following tables the figures given for square feet of Radiator surface are correct when the most customary radiators are used, viz., 36 *inches high, two column, average number of loops or sections per radiator being* 8 *to* 12, *emitting* 135 *B.Th.U. per square foot, per hour, when fully hot in cold weather, the temperature of the room (when warmed) being* 60°*F.*

SIZES OF MAIN CIRCULATING PIPES

That will serve various amounts of radiation under different conditions as to height and distance.

Size of Pipes . .		1	1¼	1½	2	2½	3	4 inch.	
Mains not extending out more than 50 feet in a horizontal direction from the boiler.	Height from centre of boiler to radiator branch								
	Up to 10 feet	6,100	11,450	18,900	36,400	62,800	99,900	194,000	B.Th.U.
	,, ,,	**45**	**85**	**140**	**270**	**465**	**740**	**1,440**	Sq. feet
	,, 15 ,,	7,500	13,500	23,000	44,500	75,600	120,200	233,000	B.Th.U.
	,, ,, ,,	**55**	**100**	**170**	**330**	**560**	**890**	**1,728**	Sq. feet
	,, 20 ,,	8,800	15,500	27,000	52,600	88,400	140,400	270,000	B.Th.U.
	,, ,, ,,	**65**	**115**	**200**	**390**	**655**	**1,040**	**2,000**	Sq. feet
	,, 25 ,,	10,100	17,500	31,000	60,700	101,300	160,700	309,000	B.Th.U.
	,, ,, ,,	**75**	**130**	**230**	**450**	**750**	**1,190**	**2,290**	Sq. feet
	,, 30 ,,	11,450	20,200	35,800	69,500	114,750	182,300	351,000	B.Th.U.
	,, ,, ,,	**85**	**150**	**265**	**515**	**850**	**1,350**	**2,600**	Sq. feet
Mains extending out from 50 to 100 feet in a horizontal direction from the boiler, or up to 150 feet with the larger sizes of pipes	Up to 10 feet	—	9,450	15,500	29,700	51,300	81,000	162,000	B.Th.U.
	,, ,, ,,	—	**70**	**115**	**220**	**380**	**600**	**1,200**	Sq. feet
	,, 20 ,,	—	13,200	22,300	45,900	74,200	121,500	236,000	B.Th.U.
	,, ,, ,,	—	**98**	**165**	**340**	**550**	**900**	**1,750**	Sq. feet
	,, 30 ,,	—	16,900	29,700	63,400	98,500	162,000	310,000	B.Th.U.
	,, ,, ,,	—	**125**	**220**	**471**	**730**	**1,200**	**2,300**	Sq. feet
	,, 40 ,,	—	20,200	36,400	81,000	121,500	202,000	378,000	B.Th.U.
	,, ,, ,,	—	**150**	**270**	**600**	**900**	**1,500**	**2,800**	Sq. feet
	,, 50	—	23,600	44,500	97,200	143,000	243,000	445,000	B.Th.U.
	,, ,,	—	**175**	**330**	**720**	**1,060**	**1,800**	**3,300**	Sq. feet

Sizes of Radiator Branches

i.e., Branch circulations carrying from one to three or four Radiators and which would not be considered as Main circulations.

	Sizes of Pipes.	½	¾	1 inch.	
Branches not extending out more than 10 feet in a horizontal direction from the main which serves them.	Height from Main (from which branch is taken) to radiator.				
	Up to 3 feet	2,200	4,000	8,100	B.Th.U.
	,, ,, ,,	**16**	**30**	**60**	Sq. feet
	,, 10 ,,	2,450	4,700	9,450	B.Th.U.
	,, ,, ,,	**18**	**35**	**70**	Sq. feet
	,, 15 ,,	2,700	5,400	10,800	B.Th.U.
	,, ,, ,,	**20**	**40**	**80**	Sq. feet
	,, 20 ,,	3,000	6,100	12,100	B.Th.U.
	,, ,, ,,	**22**	**45**	**90**	Sq. feet
	,, 25 ,,	3,400	6,750	13,500	B.Th.U.
	,, ,, ,,	**25**	**50**	**100**	Sq. feet
	,, 30 ,,	3,800	7,500	14,800	B.Th.U.
	,, ,, ,,	**28**	**55**	**110**	Sq. feet
Branches extending out from 10 feet to 20 feet in a horizontal direction from the main which serves them.	Up to 3 feet	—	3,400	6,700	B.Th.U.
	,, ,, ,,	—	**25**	**50**	Sq. feet
	,, 10 ,,	2,000	4,000	8,100	B.Th.U.
	,, ,, ,,	**15**	**30**	**60**	Sq. feet
	,, 15 ,,	2,400	4,700	9,450	B.Th.U.
	,, ,, ,,	**18**	**35**	**70**	Sq. feet
	,, 20 ,,	2,700	5,400	10,800	B.Th.U.
	,, ,, ,,	**20**	**40**	**80**	Sq. feet
	,, 25 ,,	3,000	6,100	12,100	B.Th.U.
	,, ,, ,,	**22**	**45**	**90**	Sq. feet
	,, 30 ,,	3,400	6,700	13,500	B.Th.U.
	,, ,, ,,	**25**	**50**	**100**	Sq. feet

safety when the conditions are good, but, as previously stated, the pipes can give trouble, if too large, when any apparatus has several sections or several branch main circulations. In consequence of this one authority has stated that he always uses double-adjustment valves at the radiators (to check the circulation if it is too free), these being valves which can have an internal part adjusted so that its "full open" bore can be varied in size. There are different makes of these, Fig 45 showing, in section, one of the designs of the National Radiator Co., Ltd. This might be described as a simple quick-opening plug valve (made straight as shown, or angle shape) and regulation is effected by adjusting the plate which controls the travel of the lever handle. Another simple means, when it is not desired to use a valve, is the Regulating Tee shown in section by Fig. 46; this needs no description. There are also Regulating Elbows and other devices all being intended to *check* the circulation, not increase it, theoretical pipe sizes having to err somewhat on the side of largeness to allow for bad conditions.

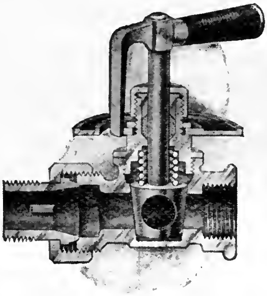

FIG. 45.—Radiator valve constructed to admit of permanently checking the circulation through it.

CHAPTER IX

EXAMPLES OF LOW-PRESSURE HOT-WATER HEATING APPARATUS FOR GLASS-HOUSES AND HORTICULTURAL BUILDINGS

For the general elementary description and details of a hot-water heating apparatus, the reader is referred to Chapter IV., page 39.

In glass-house work it will be found that the radiator is seldom used (unless it be in a conservatory or winter garden), while the 4-inch pipe, or at the smallest the 3-inch pipe, is the favoured radiating surface. Probably cheapness may be a factor in this, also the ease with which almost unskilled men can do the work in the ranges of houses used by market growers; but an important feature with the 4-inch pipe is that it holds more water for a given surface than any other radiating medium that is generally used. Besides this, rows of pipe give a more uniform and well distributed heat in a building that is so largely composed of heat losing material—glass.

The advantage of a good bulk of water in a horticultural apparatus is that it does not readily show any variation in the stoking. It is slow to heat and slow to cool, both advantageous, for once the place is got to the required warmth, the gardener or grower does not want the temperature rising and falling every time the furnace is attended to, or wants attending to, or is neglected a little.

Horticultural glass-houses may be said to be of two kinds, viz. those which are built against a wall and would be called "lean-to," and those that rise to a ridge in the middle, both sides of which are alike (not being bounded by a high wall), and are called "span" houses. With a lean-to house it is commonly sufficient to run the pipes along the side furthest from the back wall, and this gives quite satisfactory results. The wall side requires no pipes, unless it should be a tropical house, or "stove," for forcing, etc., in which case pipes are put wherever they can be got as the quantity is considerable. In span houses (which might be said to resemble two lean-to houses leaning or standing against one another) the pipes are run on both sides and, when necessary, pipes may be carried around the ends and up the centre also.

The reason for this arrangement of the pipes is that the glass is the heat losing material, compared to which brick walls may be considered heat-proof. In calculating the length of pipe required to afford a certain amount of heat in this work, the glass measurement only is taken, all brick and woodwork being ignored as taking such a little part in the heat-loss which has to be constantly made good. This is referred to fully in the chapter on QUANTITIES, which deals with the heating surface required to afford certain temperatures.

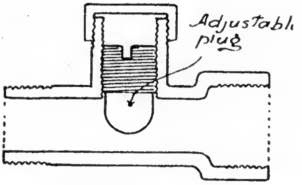

FIG. 46.—Special tee-piece with means of permanently checking the circulation through a pipe.

Let it be explained here that it is the exception and not the rule for the heating engineer to dispose the pipes, that is, to say where they had best, or shall, be run. The gardener settles this, and much more, and if the engineer does not at first realize that the gardener has a ruling voice in this work, he doubtless will soon be made to know it. Practically every residence or place requiring glass-houses, even on a moderate scale, has a regular gardener, and he must be considered in every possible way.

The most simple form of apparatus we have for heating glass-houses, yet about the most ingenious, is that in which the boiler is built in the thickness of the low brickwork at one end of the greenhouse, and which, therefore, requires no pit nor house to accommodate it. It has the further advantage of requiring no connecting pipes between the boiler and those which heat the house, for the back of the boiler comes inside the house, and the heating pipes proceed directly from it. Again, the water-supply detail is greatly simplified, for the "expansion-box" forms a feed cistern, a syphon-end for the pipes, also a support to them and an air vent at the same time.

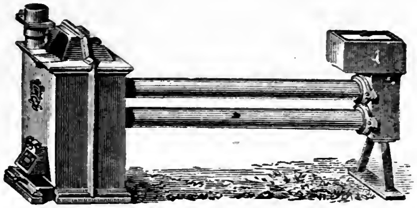

Fig. 47.—Complete heating apparatus for amateurs' greenhouses.

Figs. 47 and 48 show such an apparatus, the first showing the detail of parts, the second showing it fixed in position for heating a small lean-to house. It will be noticed that the fixing is of the most simple description, the boiler being either built in as the dwarf wall is made, or a suitable hole is cut and the boiler placed in and cemented round. This boiler has no water-way at the front but is lined with fire-brick there, so that if rain or snow beat upon it the heat of the apparatus is not reduced and no harm is done. All stoking and attention is done outside, so that the door of the house need not be opened, nor is any dust made within.

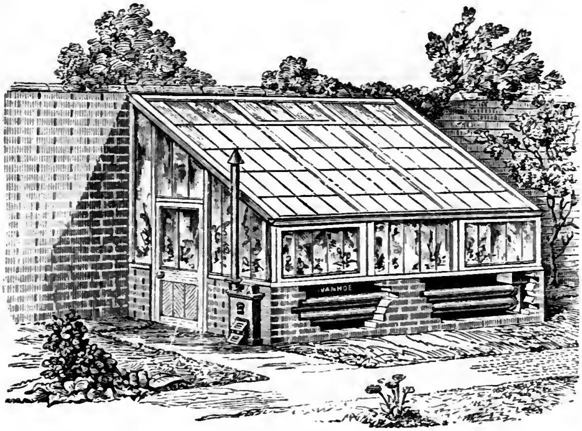

Fig. 48.—Showing the apparatus, Fig 47, installed.

This apparatus, in some similar form, appears in most catalogues, and is sold complete with a simple kind of rubber collar joint for the pipes, so that amateurs may erect it complete if they so desire. The cistern (expansion-box) would be hand-fed and need not have a ball-valve.

Fig. 49 shows a simple installation adapted for warming two adjoining houses, without the use of the mains which appear in the next example. It may be supposed that one is a hot house, while the other larger one is for vines or general purposes, and would be ten or fifteen degrees cooler. Only the flow pipes, that is the top pipes, are shown, this being a plan drawing, but it can be easily understood that the return pipes would be exactly the same, but beneath the flows. The valves in the positions shown admit of the two houses having their heat regulated independently. This is very necessary, as will be understood, yet very commonly neglected. At the point marked, or thereabouts, an **H** piece would have to be inserted to admit of a return circulation occurring from there when the valve in the larger house should be closed. Air pipes would be needed at the points marked, these being highest points of circulation, while one is on the boiler side of the valve of the larger house. The valves being for regulating they need only be in the flow pipes, there need not be any in the returns. The dotted piece of circulation near the boiler is kept just beneath the ground level until it has passed the door and footway.

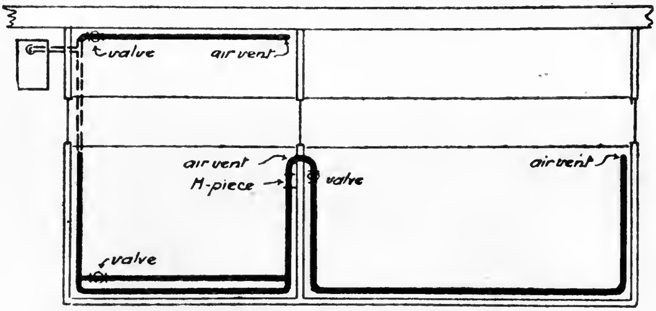

FIG. 49.—Plan of piping system in two adjacent glass-houses.

The cold supply to this apparatus might be an expansion box-end forming a syphon-end to the circulation in the larger house, the same as that shown with the small example Fig. 47, but it is more usual to put a cistern as near the boiler as possible and let the cold supply pipe enter a return pipe, near the boiler, with a small dip, as Fig. 50. The cistern need only be just above the level of the highest part of the circulating pipes, and is thus convenient for inspection and replenishing, as practically all horticultural heating apparatus are hand-fed. It is as well to let the cistern have a lid, otherwise dirt and vegetable débris may get in. There is generally quite enough of this in the water that the apparatus is fed with [1] without adding any from other sources. For further particulars relating to cold supply services the reader is recommended to refer to page 45, and the pages following it.

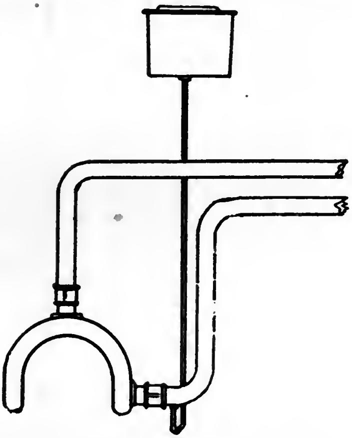

FIG. 50.—The usual correct way of arranging the cold supply to a horticultural hot-water apparatus.

The air pipes from this and all horticultural heating apparatus are usually of $\frac{1}{4}$-inch or $\frac{3}{8}$-inch size (internal diameter), and while some use composition piping for these it is better to use iron or copper. [2] The important thing to remember is that air pipes must be run with a rise, all the way from the pipe they are connected to, to their upper extremities, and no part of them containing water must go outside the house where frost can attack them. The reason for the rise given to these pipes is that at no point must the air be expected to

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[1] Gardeners are often very careless regarding this, pipes sometimes being found half filled with mud, while many boilers are destroyed by dirt accumulating in the lowest part of the waterway.

[2] Thin copper tube does not come so expensive as it may sound, while it is everlasting and is not so easily injured as compo pipe.

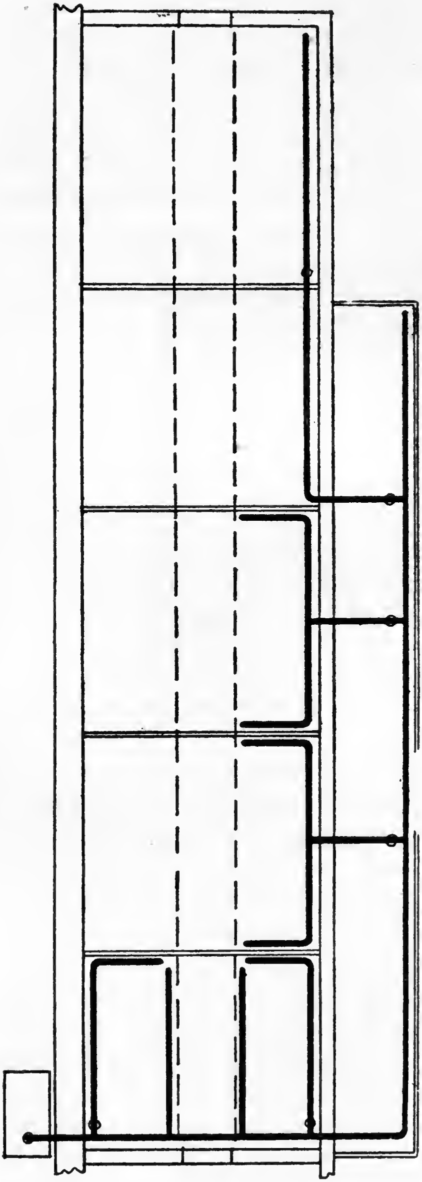

FIG. 51.—Plan of piping system in a range of glass-houses and pits.

go *downwards through water*. If there is a dip in the part of the pipe that is below water level, air will not get through it. If there is a dip in the pipe above water level, it is highly probable that a little water will get into this and this will act as a barrier to the free escape of air. An air pipe must not descend at any point, nor should it be quite horizontal.

Fig. 51 is an example apparatus such as might appear in a range of five glass-houses, with melon pits in front. Only the flow, i.e. the top pipes, are shown, this being a plan drawing; the returns would be immediately beneath them. The circular marks in the pipes represent the positions of the control or throttle valves, but these would be in the flow pipes only, not the returns.

This illustration introduces the mains that have sometimes to appear in this work. It is hopeless attempting to heat several houses in a line, giving independent regulation to each, yet letting the pipes continue from house to house without mains. As a rule the mains are made use of to heat melon and cucumber pits, which are built along the fronts of the houses, and as these have movable lights the heat in them can be regulated without interfering with that in the pipes; or a piece of matting is laid over part of the pipes to reduce the heat. If the mains are not carried along through melon pits, they may be carried beneath the floor level; or they can in some cases be carried along the other side of the wall the houses lean against. It may be that on the other side there is a gun-room, stores, etc., that will benefit by the warmth.

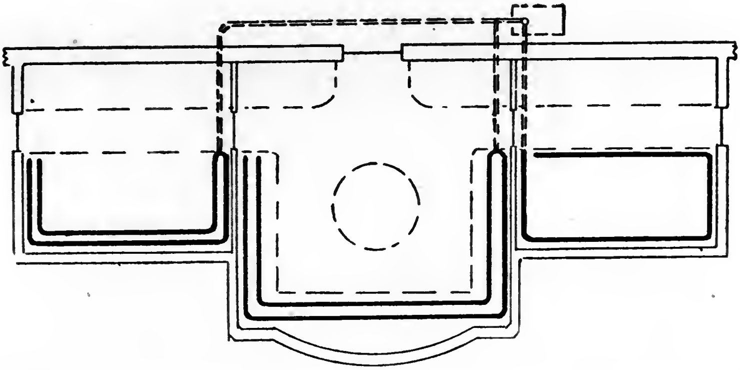

FIG. 52.—Plan of piping system for suggested vineries and winter garden.

This illustration needs no further description except to say that the mains are beneath the floor line, where they cross the house from the boiler to the melon pits, and the branch circulation up the path could be under a grating or alongside a bed. Details of cold supply, air-pipes, etc., were given with the example preceding this.

In Fig. 52 is given an example of work as might appear in some well-built houses attached to a large residence. The centre house would, perhaps, have a domed roof for palms, and would possibly be used as a winter garden. The two side houses might be an early and a late vinery. In the vineries the pipes would be around the beds, but in the centre house the pipes would be hidden beneath the stagings.

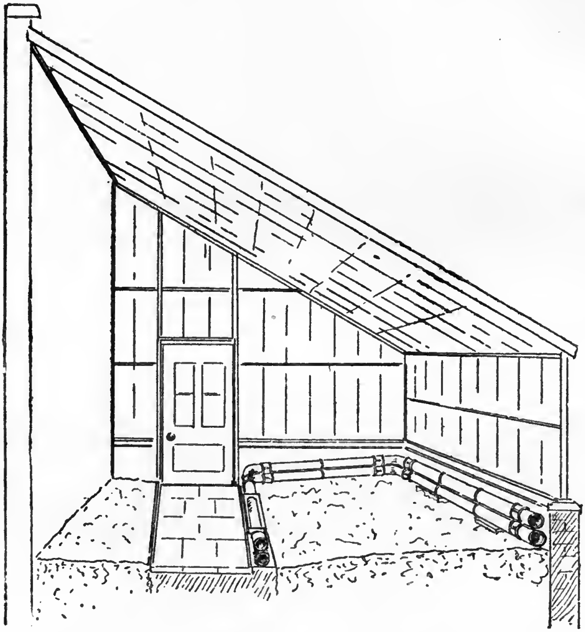

FIG. 53.—Piping around bed in tomato or cucumber house, or vinery.

In disposing hot-water pipes, if the engineer should do this in the absence of a gardener, the common practice for moderate temperatures, in what may be termed the ordinary type of lean-to greenhouse, is to carry them along the dwarf wall beneath the lowest part of the roof, while with a span house

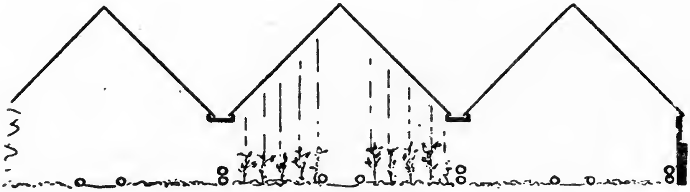

FIG. 54.—Arrangement of span houses and piping for tomato growing for the market.

they occupy a similar position on each side, beneath the two lowest edges of the roof. This has been explained already, and a different arrangement can be shown in Fig. 53, which represents the piping as usually done in tomato and cucumber houses and in vineries. In these there is no staging, and the plants are rooted directly into the earth, which forms the floor of the house. For very early produce a pair of pipes may be needed, as shown in the illustration, but for a little later time or market one pipe only is used. On the upper pipe alongside the path a trough is shown. This, when filled with water, gives off vapour and makes the air humid, as required in certain stages of growth with various plants.

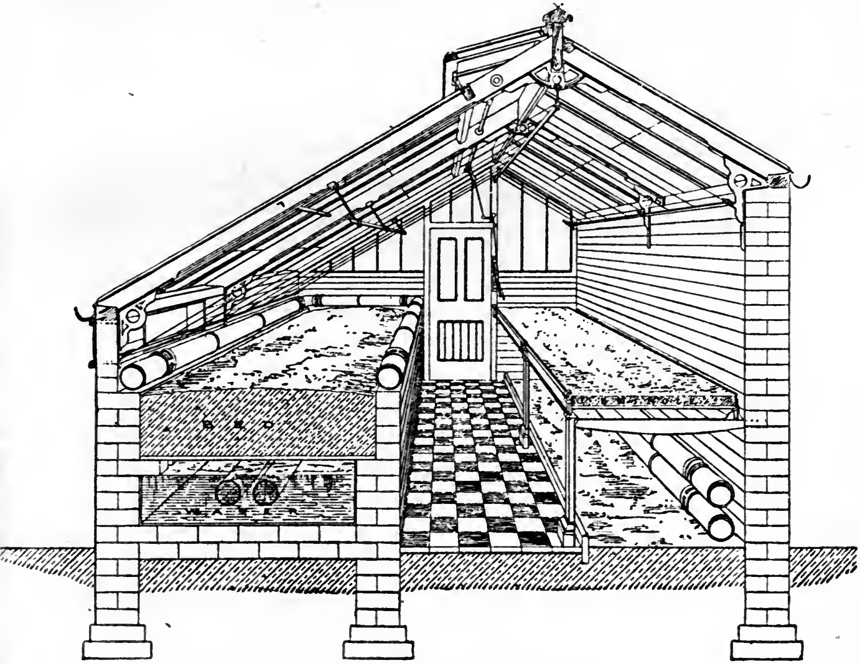

FIG 55.—A well-equipped forcing-house.

Tomato and cucumber growing for the early market is now a great industry, and for this purpose rows of low span houses, placed side by side, are used. In these a somewhat ingenious plan for getting a uniform temperature is adopted by having an open division between each house, and carrying one or two pipes there. Fig. 54 will give an idea of this. It is a cross section, or end view, of some houses, and between each is a valley gutter, as shown, and as is necessary. This gutter is supported by light brick piers, coming about every 8 feet, and which the pipes shown either pass through or run alongside of. There are also pipes each side of the paths, as indicated.

The details of a well-equipped forcing-house as erected by Messenger & Co. are shown in Fig. 55. This shows a bed on one side, with bottom heat, and a pipe around its upper edge, while on the other side is a stage with pipes beneath.

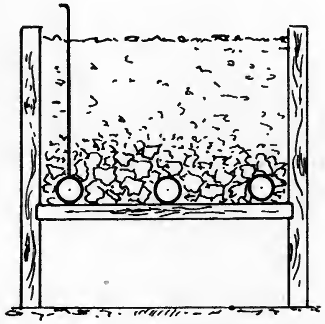
Fig. 56.—Independent hot bed.

Referring to the provision of bottom heat to beds, it is often required that an independent bed, or pit, be built in a glass-house, and Fig. 56 shows the customary method of providing the heat. Pipes are carried along lying on the bottom of the bed and over these clinker and rough material is spread. Above this is some finer stuff and on top comes the earth. The rough material allows of the heat circulating throughout the bottom of the bed, and answers well in this respect. Occasionally the bottom of the bed is well perforated, and rough stuff put in, as described, but the pipes are within the low enclosed space beneath the bed. The gardener probably settles this question.

In regard to the sizes of main pipes and branches in horticultural work, the table in Chap. VIII. could be referred to, but the fact is a table for mains is seldom if ever required in this work. In all works but the smallest the radiating pipes are of 4-inch size, and as the boiler is kept close to the work the pipes coming from it are 4 inches also. The limit of work that should be put on a pair of 4-inch mains is about

950 to 1,050 lineal feet, and if a job contained more radiating pipe than this it would be necessary to use larger mains, provided that only one pair of mains could be used. As a rule, in large works, the boiler is so situated that two or more pairs of mains have to be, or can be, used, therefore the 4-inch pipe nearly always remains large enough.

CHAPTER X

ACCELERATED CIRCULATIONS

The ordinary circulatory movement of heated water in a piping system is due to gravity, that is a difference in weight of the flow and return columns. An extremely small difference in temperature and a restricted amount of vertical pipe is usually sufficient to give all the movement desired, yet there are occasions when conditions interfere and success can only be had by adopting some means of " accelerating " the circulation. As now understood it will be found that this means introducing some assisting force to compel a circulation—to use force directly or else bring some other force into play. One means of effecting this has been to use a pump, which serves to show that mechanical force may be employed, but a widely employed means is steam which is made to serve the purpose in more or less novel ways.

The engineer who is not bound to any particular method of work probably always adopts one of the simple gravity systems when he can do so, which means in the majority of cases, while his adoption of any special accelerated system will be governed by the conditions he has to deal with. Accelerated systems may be used in the literal sense of the term to accelerate the circulation in an apparatus extending over a great area where only a small rise is possible and a gravity circulation would be reasonably expected to be sluggish. They are used when the levels are irregular in a way that might be expected to quite prevent a gravity circulation occurring. They may also be adopted under more ordinary conditions with a view to reducing pipe sizes. Those who make a specialty of this work often introduce an accelerated system (where a gravity system would work quite well) to use smaller and less conspicuous piping, this being possible by the higher speed of circulation carrying all the hot water needed by the radiation through smaller pipes than the ordinary gravity system would admit of. With some accelerated systems it is claimed that the pipe areas may be one-fourth those necessary with gravity work, so that a 1-inch pipe will do the work of a 2-inch, or a 1½-inch pipe that of a 3-inch, and so on. Of course in very large buildings this claim has a special meaning, for if a 4-inch pipe will do duty instead of an 8-inch, the reduction in first cost is enormous, while it may be almost impossible to accommodate or use pipes of the very large sizes a gravity apparatus in such a building would necessitate.

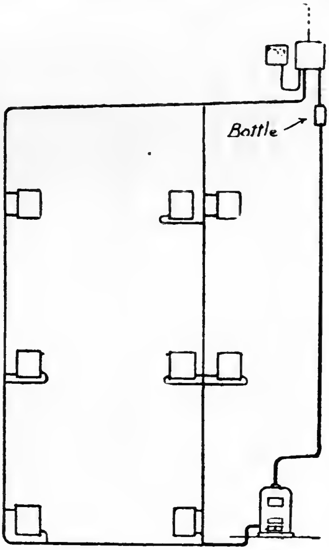

FIG. 57.—Accelerated circulation: an early method.

Acceleration due to Steam Production by Hot-water Boilers.—A simple example, and what is believed to be the earlier method employed, is illustrated in Fig. 57. This much resembles an "Overhead" gravity apparatus (Chapter VII. page 83) the chief special detail being the "bottle" or enlargement in the flow rising main near to the top. To get an accelerated circulation in this, or any accelerated system acting on this principle, the water in the boiler has to reach and exceed ordinary boiling temperature (212° F.), as, of course, it can when the water in the boiler is under pressure, as it always is with a piping system full of water above it. Assuming therefore that the water in the boiler is above 212° F. and this water ascends the flow pipe, it will, as it rises, experience a less and less pressure until on entering the bottle referred to it will experience relief which causes steam to be formed—it will boil as it may be expressed

—and the contents of the bottle and the short length of pipe above it will contain an emulsion of steam and water. *This emulsion or intimate mixture of steam and water is what brings about the accelerated circulation,* for not only does the steam production exert some degree of force, more easily relieved upwards than downwards, but *the mixture is so much lighter than water* and, like the gravity system, the speed of circulation increases as the difference in weight of the flow and return columns is made greater. Briefly, if a flow pipe, or part of it is sufficient, contains an emulsion of steam and water, while the return contains water without steam, the speed of circulation is very much faster than any ordinary gravity system can account for.

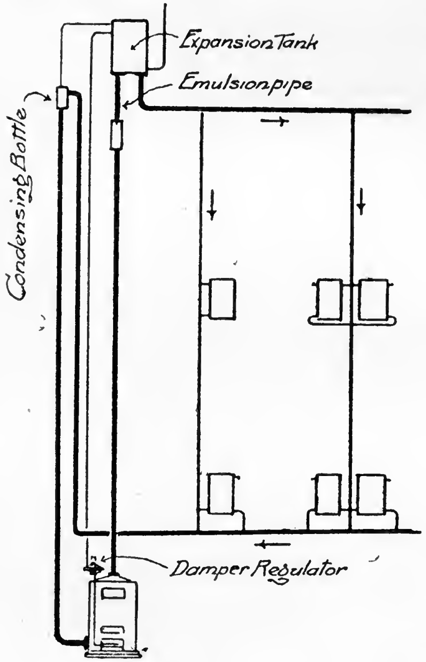

Fig. 58.—Accelerated circulation: The "Hornet" System.

The objection to the apparatus as Fig. 57 shows it, is that steam must escape from the exhaust pipe shown. It will be understood that the upper tank is necessary to allow of the steam separating from the water quietly and without water being ejected from the exhaust pipe, but when the steam is separated it must be disposed of and if it blows to waste it will entail loss of heat, waste of water (with furring of the boiler in hard water districts) and other faults. On this account the apparatus as shown is not considered so practical as one which has no loss of steam.

The "Hornet" System.—The general details of this are given in Fig. 58, and it may be described as having a working principle similar to the example just described (Fig. 57) but with the faulty detail—the loss of steam—eliminated. To effect the latter desirable feature the main return service, which is the coolest pipe, is carried up to a short distance below the expansion tank and is fitted with a "bottle" or enlarged part at that point. To this bottle a steam service comes from the upper or steam half of the expansion tank, so that the steam, when it gains a little pressure, is caused to mix with the return water and be condensed. The reason for having the "condensing-bottle" so high is to admit of the steam entering it with a minimum of pressure, as pressure (of steam) has to be avoided.

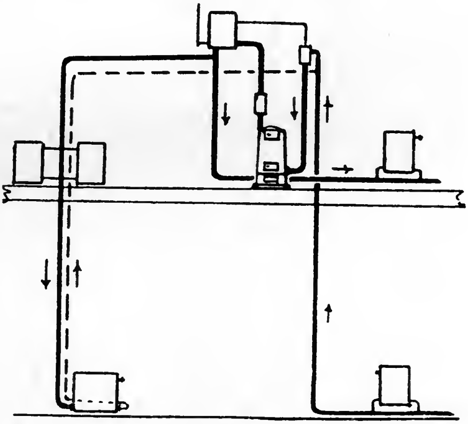

FIG. 59.—Accelerated circulation: another example of the "Hornet" system.

A feature that is considered of some importance with systems in which steam collects in a confined space is a provision for automatic regulation of the boiler damper, that the fire may be controlled so as not to produce steam in excess. Excess would mean unnecessary volume and, particularly, undesirable pressure. The fine drop service, shown in the illustration, coming down from the steam space of the expansion tank to the Damper Regulator of the boiler, provides for this, the steam itself being the force which operates the regulator.

Fig. 59 shows the same system applied to the more legitimate purpose of dealing with radiation which an ordinary gravity system could not well serve.

It will be noticed that the two examples (Figs. 58 and 59) are not provided with unsealed vent pipes and might therefore, by some authorities, not be considered to conform to the usual Building Act requirements. Fig. 60 shows a modification of the Hornet System to admit of a free unsealed vent pipe being provided without loss of steam.

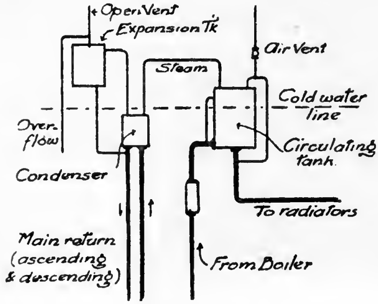

Fig. 60.—Accelerated circulation : The " Hornet " system with free vent pipe.

The Beck System.—Fig. 61 affords particulars of the special details of this apparatus and it will be found to bear some relationship to those described so far as working principle goes. In this the " bottle " in which steam appears (this and two preceding systems have ordinary hot-water boilers) is situated near down over the boiler regardless of whether the radiation is above or below. Any steam collecting in the " flow-bottle " after performing its duty passes over and is condensed in the " Syphon-bottle " shown and a particular detail of the syphon is the bye-pass (at the top of the syphon loop) with an automatic valve in it. When air has to get away this valve opens and lets it pass directly up to the expansion tank, but when steam attempts to pass the valve closes and the steam must go to the lower bottle.

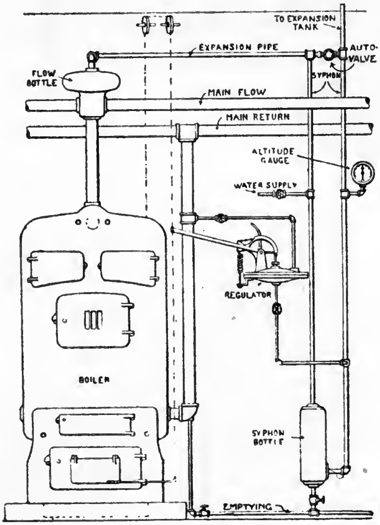

Fig. 61.—Accelerated circulation : The " Beck " system.

Here again the damper-regulator is introduced and those responsible for this system consider the regulator as serving an important purpose in controlling the fire, the consequent steam production and general operation of the system.

With this system it is considered that an emulsion of steam and water occurs in the short vertical flow pipe from the boiler and that steam separates and collects in the flow-bottle, and when it has accumulated sufficient force it exerts a propulsive action, after which it enters the syphon bottle and, at the same time, brings the damper regulator into operation to whatever extent is required.

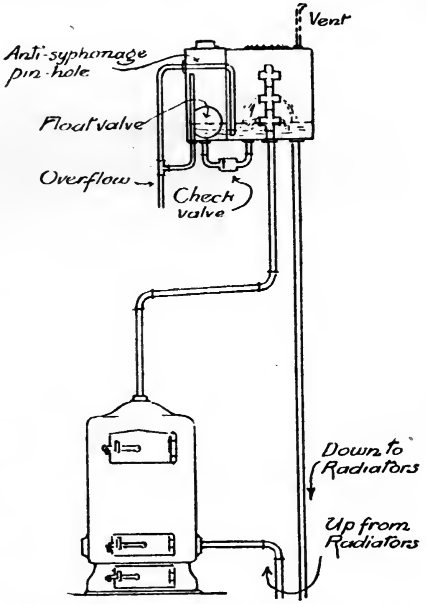

FIG. 62.—Accelerated circulation : The "Gould" system.

The Gould System. — The essential features of this apparatus appear in Fig. 62, and from the particulars obtained and the example works seen, the operative power appears to be the formation of steam in the boiler (a hot water boiler), this getting relief up the flow-pipe. The water reaches boiling temperature and a certain amount of steam is formed which, of course, passes up the flow pipe, but instead of ascending regularly or constantly, as fast as it is formed, the passage of steam is believed to take place in what may be called pulsations, the frequency of the pulsations depending on the state of the fire.

For the purpose of getting an insight to the action which takes place when steam is formed in a hot water boiler (to produce an accelerated circulation) the writer can recommend the construction of a simple and very inexpensive model in glass tube as Fig. 63. A boiler of sheet tin or copper is made, say 2½ inches dia., with metal tube outlet and inlet,[1] while the remainder of the apparatus is $\frac{5}{16}$ inch glass tube, jointed with elastic rubber tube of a size smaller than the glass tube and stretched on. Glass tees can be purchased quite cheaply or the tees can be made of metal tube, soldered. The expansion tank is a "C" gas chimney with lower end corked. The whole has to be mounted on a back board or frame to support it. A small gas flame or a spirit lamp furnishes the heat.

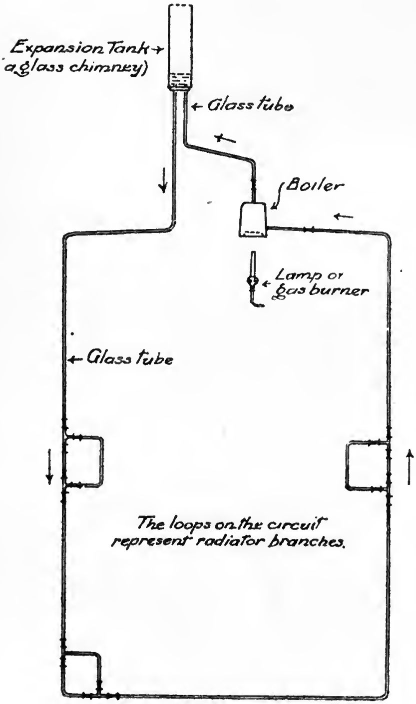

Fig. 63..—Accelerated circulation: Inexpensive model to make the action of steam acceleration visible.

The "Hyflo" System.—In Fig. 64 is shown the essential feature of this system, this being the syphon-tank, which is a tank containing a syphon shaped pipe, which at one point is formed of finely perforated metal, or of wire gauze. The writer would have considered that the acceleration of the circulation would be due to steam rising up the flow-pipe, as with the "Gould" system, but the makers claim that the syphonic pipe is the operative part in itself, it being stated that "when the fire is lighted the equilibrium of the syphon is disturbed and causes the water to flow round the system." In support of this it is said that the water commences to circulate im-

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[1] The writer used, for a boiler, a small inverted custard tin with a tin patty-pan (inverted) soldered in the larger open end.

mediately the fire is lighted and a high temperature to the water is not needed to produce a circulation.

The Pulsial System.—This is illustrated at Fig. 65. The boiler is of ordinary hot-water kind and the water circulation from it is indicated by the arrows. The operation or series of actions is as follows: The heated water first circulates through the loop *a, a,* until steam is generated, this occurring quickly. Steam, when formed, travels up pipe *b* into the first displacer. The pressure in the bottle and displacer gains sufficient power to force the water down through the boiler and into the flow main, and this, it is claimed, allows of the water in the flow main being controlled as required. When the pressure in the first displacer depresses the water below the siphon pipe *c*, steam passes into this pipe and reaches the second displacer which, up till now, has been full of water. The steam pressure is now equal in both displacers and the water in the second one falls into the first one until the syphon *c* is covered again and fills. Steam then starts exerting pressure in the first displacer again, during which time the steam left in the second chamber is condensed by the coil in the expansion tank. As

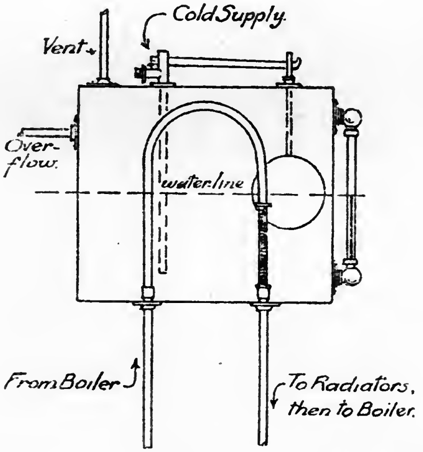


Fig. 64.—Accelerated circulation: The feature of the "Hyflo" system.

this steam is condensed water takes its place and the action from the first displacer can take place again. The second syphon *d* is to exhaust to the air should careless firing make an excess of steam which would depress the water low enough to expose this lower outlet.

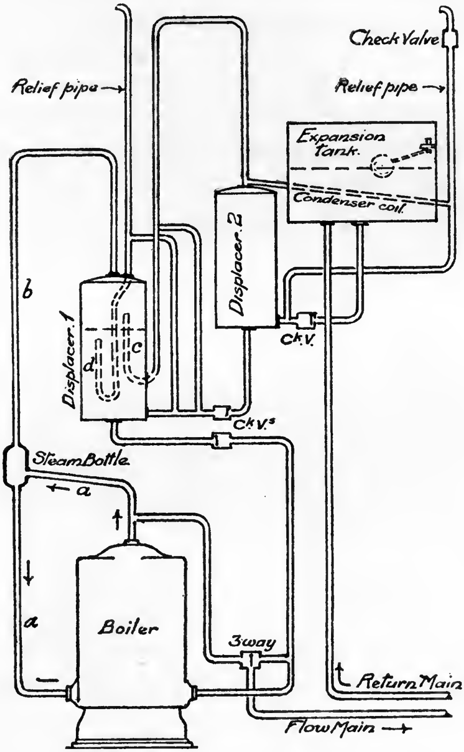


FIG. 65.—Accelerated circulation: The "Pulsial" system.

Acceleration of Hot-water Circulations by Steam from a Steam Boiler.

The "Reck" System (Fig. 66).—The boiler is of any ordinary modern make, cast or wrought, prepared for making steam at low pressure—2 lb. to 5 lb. on the gauge. It should have an automatic draught regulator to keep the steam pressure constant. Steam from a power boiler may be used but would have to be reduced. The service done by the steam is, firstly, to heat the water in the "re-heater," which is a calorifier, and, secondly, to make an emulsion by mixing with the water in the "circulator." The re-heater has a steam service to it and a condense-pipe from it (as an ordinary calorifier would have), while a hot-water flow-pipe goes up from the re-heater—this eventually passing through the radiators—with return pipe from the radiators back to it.

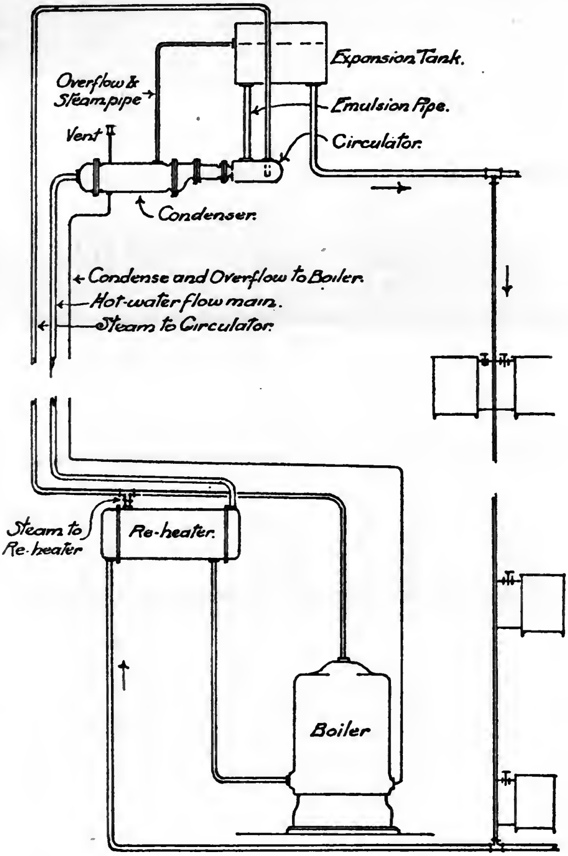
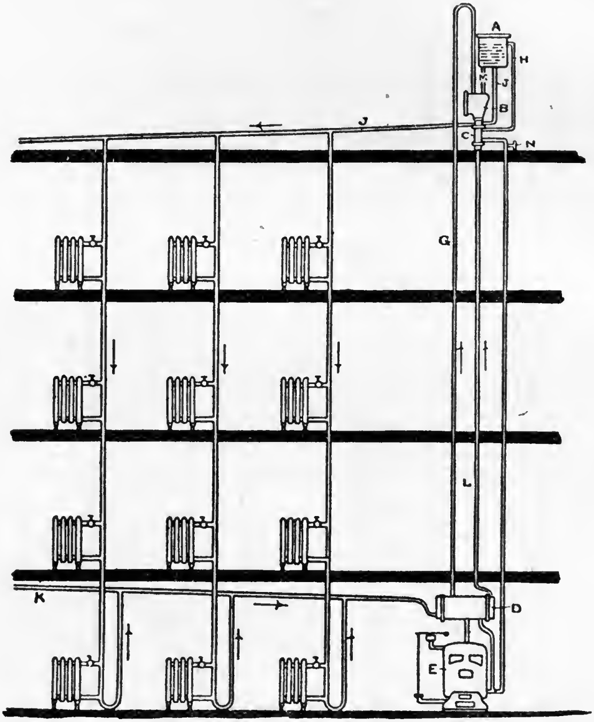


FIG. 66.—Accelerated circulation: The "Reck" system.

Thus the re-heater has four pipes, two being a steam circulation to heat it, the other two being a hot-water circulation to distribute the heat.

The steam service which goes to the re-heater continues up to the "circulator" which is a chamber where steam can mix with water to form an emulsion, this rising up the emulsion or motive pipe and bringing about the accelerated circulation by the fact of an emulsion of steam and water being so much lighter than water only. The purpose of the "condenser" is to condense the steam which separates from the



A. Expansion Tank.
B. Circulator.
C. Condenser.
D. Re-heater.
E. Boiler.
G. Steam.
H. Overflow and Steam.
J. To Radiators.
K. From Radiators.
L. Flow Main.
M. Emulsion Pipe.
N. Condense and Overflow water.

FIG. 67.—Accelerated circulation: The "Reck" system: Second example.

emulsion in the expansion tank, for if the steam was not condensed it would gather pressure sufficient to defeat the proper action of the system. The condenser contains hot water—being part of the flow pipe—but this is found capable of condensing the steam sufficiently.

Fig. 67 is from one of the promoters' illustrations [1] and is given to show a different design and arrangement which the parts sometimes take.

Circulation of Water in Pipes, heated and driven by the Direct Injection of Steam.—It will be readily understood that if a satisfactory means is devised of injecting steam into a piping system containing water, the water can be both heated and driven along in any direction desired, and if the pipe is a circuit or series of circuits then the water will travel round and round, receiving heat each time it passes the injector, and so be as effective as if it circulated out from and back to a boiler. As regards travelling distances, or in unusual directions, the force exerted by the steam would, of course, ensure a stronger and more positive circulation than a gravity system.

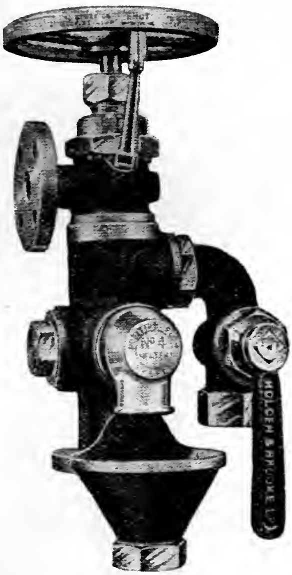


Fig. 68.—Forced circulation : Steam injector.

Fig. 68 shows an injector designed expressly for this purpose,[2] Fig 69, a pair of injectors arranged to work together, while Fig. 70 affords an idea of the irregular piping permissible by this system. Fig. 71 is a special Radiator or branch circuit valve that may be employed. The makers of these appliances name the arrangement the "Positive Flow" hot-water system and claim that their injector admits of the

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[1] Messrs. G. N. Haden & Sons, London and Trowbridge.

[2] Holden and Brooke, Ltd., London and Manchester.

steam passing into the water silently. As with all accelerated systems the pipes may be of smaller bore for a given duty than those required for ordinary gravity systems. The makers also supply injectors to operate with exhaust steam, for this work.

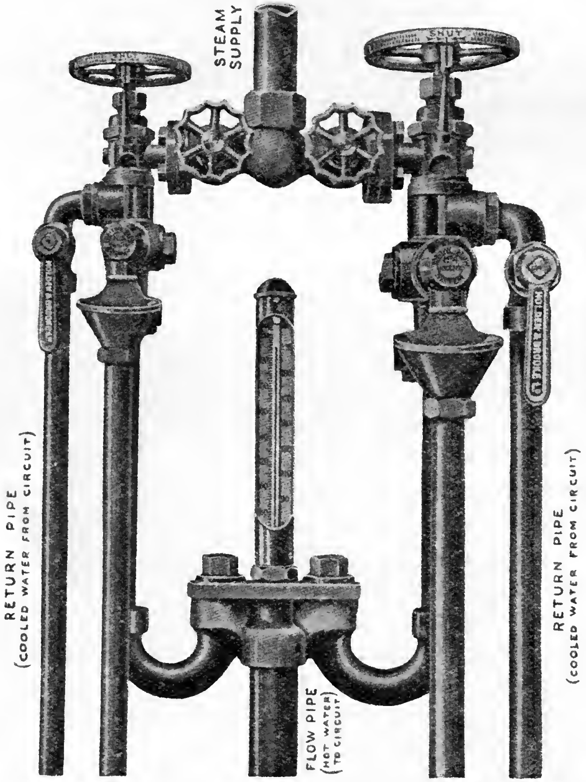

FIG. 69.—Forced circulation: a pair of steam injectors.

One detail which has to be noted is that when steam is driven into water, condensation takes place more or less quickly and the condense-water adds to the bulk of the water already in the piping system. To provide for this an overflow pipe has to be fitted and this is usually carried so as to discharge into the boiler feed-tank and so avoid

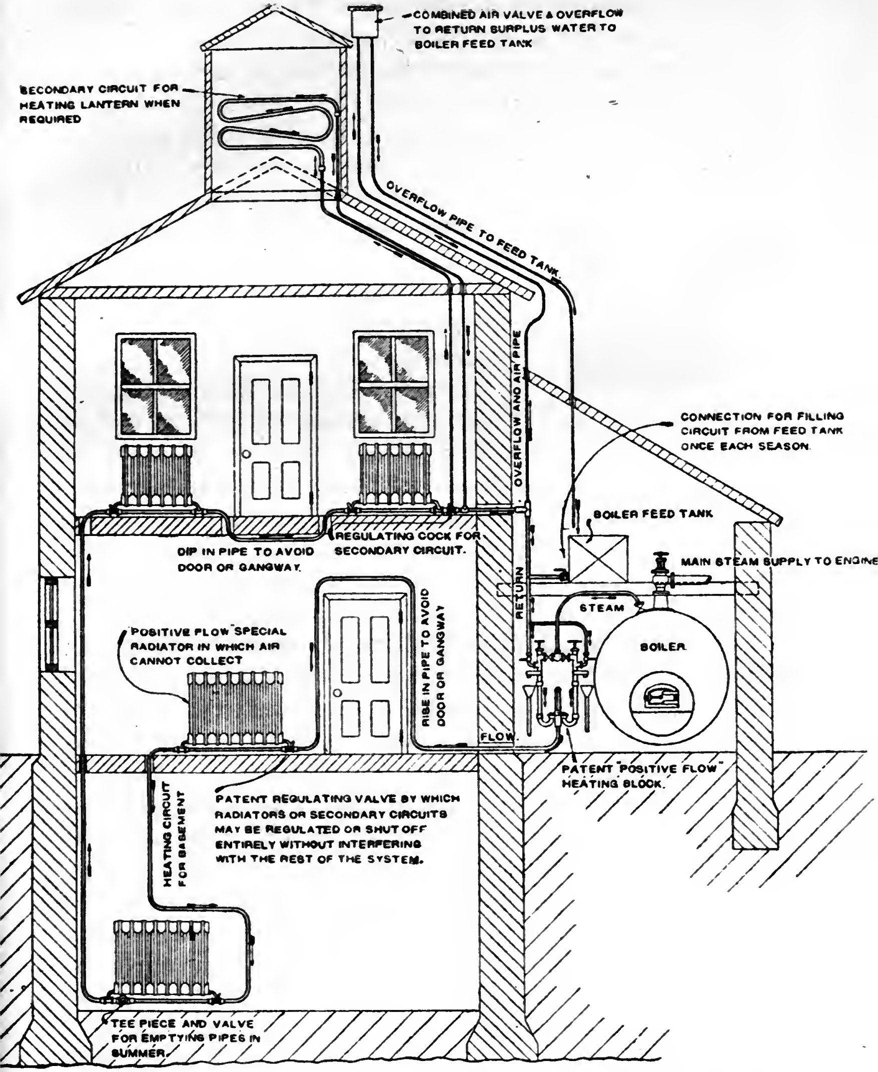

FIG. 70.—Forced circulation : The "Positive Flow" system.

waste. This is a very desirable arrangement, when possible, as the overflow water is soon wholly soft although the apparatus may have first been filled with hard water.

The idea of having two injectors, one large and one smaller, like the pair illustrated, even when the one larger one might be sufficient by itself, is to admit of quick heating up, then, afterwards, using either one as may be required. It also admits of one being opened up for cleaning, etc., while the other is at work. This applies equally when the apparatus is large enough to require several sets or " blocks " of injectors.

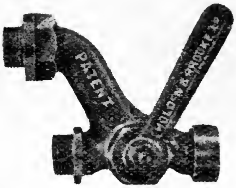

FIG. 71.—Circuit Valve.

As a general rule this method of heating is associated with power or other steam boilers working at moderate to high pressures, it being a system specially suitable for adoption in places where a steam power boiler already exists. The writer has this method of heating at a large school where a boiler is working at 50lbs. pressure for laundry, dynamo, and bath heating requirements, etc.

The Mechanical Propulsion of Heated Water in Pipes.—To the best of belief the propulsion of heated water through a system of circulating pipes, by means of pumps or other mechanical means, was practised before any of the recent " accelerated " systems were introduced. Needless to say it requires power, steam or electric (or water power if practicable) to drive the propeller, but if such power is available then there can be no doubt of a circulation being assured regardless of direction and level, or distance the pipes may run. With this again the pipes need not be large as the movement is assured and any speed of movement is gained by using a suitable propeller run sufficiently fast.

There are several forms of propellers or " circulators " made for this purpose, the earlier type being a centrifugal pump, but the bladed propeller (much like that used for propelling steam ships, only that the device propels the water in this case and not the apparatus it is attached to) is now having favour. As a rule the " circulator " is attached to or inserted in the return pipe only, or if there are several returns they are joined up to one larger main return with the circulator in it and in practically all cases the results are all they need be ; but occasionally some more positive action is required and then a double action circulator may be had, as Fig. 72,[1] this showing the device in section. A is flow connection to Mains, B flow connection to boiler, C return to boiler, D Main return.

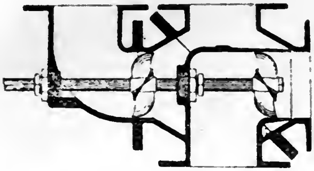

FIG. 72.—Forced circulation : Mechanical propellor.

Note as to Pipe Sizes.—No attempt can well be made to suggest sizes of pipes for Accelerated Systems as the motive power varies to some extent with each of them. As, in practically all cases, a device or part of the apparatus has to be purchased from patentees or makers, it is best to rely on the latter for general working particulars, which they are all ready to give.

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[1] The Beeston Foundry Co., who supply single and double acting kinds.

CHAPTER XI

MISCELLANEOUS DETAILS AND DIFFICULTIES

Air in Pipes—Loss of Heat—Conditions which interfere with the Circulation—Dipped Pipes—Causes of Failure—Chimneys—Decorating Radiators—Covering Pipes, etc.

Troubles with Air (in ordinary gravity systems of apparatus).[1]—It cannot be too plainly stated that air can give as much, if not more, trouble to the heating engineer than any fluid or solid substance he has to deal with, yet the study of this detail is much neglected, probably more than any other. Numberless are the failures in apparatus which appear to be erected on perfect lines, the failure being wholly due to air, not even assisted by faulty construction. Take the following instance, for example. A properly designed apparatus, of a good size and extent, was filled, and, after inspection, tested with the fire alight. One branch or section of the apparatus failed to heat, and the writer's opinion was asked. There might be several causes of this failure, as will be learned in this chapter, but by good fortune the actual cause was diagnosed at once. It appears that for want of sufficient assistance the fitter had charged the apparatus with water with all the air cocks closed, and he afterwards went round and opened them to discharge the air and allow the water to follow up and enter the radiators and

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[1] Much of the information in this chapter must apply only to the ordinary types of hot-water apparatus (Chaps. V. VI. VII.), which rely on gravity for the circulation which occurs within them. With the Accelerated Systems some of the causes of trouble explained—or actions which interfere with successful working—do not apply to the same extent, if at all.

pipes. This is a practice often indulged in, for, with a large apparatus, and sometimes a small one, it is difficult to charge with all air-cocks open, as this means a sudden issue of water at all the cocks on the same level, when the air is discharged, and a difficulty in running round to close all the cocks before the issue of water has done any damage. It will be understood that if a dozen radiators were on a floor, there would be a dozen air cocks discharging air, all of which would have water following the air almost simultaneously, and perhaps only two men to get these cocks closed on the arrival of water from them. The consequence is that the cocks are kept closed, and the man or men go round and open them to discharge the air, one at a time, afterwards. This is what had been done in the case cited, and the result was the very common one attending the practice, air locked in one of the pipes. The question was asked if the apparatus had been charged with all the air cocks open, and the answer was no, they had been kept closed and opened afterwards. It was then suggested that, before any expense was incurred, the apparatus should be emptied,[1] and refilled slowly with all air cocks open, to ensure all air being discharged as fast as the water could rise behind it, and the result was an entire success.

Expelling Air when Filling.—In filling an apparatus, means must be adopted to ensure all air being expelled as the water enters and rises up in the pipes and parts. This is the reason why the cold supply is connected to the lowest point in the apparatus (see page 49), but the expense of bringing the cold pipe to the lowest point can be defeated, temporarily, at least, by charging with the air cocks closed. What happens is that the water works along the pipes past the air that is enclosed, and then when the air cocks are opened advance water may reach the vent before the air behind it can get there, and trouble commences from that moment. It is probably thought that while the air cocks

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[1] When emptying an apparatus all air cocks should be opened at the earliest moment, for water will not flow out of pipes if air cannot get in, and if water is left hung up in the branches, the subsequent refilling may be imperfect by air being locked between the incoming water and that which has been retained.

are closed the air remains in front of the water, that is, at the highest parts, but in practice this cannot be relied on, though it often happens. It is in horizontal pipes that the water will work along and cut off the air, and the rule should be, whatever the inconvenience or difficulty, to have all air vents open when charging an apparatus with water. If necessary, assistance should be borrowed from other trades in the building, or from outside; or cans or pails be put under for the brief time the filling takes.

For the reason just stated an apparatus might with advantage have air-pipes to the radiators instead of air cocks, as air pipes are always open whether at first filling or subsequently. This, however, is seldom possible, except in horticultural works or an apparatus confined to one floor level. Even in the latter case air pipes, small as they may be, are not always allowed in residence work. If the pipes could be chased into the wall, it might do, but, failing this, nickel-plated air cocks have a far better appearance than air pipes or pipe connections.

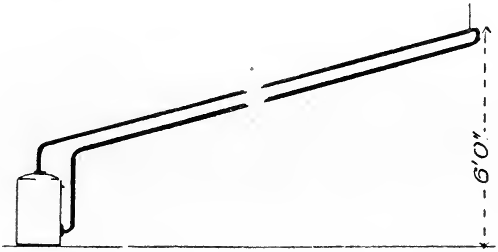

FIG. 73.—To illustrate the effect of rising circulating pipes.

Why Circulating Pipes are given a Rise from the Boiler.—It may not be generally recognized that the chief reason for giving a rise to hot-water circulating pipes [1] is to admit of air escaping freely. Many people think that the rise is to ensure the circulation occurring, or to favour it, but it is not so, for a circulation extending to the same height, either as Fig. 73 or Fig. 74, will work equally well if it could be ensured that the latter would keep free and clear of air.

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[1] The least rise is 1 inch in 10 feet, but this should be exceeded whenever possible.

Air Difficulties when Re-filling.—At first filling, an apparatus of quite a bad design may fill properly and a circulation occur, but after working for a time, or if it has to be emptied and refilled, the good results fail. Water carries a good volume of air, and when heated the air separates and moves into and along the pipes; consequently, when an apparatus is newly filled, or when it is periodically replenished, some free air will soon appear in the apparatus and must have a free exit, or an unobstructed passage to a point where it will give no trouble. If pipes are horizontal or have insufficient rise, the air will hang along in huge bubbles as Fig. 75, and as there are no large taps to be opened on this apparatus there are no rushes of water or other disturbances to move the air. In the flow-pipe the direction of the circulation and the direction in which the air should travel to make its escape are usually alike, but even this fact makes but little difference to the air movement. The air appears to be stuck to the pipes, and a simple experiment with the glass model apparatus, recommended on page 22, will show that the circulatory movement, while as active as it can be through a pipe half choked with air, makes not the least impression in causing the air to move. The circulation will be seen occurring as shown by the dotted lines in Fig. 75, slipping past the imprisoned air as if it was solid material. It is to prevent air locating itself along the circulating pipes that a rise is given to the pipes, and although 1 inch in 10 feet will suffice when no better rise can be got, it is not as successful as it might be, as experiment will show; 1 inch

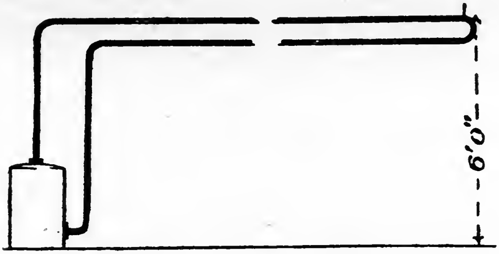

FIG. 74.—Of equal circulating effectiveness to Fig. 73.

in 5 feet is better. It will be found that small pipes require more rise than large ones to keep them free of air; and let it always be remembered that in a heating apparatus the air has to escape of its own accord, which is quite different to the assistance it gets in a domestic hot-water supply apparatus on which ½-inch and ¾-inch taps are being opened many times a day. In such works the difficulty might be to keep air in the pipes, if it was wanted there, for an open ¾-inch tap branched from a 1-inch main circulation will sweep air out quicker than it could be followed with the eye. In a heating apparatus assistance of this kind is quite absent.

The Effects of Dips in Circulating Pipes.—Troublesome results, due to air, quite commonly occur when dips are made in horizontal circulating mains or branches. The common impression is that the dip interferes with or prevents the circulation, that its existence is a power, or exerts a power, that counteracts the force of the circulation, and so brings it to a standstill, or nearly so. On the contrary it may be said that dips, as ordinarily made to pass doorways for instance, are nearly always permissible, it being quite the exception and not the rule for them to be otherwise; but unless certain precautions are taken, trouble and a stoppage of the circulation may result. Dips do certainly cause a power to be exerted contrary to the progress of a normal circulation, that is, favouring a retrograde circulation; but with dips of about 6 to 9 inches depth and 4 to 6 feet length their harmful power is so feeble as to be unnoticed even in an apparatus wholly confined to one floor.

FIG. 75.—Showing how large bubbles of air hang along horizontal circulating pipes.

To show the effects of air with a dipped circulation a very obvious example, an actual instance, may be given in Fig. 76. This was an apparatus erected to heat a small place of worship, a single-pipe 2-inch main passing round the wall and carrying four 30-feet radiators. At the point shown a dip was made to pass a vestry doorway, and as the expansion pipe on the highest point existed where shown, it was, somewhat naturally, considered that an air-cock on the further side of the dip would suffice.

In ordinary working, this arrangement would do quite well and, as the results showed, the first filling and testing with the fire alight gave quite satisfactory results, but there was a leak which necessitated emptying the apparatus and subsequently refilling. On this being done it was found that the apparatus was as much a failure as it had previously been a success, and it required a deal of explanation to show that the two different results were due, the first to the apparatus being new and therefore quite empty when first charged and tested with good results, the second to the fact that the dip was already full of water when the apparatus was charged the second time.

The fault wholly lay in the dip not being vented on both sides, and it may be added that for perfect results the vents should be pipes and not cocks, unless care is taken to *fill slowly with the cocks full open*. These dips have to be vented on both sides, but the necessity of this only arises when the apparatus is being charged with the dip already full of water. It would be an equally good measure to arrange for the dip to be emptied previous to recharging, but this is not necessary if each side of the dip is vented. Of course every dip requires an air-vent on one side for ordinary working, as one side must be the highest point of that part of the circulation, and cut off, by the dip, from the ordinary highest point. This had been put in the example just given, but the vent for discharging air when refilling had been omitted.

While a dip, to pass a doorway as Fig. 76, may be considered quite permissible, it offers a certain amount of resistance to the circulation, consequently if there were several doorways to pass and the circulation was confined to a ground floor, and low in motive force in consequence, thought would have to be given as to whether a series of dips might not limit success to the extent of being a failure more or less. In such a case—and in all cases when possible—the writer favours carrying the pipe over the doorway instead of beneath it. This actually increases the motive force of the circulation and is helpful generally. A glance at Fig. 77 will show that each loop has the hottest water ascending one side with slightly cooler water descending the other, which is as it should be and must favour the

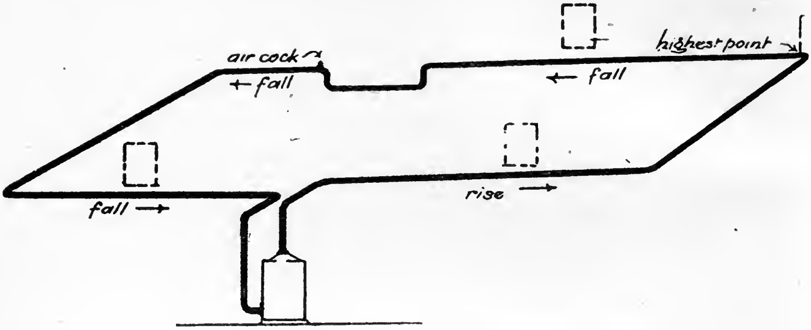

FIG. 76.—Dip in one pipe circuit, insufficiently vented.

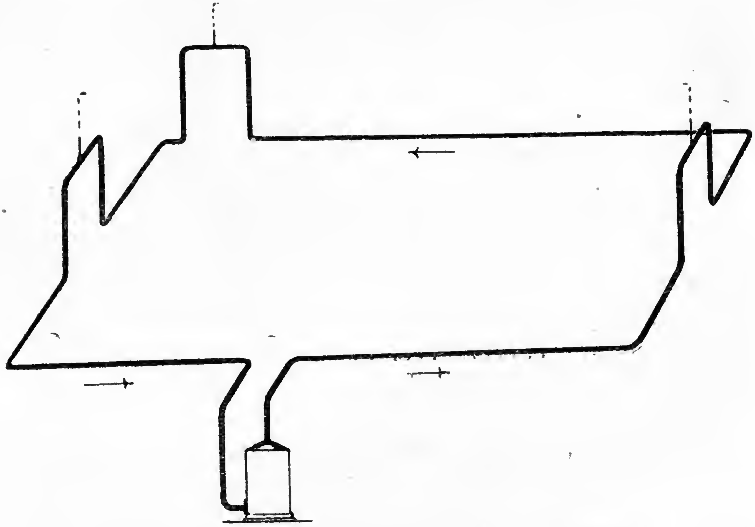

FIG. 77.—One pipe circuit with loops over doorways.

circulatory movement. The drawing is intended to show a simple one-pipe circuit around the skirting of a room or warehouse having three doorways to be passed. Each loop has a single vent pipe at the top, which is sufficient.

Air-lock due to Stop Valves.—Another cause of air-lockage, which, although fairly well known now, has hitherto been overlooked or not understood, is the use of an improper kind of stop-valve. The customary present plan when connecting radiators is to use the angle-valve, as shown in Fig. 39, page 76, this valve being illustrated and described in a later chapter (Chapter XVII.). It is quite impossible to have air locked in this valve, and its construction admits of its having a nearly full way or passage through it. As near as appears to be possible, a 1-inch valve of this kind has a fairly clear 1-inch way through it, when it is fully open.[1] Where trouble has occurred is in the use of what may be termed the ordinary kind of screw-down stop-valve, a section of which (one of a good make) is given in Fig. 78. This is a valve that is fixed in a straight run of pipe (the opposite of an angle valve), and the up-and-down way through the valve must cause air to be locked in when fixed in a pipe run horizontally. Air (in heating works) will not descend to pass an obstacle, consequently the ignorant use of this valve has often caused trouble. When no other valve is obtainable or possible, then a skilled engineer may use this one which has just been condemned, but he fixes it on its side—horizontally as it is called. The air cannot then be locked

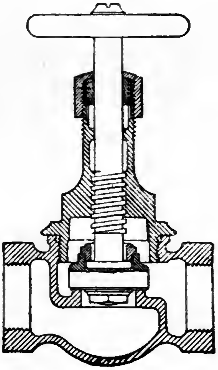

FIG. 78.—Undesirable kind of stop-valve.

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[1] It has always seemed most unreasonable to give sizes to valves which they do not possess except at their screwed ends. According to the kind that is being used or examined, it will be found that an ordinary screw-down stop-valve of 1-inch size may have a $\frac{1}{2}$-inch to $\frac{3}{4}$-inch way through it, and from this it may be anything up to 1 inch clear. The writer's contention is that a 1-inch valve should have a 1-inch way through it, as straight and clear as possible, and other sizes accordingly.

in so readily, but the valve is still faulty by having a very choked and crooked way through it. While we have the angle-valve, for angles, and the gate, or Peet's valve, for straight runs, the use of the valve just mentioned may cease with advantage.

Air-locked Cold Supply Pipe.—The cold supply service can be made to give trouble by air collecting in it, and by air being locked on the supply side of a dip. In an instance that came to notice, the cold supply to a boiler was as Fig. 79, and although the apparatus had worked well when first filled, it had given trouble since it had been emptied and refilled for some purpose. After a thorough examination no fault could be found, and the fact of the apparatus being partially empty could not be discovered, as all vents were air-pipes. It was subsequently found that water did not enter the apparatus as it should do, and there was the clearest proof that when an attempt was made to recharge the apparatus, with the deep dip in the cold supply already full of water, the water carried air down into this pipe, and locked it there. Had this dip been down near the boiler it might possibly have happened that the head of water would carry the air right through, instead of its holding itself up in the high loop, but a perfect remedy resulted when the cold supply was re-arranged, as described on page 50, and as it always should be.

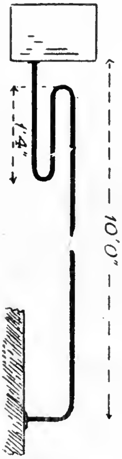

FIG. 79.

Air Pipes can be Water-locked.—Air-pipes, too, can be a means of locking air in an apparatus, if they are not properly run. They must have a rise from the pipe or radiator which they are venting, all the way to their highest extremity. If there is a dip in any part of the pipe containing water, then air will collect in the high point on the boiler side of the dip, and there is nothing to make it work beyond there. If there is a dip in the empty part of the air-pipe, then this dip will soon have water collect in it, and so obstruct the free exit of air. Both cold-supply services and air-pipes must be run properly, the former with a fall all the way towards the boiler, the latter with a rise all their length from the radiator or pipe they are attached to.

In an earlier part of this book, when speaking of expansion pipes (page 44), it was explained that this pipe need not be on the highest point of a circuit, if a radiator was there, as the latter would take the air that collected, and only need to have its air cock opened now and again to discharge the air. A radiator of an ordinary kind has accommodation for a fair volume of air at its top, without noticeably affecting the circulation of water within it and its general efficacy; therefore a radiator answers well to vent a high point, if the expansion pipe or an air pipe cannot be put there. What has to be guarded against is attempting to vent a high point in a main or branch circulation with an air cock. It is sure to be neglected, even if a pipe is brought down (with the cock on the end of it) to a convenient point for regular attention. It would require to be opened with some frequency, as even a small volume of air will impede the circulation in a pipe to some extent. What must be aimed at in cases such as these is the free and instant escape of all air that collects at high points in circulating pipes.

Common Peculiar Effect of Insufficient Boiler-power.—When an apparatus fails to heat from insufficient boiler power the result often puzzles the inexperienced by the failure being confined to a part of the work, and not to the whole. It would be reasonable to expect that a boiler under power would show its weakness everywhere, the whole apparatus working sluggishly, and heating badly. Instead of this the more customary result is for a part of the apparatus to heat well, or fairly well, while another part, or parts, quite fail. This is, of course, supposing that the apparatus is not one single circuit, but consists of two or more sections. Sometimes the difference in results is so marked as to make it appear certain that the fault is a stoppage of some kind in the cool section, as the other part works so freely, and heats so well. It is difficult to diagnose the fault in such cases; but measurements and tables soon show what the fault may reasonably be attributed to. What is intended to be conveyed by this, is, that the failure of the water to heat in a branch or section of an apparatus is not always an indication of anything being wrong in that part, but may possibly be due to want of power in the boiler.

Effect of Small Main Circulations.—A similar faulty result to that just explained can be obtained by using pipes of insufficient size. This particularly refers to mains and branch mains. Supposing a main of insufficient size was put to supply, say, three branch circuits; the reasonable assumption would be that if it could not carry water sufficient to keep them all hot, there would be a general shortage and want of heat in all alike. Instead of this, it is more likely than not that one or two of the circuits may heat well, or fairly well, and the other one or two be a complete failure.

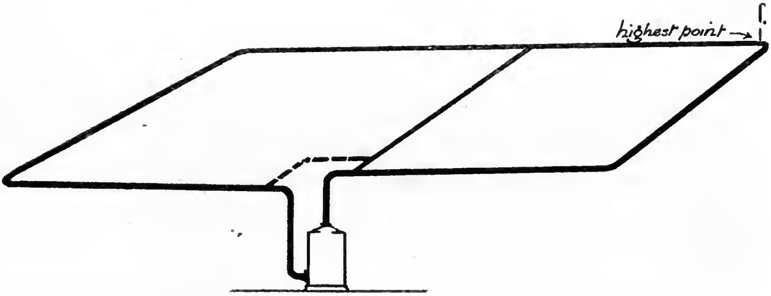

FIG. 80.—Faulty flow branch to one-pipe circuit.

The number of Flow Mains must not exceed the number of Returns.—Similar results are again obtained when branch circuits or lines of pipes are badly arranged. In one instance that came to notice, a complete one-pipe circuit had been carried around a large building, and as there had to be some radiators in the centre, a central branch was carried across as Fig. 80. solid lines. When tested, the central pipe remained absolutely cold, while the outside circuit heated perfectly. It was not a case of air lockage, nor want of boiler power or pipe area, yet, except for about 2 feet at each end of this pipe, the remainder of it might have been empty for all the circulation that occurred through it. A perfect remedy was found in making the central pipe a return instead of a flow, the connection being altered as shown in dotted line. It will be found in an earlier part of this book that while a return may be branched many times, and almost anyhow, a flow can only be branched when the conditions are clearly correct and favourable.

When main pipes are too small, the bad results that must occur appear somewhat differently with the one-pipe and two-pipe systems. With the one-pipe, if it is a single circuit of too small a pipe, it follows that the first radiators are much hotter than those that come after, and this occurs not only when firing up, but afterwards and at all times. The last radiator may only have water at about 100° F. in it, and only excessive firing will raise it to 120° F., and this is insufficient for cold weather. With the two-pipe system the result is usually short-circuit. This, as has been explained, is that a circulation occurs up to a certain branch or point, while beyond that the pipes are cold, and remain cold as if they were quite shut off from the main circulation.

Chimney Troubles.—Occasionally an apparatus, practically perfect in all details, may fail, due to the chimney being wanting in draught—that is a draught sufficient for the boiler. The subject of faulty chimneys is too long a one for these pages; but supposing that the chimney be of full height, and terminating well above surrounding buildings, so that it will not suffer with down-blow, then a rule that may be worked to is here given. A chimney, if too small, cannot cause air to pass through the boiler in sufficient volume to admit of combustion occurring freely, and a comparatively dull fire is the result. As a rule the fire is not conspicuously dull, and is, in this respect, misleading. It is found, however, that the water does not heat, and there is a feeling that the fuel is wanting in quality. The actual result is about the same as is obtained when a bright fire has the damper shut upon it; it remains quite a bright looking fire for a considerable time, but the heat it affords to the water falls off after the draught is checked.

The "Golden Rule" with Flues and Chimneys.—

All boilers, and iron or earthenware flue-pipe connections, must communicate with the chimney in an air-tight manner. Joints, at all points, must be soundly made—made in a manner to remain permanently air-tight, *for there must be no openings or crevices by which air can be drawn into the chimney without passing through the fire.* This is a golden rule to be observed in fixing boilers, or erecting flue pipe. *All air that enters the chimney must first pass through the fire.* There may be many boilers doing well, the fixing of which would go to prove this rule to be wrong; but because a chimney is a powerful one, and can be robbed of some of its draught and yet supply the fire with all that it needs, is no guarantee that this loss of draught may not mean failure. The fuel needs a certain volume of air, and the fixing should be done in a manner to ensure this being had. If the draught happens to be stronger than the boiler needs, then let the engineer feel satisfied that it is not the reverse, for while a strong draught is easily controlled by the damper, a weak draught means failure, more or less.

A rule that should be observed is, never put a boiler to a chimney, nor use a flue-pipe, that is less in diameter than the flue-nozzle on the boiler. With small boilers, often used for heating two or three rooms or some equally small work, it seems to be quite a common practice for those who fix them to make a reducing piece for their 6-inch nozzles, so that they may run the flue in 4-inch rain-water pipe. The writer once saw, incredible as it may seem, a 9-inch nozzle reduced and worked into a 4-inch cast flue-pipe. It was a total failure, and the fixer, a builder, said he considered it large enough. He acknowledged that if he was building a brick chimney for the boiler, he would have made it 9 inches by 9 inches, but being a pipe connection between a boiler and a brick chimney he considered 4 inches large enough.

Low Chimneys for Horticultural Buildings.—With horticultural work the chimneys are usually low, and the effect of this is to make a greater area desirable. The sizes the writer has worked to for glass-house work are as follows:—

	Area of low chimney. Square inches.
For a saddle or similar shaped boiler about 6 feet long, brick-set	320
For a saddle or similar shaped boiler about 4 feet 6 inches long, brick-set . . .	250
For a saddle or similar shaped boiler about 3 feet long, brick-set	180

These sizes are not according to any rule, but will be found to give satisfactory results where the low chimney is customary. Some authors consider that a chimney area of 12 square inches per 100 feet of surface the boiler is capable of heating, is correct, and it doubtless is when the chimney is proportionately high. By this calculation a 6-foot saddle boiler would be given only 162 square inches, or, say, a 14-inch by 12-inch chimney instead of one 18 inches by 18 inches. As stated, both figures may be correct if the height of the chimney varies considerably.

Chimneys for Brick Buildings.—The more modern boilers, heating brick buildings in which the chimneys are high and have good draughts, will work with chimneys of smaller area. Under no circumstances should a chimney be of less area than that of the nozzle on an independent boiler. The chimney itself should be a little larger, while the pipe connecting an independent boiler to a chimney should be of the same size as the nozzle (or larger if preferred).

CHIMNEYS FOR SECTIONAL BOILERS

Size of Chimney	Height of Chimney					
	20	30	40	50	60	feet
9 × 9	1,000	1,200	1,400	1,550	1,700	Catalogue rating of boiler in square feet of radiation
13½ × 9	1,600	1,900	2,200	2,400	2,600	
13½ × 13½	2,550	3,000	3,400	3,750	4,100	
18 × 13½	3,550	4,200	4,750	5,200	5,650	
18 × 18	4,400	5,300	6,200	7,000	7,600	

Heat-receiving Surfaces of Boilers must be Clean.—To obtain the best results from any boiler, the internal surfaces, and flues (if any), must be kept clean. Whether it is an independent boiler with the flues contained in it, or a brick-set boiler, the metal surfaces of the flues must be clean, and the use of a wire flue brush—a brush in which stiff wire takes the place of bristles or fibre, is the correct thing to use. The metal surfaces want dry-scrubbing to clean them properly, and let it be remembered that the use of coke fuel does not make flue cleaning unnecessary.

Radiating Surfaces must be Clean.—In the same way that a clean boiler surface is necessary for the proper absorption of heat, so is a clean radiating surface necessary for the proper or free emission of heat. Although the exposed radiator is now largely used, there are still works done in which the heating surface consists of pipes in trenches (with gratings over), also coils of pipes in coil-cases; and there are, of course, indirect radiators also encased. All these surfaces can readily get loaded with dust, but pipes in trenches, as in church work, are particularly liable to having dust and dirt material literally heaped upon them. As all dust and dirt consists of materials which are poor conductors of heat (grit, which is chiefly silica, fibre, hair, wool, cotton, etc.), it follows that heating surfaces with no more than a moderate coating of this mixture must have their heat emission qualities greatly retarded, and it is not unreasonable to suppose that the pipes in nearly all churches do little if any more than half the heating they are capable of. They cannot be kept clean by the ordinary church attendants, and there appears to be no arrangement as to their being cleaned by any one else. It is a fault without any simple remedy, except to avoid putting pipes in trenches or cases whenever possible. The visible pipe or radiator always gets dusted and kept clean, but only these.

Covering Pipes to Prevent Loss of Heat.—It will be quite recognized, of course, that the purpose for which fuel is consumed in a boiler is to afford warmth in various rooms or places, where radiators or pipes are disposed for this purpose. It follows, therefore, that any heat dissipated between the boiler and the rooms will probably be lost, and must, to a more or less extent, defeat the object for which the apparatus is erected. Loss of heat, too, is always a loss of fuel, as the two terms, heat and fuel, are practically synonymous in this work.

Although the foregoing may be recognized as being strictly correct and beyond dispute, yet the majority of heating works have considerable amounts of exposed main and branch circulating pipes, uncovered and losing heat, and the wonder is that this is allowed to be so, when the loss is so real and so well known. It may often be true that the boiler is fully powerful, and the radiation fully sufficient, but this is no excuse for heat loss, and would rather go to show that a margin of boiler power and radiation was provided to meet it. It is wrong, and always wrong, to have heat dissipated from pipes which are expressly run to convey the heat somewhere else. The troublesome results are not confined to heat loss and waste of fuel, but are accompanied by delay in obtaining a full heat, while in some cases the full heat cannot be obtained at all.

The instances of reckless loss of heat that come to notice are numberless, making it appear as if the covering of pipes to prevent the loss was the exception and not the rule. Instances are met with in which main circulations are run in the customary shallow space beneath the joists of a ground floor. It is a common practice, but if the pipes are uncovered, the heat loss must be quite serious. It is the coldest space in a building, and is always well ventilated to prevent "dry-rot" occurring. There must be times, on winter days and nights, when the pipes are robbed of heat as fast as they would be if run outside the house. In such situations and with all circulations run beneath upstairs floor boards the pipes should be covered thickly and well. The same applies to pipes in corridors and practically everywhere. It should always be remembered that main pipes serve the special purpose of being conduits, to carry hot water, and they should conserve the heat of the water, not dissipate it. If radiators or radiating pipes are provided to afford warmth then the main is failing in its duty, so to speak, if it wastes heat on its way to the true heat-distributing surfaces, as in every case there is loss of heat, fuel, time, and the desired results.

By referring to Chapter I., page 3, it will be seen how greatly the conductive powers of materials differ, and while iron is a good conductor, which makes it serve the best of purposes in a boiler plate or a radiator casting, its good quality in this respect becomes a bad one where the diffusion of heat entails a waste. As, therefore, the material of the pipe cannot be changed, recourse must be had to covering it with a substance that will resist the passage of heat. A very successful material is hair felt. This is cheap and easily applied, but it has a rough appearance, and is said to harbour insects. The writer has used quantities of it, and never had the insect trouble that others say the felt is liable to, and he would not hesitate to use it again. The next material to hair felt in cheapness and efficacy is silicate cotton. This is a substance closely resembling cotton-wool, but it is really a glass or silica-wool, a waste product from blast furnaces, and commonly called slag-wool. This has the advantage of being non-inflammable, but is difficult of application to pipes, unless they are surrounded with a wood or other casing, in which the wool can be packed. Certain factors of this material sell it sewn or secured on to a canvas backing, to admit of its being wrapped on pipes, and in this way it can be effectively applied, though it has practically as rough an appearance as hair felt when it is finished.

Asbestos does not rank as a particularly successful poor-conductor, although there is a common impression to the contrary. It is non-inflammable, and can be used if specified or desired, but may be said to be little more than half as good as hair felt or silicate cotton. There is no doubt that these two latter owe a large proportion of their efficacy to the numberless air spaces within their substance, for air is a good poor-conductor if it can be held in a great number of minute cells, and does not have a free circulation.

The felt and cotton named are the only two materials in general use, and failing these recourse is had to a composition, There are a number on the market, as reference to a directory or trade journal will show. It is doubtful if any of them are quite as efficient as the two loose materials stated, but they all rank as efficient in a general sense. The writer has used Fossil Meal, and found it successful; also a composition made by Leroy & Co. These are applied in successive half-inch coatings with a trowel, the last coating being finished off clean and smooth. It is best before applying the first coat to well rub some of the substance on to the metal surface, and let this dry. It will form a key for the next coat, and ensure better contact. As a rule, the boiler and pipes require to be moderately hot when these materials are applied. Plaster can be added, if desired, while some put plaster in the last coat, so as to trowel it to a good finish. There should not be much, as these compositions require to be slightly elastic. From 1½ inch to 2 inches is the customary thickness of all composition coverings.

For external work the finished composition is covered with canvas, sewn on, and then well tarred to make it weather proof. The canvas should not be the common jute kind (hessian), but of good cotton quality. "Willesden" canvas is good.

Painting Radiators.—The decoration of a radiator may not call for much description, but it is desirable to point out that this means of heating has been actually prejudiced by the ugly and depressing colours that radiators have been decorated (?) with. A colour that appears to have most favour is purple-brown, and it is difficult to imagine anything that gives a worse appearance and impression; even black would be better, if properly applied. There can be little doubt that the colours so commonly used, and which make radiators look so much like ironwork and factory goods, have retarded their use in residences and other good interiors. It matters not how beautiful the design of a radiator may be, if it is painted purple-brown it will be instantly barred from entering any good residence. Ladies cannot see how nice a radiator can be made to look, when it is so coloured. White is the writer's favourite decoration, and it suits all radiators. With some it makes them look like porcelain, while the plainest are improved. Strange as it may sound, a white radiator is by no means a conspicuous object in a room. The white should be good and not assume a cream tint in the course of a short time. Either dead white or enamel look well, or the two can be worked together. If white is objected to, then make it an object to use *light tints* if any way possible. They make a radiator less conspicuous than dark colours, and are pleasing to any eye that rests upon them.

Reference to page 8 will show that all colours are available for this work, but a certain amount of doubt exists as to how bronze powders affect the radiating qualities of the surfaces they may be applied to. In the majority of cases bronze powder decoration does not show the best taste, and might well be left out of use entirely.

On page 59 is given particulars as to how the decoration of radiators entails some extra and special work, and this must always be borne in mind when estimating the cost of erecting an apparatus.

CHAPTER XII

HEAT EMISSION FROM RADIATORS AND PIPES

This subject has a very near relationship to that of the next Chapter, which is devoted to the amount or area of radiating surface required to afford certain temperatures in rooms of various sizes under varying conditions. The present chapter shows how radiators differ in the amount of heat they afford (emit) and how they differ to pipes in this respect. The pipe is the more effective heat distributor provided there are not several pipes close together; then they are practically no more effective than radiators, these latter amounting to being each a cluster of vertical pipes.

The hot surface which has unwarmed air round it and which permits the warmed air to leave it as immediately as possible is the surface which emits or parts with more heat than surfaces which are near one another or do not have the warmed air get away at once. Thus two pipes close together, whether vertical or horizontal, present one surface of each to the other, and needless to say a surface which is receiving heat is not effective in emitting heat. Also with pipe fixed vertically the air warmed by the lower part streams up around the upper part and defeats the latter in heat emission, more or less. Radiator sections are on this account very seldom as effective as pipes, as they amount to being a number of wholly vertical pipes massed together, and only when pipes are upright and massed (as in some very old types of coils) are they to be compared equally with radiators in low effectiveness. The most effective surface for heat emission is a horizontal pipe of small diameter, but it is seldom that such is used as radiation in modern heating work. *It must be remembered, however, that in every apparatus, there is usually a fair—perhaps a large—amount of small to large horizontal pipes in the under-floor circulations, and these, if uncovered, can show more effectiveness in heat distribution than the radiators in the rooms.* In other words, if the circulating pipes (which serve the radiation) are exposed they can, and probably will, emit more heat to waste than an equal area of radiation in the rooms can emit for serviceable use.

Outer Surfaces of Radiators and Pipes.—The heat emission from what is called radiating surface can be widely affected by the surface itself. A polished metallic surface has the lowest effectiveness in this respect, therefore it would not be desirable to have radiators or pipes of polished iron, brass or copper, nor should either be gilded or even be coated with foil or gold leaf. Yet if any of these surfaces be given a good coat of lacquer or varnish the effectiveness is restored to about that of an unpolished surface. It is the true outer surface, the skin of the pipe or radiator, which affects heat emission and, as will be found elsewhere, a plain cast-iron surface is good in this respect, while a coat of lampblack or white lead actually adds to effectiveness. The various paints, oil-colour or enamel, may all be used without noticeably reducing the heating duty of radiators or pipes.

VALUE OF K. Being the number of British Thermal Units emitted from Hot-water Pipes and Radiators per square foot of surface, per hour, for each degree (Fah.) difference between the temperature of the water in the pipes and that of the air of the room. The difference most commonly worked to is 100 degrees, viz. Water 160°, Air 60°, for which difference the decimal point in the following figures is removed—thus 1·35 B.Th.U. per degree difference becomes 135 B.Th.U. per 100 degrees difference.

Nature of Surface.	*K*
SINGLE HORIZONTAL PIPES.	
1 inch internal diameter	2·3
1¼ ,, ,, ,,	2·2
1½ ,, ,, ,,	2·1
2 ,, ,, ,,	2·0
2½ ,, ,, ,,	1·95
3 ,, ,, ,,	1·9
4 ,, ,, ,,	1·85

When horizontal pipes are closely above one another, as in coils, deduct 5 per cent. for each additional pipe. Thus a 6 pipe coil (horizontal pipes) of 1 inch pipe would be given 1·75 as the value of *K*, viz., 5 × 5 = 25 per cent. less effectiveness per sq. foot than a single pipe.

SINGLE VERTICAL PIPES, 10 per cent. less than single horizontal.

When two vertical pipes come close together deduct a further 5 per cent.

HEAT EMISSION IN B.TH.U. PER HOUR PER lineal FOOT FOR SINGLE HORIZONTAL PIPES.

Size of Pipe.	Temperature of water in pipes and air of room.		
	150—60°	160—60°	170—60°
1 inch	69	77	84
1¼ ,,	86	95	105
1½ ,,	94	104	115
2 ,,	112	124	137
2½ ,,	132	147	161
3 ,,	157	174	191
4 ,,	196	218	240

Nature of Surface.	*K*
RADIATORS.	
Single Column	1·4
Two ,,	1·35
Three ,,	1·3
Four ,,	1·25

It is assumed that all radiators are fixed not less than 2½ inches from the wall to allow of free ascent of all heated air.

It is also supposed that radiators used are of an average number of sections or loops, say 6 to 10, as, of course, there are only two end sections to a radiator, and these sections emit more heat than middle sections, so that three 4-section radiators fixed 12 inches apart would show a better effectiveness than one 12-section. The difference, however, is not great enough to do with a section less by this means.

Nature of Surface.	*K*
GILLED PIPE (as p. 4).	0·85

When gilled pipes are assembled in "coils," that is two or more pipes fixed horizontally above one another, a deduction of 5 per cent. must be made as explained with Horizontal plain Pipes.

THE EFFECTS OF PUTTING SHELVES OVER RADIATORS, ENCASING RADIATORS, OR PLACING RADIATORS IN RECESSES

For best effectiveness, radiators should be well away from walls, not only for the free emission of heat and movement of the warmed air, but also to prevent the soiling of walls. Radiators should not be nearer than 2½ inches to a wall, further when possible.

Occasionally it is desired or is necessary that radiators be encased or placed in recesses and in nearly all such instances the heat emission, or value of K, is reduced. A common practice, too, is to put a shelf over a radiator, and this reduces effectiveness if placed down too close. A glass shelf on brass brackets has a nice appearance above a radiator and does much in preventing the soiling of the wall. It is permissible if the shelf is not too low down or of too great a projection.

Cases or enclosures to radiators must leave 2½ inches clear space at front and back of radiator, as Fig. 83.

RADIATORS UNDER WINDOWS

While there may be difference of opinion the writer considers that when radiators are placed beneath windows it must be considered that there is a 10 to 15 per cent. loss in effect, depending on the size of the window (see page 62).

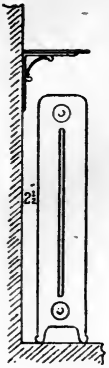

FIG. 81.

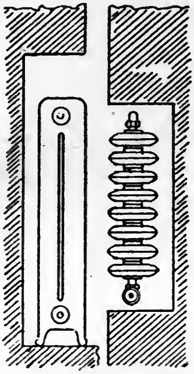

FIG. 82.

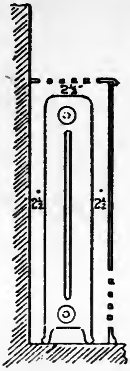

FIG. 83.

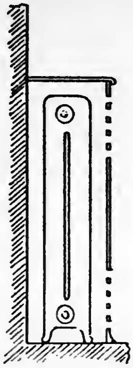

FIG. 84.

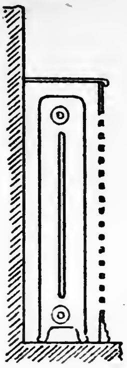

FIG. 85.

Fig. 81.	Fig. 82.	Fig. 83.	Fig. 84.	Fig. 85.
Flat shelf above radiator. Loss of effectiveness, per cent. Shelf, 7 inches projection. 1½ in. above 5 3 ,, ,, 2½ 4 ,, ,, 0 Shelf, 13 inches projection. 1½ in. above 7 3 ,, ,, 5 4 ,, ,, 3	Radiator in recess, open front. Width of recess is not material. Loss of effectiveness by height of recess, per cent. Top of recess. 1½ in. above 10 3 ,, ,, 7 4 ,, ,, 5	Enclosure, front, sides and top; wall at back. Grated top and grated bottom inlet. It is essential that top be wholly grating of open pattern and inlet grating of equal size. 2½ inches clear space front and back. Loss of effectiveness. None. As gratings decrease in size to that specfied above loss is experienced, sometimes 15 per cent.	Enclosure front, sides and top; wall at back. Grated top and bottom at front. Solid or close covered top. Loss of effectiveness, per cent. Gratings full width. 9 in. high 15 6 ,, ,, 25 4 ,, ,, 40	Enclosure, front, sides, and top; wall at back. Grated front only. Loss of effectiveness, per cent. Grating full area of front 20.

The above figures are for clean radiators. If the enclosure admits of their getting loaded with dust a greater loss is experienced.

CHAPTER XIII

QUANTITIES:

BEING THE AMOUNT OF HEATING SURFACE REQUIRED TO AFFORD CERTAIN TEMPERATURES

LET it be first stated that although the quantities for warming brick buildings and those for glass-houses are both dealt with in this chapter, they have to be treated from a rather different standpoint and are therefore kept separate. The warming of brick buildings is dealt with first.

QUANTITIES FOR BRICK BUILDINGS

Until recent years it was the practice to find the amount or area of radiating surface required in a room by simply ascertaining the cubic feet of space in it and allowing a certain quantity (square feet) of radiating surface per thousand cubic feet of space, the latter figure varying according to the temperature required. Nothing could be more simple, nor more reliable, if the conditions never varied, but, instead of this, a variation in conditions is the thing that may always be expected, consequently the simple rule just mentioned can seldom work out correctly. Notwithstanding this there are engineers who still calculate in this way, using judgment as to what will meet the conditions, but it requires skill and long practice to possess the degree of judgment needed.

The Co-efficient method is now almost universally employed, and while this aims at meeting all varying conditions, yet there is a feeling that some improvement on this will presently be possible. For those who have not a suitable office staff the method is distinctly tiresome, if not impossible in some cases, and on this account a Table for calculating by cubic contents is also given, with a provision of "allowances," for those who find the co-efficient method difficult.

While there is a feeling that the co-efficients for heat-losses from walls, roofs, glass, etc., are now fairly accurate, there always remains an uncertainty as to the changes of air, i.e. the number of times per hour the air of a room is changed, and unless there is certainty regarding this the calculation must give an uncertain figure accordingly.

It will be understood that a table of co-efficients is used in conjunction with a table which gives the heat-emission from radiating surfaces and the latter will be found on page 147.

TABLE OF CO-EFFICIENTS FOR HEAT-LOSSES FROM WINDOWS WALLS, ETC. (see page 147 for Table of Heat Emission from Radiating Surfaces).

Material of wall or other part of the room	Value of *K*. Being the amount of heat lost in B.Th.U. per square foot of surface, per hour, per degree difference between the temperature of the room and that of the outer air (Fah.)	Value of *K* for the customary difference in temperature worked to, viz. 60° F. required inside when the outer air is 30° F.
Brick outside walls—		
4½ inches thick . .	0·5	15
9 ,, ,, . .	0·36	10·8
13½ ,, ,, . .	0·28	8·4
18 ,, ,, . .	0·23 Note: Add 10 per cent. for outside walls facing north and east.	6·9
Brick inside walls, if unwarmed room on other side—		
4½ inches thick . .	0·4	12
9 ,, ,, . .	0·3	9

TABLE OF CO-EFFICIENTS—*continued.*

Material of wall or other part of the room	Value of *K*. Being the amount of heat lost in B.Th.U. per square foot of surface per hour, per degree difference between the temperature of the room and that of the outer air (Fah.)	Value of *K* for the customary difference in temperature worked to, viz. 60° F. required inside when the outer air is 30° F.
Studding partition wall, lathed and plastered both sides (cold room on the other side) . .	0·35	10·5
Ditto Match-boarded both sides	0·4	12
Ditto Match-boarded one side	0·8	24
Ordinary framed door .	0·5	15
Windows, Single . . .	1·0	30
,, Double. . .	0·5	15
Skylights, single . . .	1·2	36
Corrugated iron walls or roofs, not lined . . .	2·0	60
Outside walls of feather-edge boards on wood framing, lined with lath and plaster, or match-boarding or composition board.	0·5	15
Floor: Boards on wood joists, cold air ventilation beneath	0·05	1·5
Floor: Concrete and iron, cold air beneath . .	0·1	3
Ceiling: Lath and plaster on joists with boarded floor of unwarmed room above, cold air ventilation between . . .	0·4	12
Ceiling: ditto with unboarded roof space above	0·5	15

TABLE OF CO-EFFICIENTS—*continued.*

Material of wall or other part of the room	Value of *K*. Being the amount of heat lost in B.Th.U. per square foot of surface per hour, per degree difference between the temperature of the room and that of the outer air (Fah.)	Value of *K* for the customary difference in temperature worked to, viz. 60°F. required inside when the outer air is 30° F.
Ceiling : Concrete and iron, with unwarmed room above	0·3	9
Roof : Tiled on rafter battens, not lined, but sound tiling . . .	1·0	30
Roof : Tiled on boards (exposed rafters inside) .	0·4	12
Roof : Ditto, boarded on inside of rafters also .	0·2	6
Roof : Concrete and iron (flat) top surface asphated.		
6 ins. thick	0·3	9
9 ,, ,,	0·25	
Roof : Wood (flat) covered with sheet lead or zinc, lath and plaster or boarded ceiling inside	0·25	7·5
Air of room (per cubic foot)	0·02	0·6
Note.—For general calculations for air changes it is allowed that 1 B.Th.U. will raise the temperature of 50 cubic feet of air 1° Fah.	Note.—The above figure for air serves for general purposes, but for very accurate work the table in the appendix may be referred to in which it will be seen that the coefficient varies from 0·019 to 0·018 as the temperature rises.	

TABLE FOR ASCERTAINING THE AMOUNT OF RADIATING SURFACE REQUIRED IN ORDINARY BRICK-BUILT ROOMS AND PLACES, BASING THE CALCULATION ON THE CUBIC CONTENTS ONLY.

Note : This table is provided for those who prefer it for simple works and normal conditions. The co-efficient method, however, may be considered as the only accurate means of finding the area of radiation required and should be used whenever possible. One method may be used to more or less check the other when it is desired to see what differences abnormal conditions may bring about.

Temperature required inside when 30° outside (Fah.)	Square feet of radiator surface required per 1,000 cubic feet capacity	Some of the purposes to which the rooms or places may be put
50°	11	Coach-houses, Stores, etc.
55	13½	Some Churches (when empty), Workshops, Factories, Garages.
58	15	Some Places of Worship, Places of Entertainment (when empty), Workrooms (when empty), Sleeping Apartments.
60	16	Banks, Offices, Shops, etc.
62	17½	Living Rooms.[1]
65	20	
70	25	Bath Rooms ; also to afford 60° in Entrance Halls and Lobbies.
75	32	Drying Rooms (good walls, not glass), when empty and fan not running full. Temperature lowers when wet goods put in and fan running full.
80	40	
90	68	
100	100	
		Note.—In Research Laboratories, etc., the hot rooms which are specially built to prevent heat-loss, and have small ventilation, can be raised to 100° F. with one half the radiation given above.

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[1] A widely adopted practice is to specify a temperature of 60° for living-rooms. It is not sufficient, as it is chilly except to the young or very robust.

Notes and Working Allowances for foregoing table :—

It is supposed that the radiators will contain water averaging about 160° F. in coldest weather.

For Drying Rooms the radiation should carry water at about 170–180° F.

If pipes are used for radiation a less area of surface will be sufficient. For proportion of pipe surface to radiator surface see the subject of Heat Emission, page 145.

Add 10 per cent. for rooms facing north and east.

Add an additional 10 per cent. for each outside wall more than one.

Add 1 square foot of radiator surface for each 8 square feet of glass more than 20 square feet per 1,000 cubic feet of space. (It is considered that the normal area of glass in a room is 20 square feet per 1,000 cubic feet of space, and when exceeded requires additional radiation to deal with it. In the same way when rooms have less than the normal area of glass the radiation may be reduced.)

Places of Worship and other high interiors need only be measured to 15 feet height. See Church Heating, page 89.

In Schools and Institutions care must be exercised to ascertain if windows are kept open in severe weather and allow for this.

See the subject of Heat Emission, page 145, as to losses if radiators are cased in.

Small Rooms.—The areas of radiation given must be increased considerably with very small rooms, as the heat-losing wall surfaces are so much more per 1,000 cubic feet of space. A cloak-room, small dark-room (with window of crimson glass) and the like will require up to one-fourth more radiation per 1,000 feet of space.

Quantities for Horticultural Buildings

In calculating the heating surface required to heat glass-houses it is not necessary to make any separate calculation for loss of heat from the brick walls. There is a dwarf wall around the customary three or four sides, according to whether it is a lean-to or a span house, and there is of course the back wall of the former kind of house. But when the figures for the glass are got out, the allowance for loss from walls and for cubic contents is so comparatively small that it may reasonably be included in the general calculation for the glass area, remembering that the wall area is a mean average in practically all horticultural buildings.

The glass of these buildings is partly vertical and partly sloping, but no great difference occurs in their heat-losing qualities. In Hood's original work on warming buildings he devised a rule, based on the fact that a square foot of glass will cool 1¼ cubic foot of air (contained in a glass-house), to the temperature of the outer air, per minute and which runs as follows:

Rule.—Multiply 125 by the difference between the temperature at which the place is purposed to be kept, when at its maximum, add the temperature of the external air. Then divide this product by the difference between the temperature of the pipes and the proposed temperature of the place. The quotient thus obtained, when multiplied by the number of cubic feet of air to be warmed per minute, and this product divided by 222, will give the number of feet of 4-inch pipe which will produce the desired effect.

This rule gives a rather more liberal amount of pipe than is now allowed and may have been based on glass-houses being fixed to any aspect. The practice now is to give houses a south aspect or in some way protect them from north and east winds, failing which a house should have fifteen per cent. more pipe than the quantities now given.

A good general method that the writer now adopts is to calculate on the area of glass alone, using a co-efficient for this, included in which is a small allowance for the loss from the brick walls.

Co-efficient for glass of Horticultural Buildings (including small addition for corresponding area of dwarf brick walls)	B.Th.U. loss per hour, per square foot of glass, per degree (F.) difference between outer and inside air 1·3
Heat emission per **lineal** foot of 4-inch hot-water pipe, carrying water at an average of 110° F. higher temperature than the inside air. (Say water 160°, air of glass-house 50°, this water temperature being necessary in coldest weather.) For other temperatures of water and other sizes of pipes refer to the subjectof "Heat Emission," page 145.	240 B.Th.U.

As an example, supposing a lean-to house is 15 feet long, 10 feet wide, and 6 feet 8 inches mean height. (This would have a capacity of 1,000 cubic feet.) The glass roof would be 15 feet by 11 feet, the glass along front 15 feet by 2 feet, while each end would have 40 square feet of glass, together 275 square feet. From this it is proper to deduct one-eighth for woodwork, which makes the actual glass area 240 square feet.

240 square feet × 1·3 co-efficient × 30° rise in temperature (the outer air being 20°, the inner air 50°)=9,360 B.Th.U. loss per hour. This divided by 240 gives 39 lineal feet of 4-in pipe to keep this 1,000 feet house, with 240 square feet of glass, at 50°, when the outer air is 20° or 12° below freezing point.

The following is a simple table that may be worked to when the area of glass is normal, viz. 240 square feet per 1,000 cubic feet of space ; but it is always recommended that the glass be measured up and worked to when possible.

TABLE

HEATING SURFACE REQUIRED in lineal feet of 4-inch pipe for GLASS-HOUSES, based on their cubic contents. In this table it is calculated that there is 240 square feet of glass to each thousand cubic feet of space, and that the lowest outdoor temperature is 20° Fahr. When the weather is as cold as this, it is supposed that the water will average 160° in the pipes.

Temperature required	Length of 4-inch pipe to each 1,000 cubic feet capacity	Some of the purposes to which the houses may be put
° Fahr. 40	22	Trees, cuttings, summer bedding plants, cool-house.
45	30	Fruit trees, conservatories.
50	39	
55	48	Grapes, tomatoes, cucumbers, strawberries.
60	58	
65	70	
70	83	Tropical house, melon pits.
75	98	Forcing purposes.
80	115	

To find the lengths of 3-inch or 2-inch pipes equal to those specified for 4 inch refer to the subject of Heat Emission from Pipes, page 145.

CHAPTER XIV

DRYING-ROOMS

The successful working of a drying-room depends wholly on its being supplied with air that is deficient in moisture, air which is, so to speak, thirsty. This air will, then, readily absorb the moisture that is in the goods to be dried. *It cannot be too clearly understood that heat has no direct drying effect in itself.* It is a common impression that to subject a wet or damp substance to heat causes it to become dry, and the greater the heat is the quicker the drying will be. Heat certainly aids in the drying process, and is used with great advantage in all drying-rooms, but it has no direct drying effect, as can be shown. A very convincing instance came to the writer's experience in a brush manufacturing works. Here was built a drying-room for the washed and bleached or stained fibre. It was heated by steam pipes, and the work in this respect could not be better, but the materials put in the rooms did not dry even in so long a period as three days. They became hot, but they then only differed to their original state by being hot and damp, instead of cold and damp. They were absolutely moist after three days' heating, when the writer viewed the job.

The failure was due to the absence of ventilation. It is air that can and does deprive goods of moisture, but the useful aid that heat affords lies in the fact that heated air is more effective in robbing goods of moisture than cooler air is. Air has an active capacity for moisture, for if air is deficient in moisture (dry as it would be termed), it will pick up water wherever it can, and there is no hesitation or delay in its doing this. If dry air is introduced to wet goods, it needs no mechanical or other aid to make it rob the wet goods of moisture. All that is necessary is to bring the air and the goods together, so that the air may readily do its part.

The reason for warming the air is simply explained. Air at, say, 50° F. temperature can absorb and carry 4¼ grains of water per cubic foot. At 80° it can take 10¾ grains, while at 100° the quantity is increased to 19⅛ grains, and so on. (See table in Appendix.)[1] If, therefore, we have air at 50°, and heat it to 100° as it is entering the drying-room, it will be capable of absorbing moisture to a considerable extent, but what has to be particularly explained is that the heated air is not only capable of absorbing moisture, but it is thirsty, if it may be so expressed, and will greedily take up water from whatever moist or damp substance it may come in contact with. It is not a question of making the heated air pick up the moisture; the difficulty would be to prevent it. Let it be clearly understood that nothing is done to the air except to heat it, that is, to make it pass over some kind of hot surface that will raise its temperature. The air at 50° might and doubtless would be reasonably moist, probably carrying fully four-fifths its total moisture per foot, and would be considered humid enough for respiration and general comfort[2]; but on raising the temperature, the dryness becomes very pronounced, although the air will have lost none of its original moisture. In other words, the full moisture that air has at 50° is quite insufficient for the same air at a higher temperature, and the effect of the heating is to make the air take moisture from the first damp substance it meets. Briefly, therefore, the drying process is the absorption of moisture by the air in contact with the damp goods, and this process of absorption is greatly increased and hastened by heating the air, as by this it is given a greater capacity for moisture.

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[1] It will be found that air has its capacity for moisture about doubled with each twenty degrees rise in temperature.

[2] It may be explained that the atmosphere is seldom fully saturated, that is, carrying its utmost limit of water. Its natural degree of humidity varies with the weather, for while the mean humidity from September to March has been found to be from 81 to 89 per cent., in April to August it has only been from 74 to 79 per cent.

The next detail of the drying process to be pointed out is that there is an early limit to the amount of moisture a certain volume of air can absorb from damp goods, and although air at 100° will take about four and a half times as much water as air at 50°, it will take no more. It is, therefore, of no use filling a drying-room with heated air and expecting this one charge of air to dry the wet goods. One charge of air, though doing good work, really does exceedingly little, and the efficiency of a drying-room lies very greatly in its ventilation. There must be a positive and continuous change of air, new dry and thirsty air coming to the damp goods, and a corresponding exit of the air that is loaded with moisture, and which has lost its drying properties by having no further capacity for moisture. After the air in a drying-room has taken up its full charge of moisture, it is useless keeping it there, and the sooner it escapes the better. What is wanted is air that is in need of moisture, and as soon as its need is satisfied it must be so got rid of.

In arranging the heating and ventilating of a drying-room, therefore, the erroneous idea that putting the wet goods into a warm atmosphere will dry them must be quite abandoned. First decide the area of heating surface required, and then see how it can be disposed in relation to the ventilation. The incoming air must be made to pass over the hot pipes or surfaces to heat this air. On no account must any idea be entertained of disposing the heating surface so as to afford warmth to the wet goods, for this is quite a wrong way to go to work. What must be done is to heat the incoming air and thus increase its capacity for moisture and make it seek for more.. The inlet of new heated air, and the outlet of saturated and useless air, must also be disposed so that the new air passes over or through the wet goods to get at the outlet. If the inlet and outlet were so arranged that the air movement did not have good contact with the wet goods, then the drying could not be so successful.

The least size of fresh air inlet and the moist air outlet should be 1 square foot area for every 500 cubic feet of space in the drying-room (when empty). This would be for a room say 8 feet each way. With most drying-rooms it is important that the air be clean (in laundry work for example), and if it is a manufacturing or thickly populated district, the air should be filtered through muslin or cheesecloth, either of which has to be cleaned or changed frequently. Even for country districts a wire gauze strainer should be used to arrest particles of dirt, insects, etc.

As to inducing the necessary air movement through a drying room, this can be effected by mechanical or by natural means. By mechanical is meant the use of a fan or blower, but whenever possible the natural means is preferred as costing the least and needing the least attention. Natural ventilation is that brought about by the up-current, the draught, that occurs in brick-built chimneys. If the drying-room has such a chimney of at least twice the height of the room, the extraction of saturated air should be all that is needed, as, failing a sufficient draught, it can easily be provided with a gas ring at its base, or some similar means of inducing an active up-current. The chimney thus becomes the extractor, and supposing its top extremity to be above the building, so as not to suffer with down-blow, the change of air in the room should be all that is desired.

In Fig. 86 is suggested a drying-room in which it is supposed that the wet material can be spread out on lattice shelves or trays, through which the air can circulate. It will be understood, however, that the requirements in this work differ greatly and need different treatment, but in every case the principle laid down must be observed to ensure efficiency. It is that air is the drying medium, this being made more effective by warmth ; and the warmed air must pass close over or through the goods to be dried and then, when loaded with moisture, be carried away as quickly as possible.

It is never desirable to have the heating surface on the floor near the centre, or in a central trench beneath the floor, even though a fresh air duct can be brought to it. In such situations the pipes get loaded with dust and dirt and every effort should be made to keep the pipes away from such a situation.

Although this book deals with hot-water work it may be stated that the heating of the air of drying-rooms is usually effected by steam pipes or by a stove. Hot water is scarcely hot enough. Steam is at least 212° and usually much hotter than this, as 40 lb. to 60 lb. steam is often available in factories and such places. Stove heat is even better if a high temperature air is admissible. Stoves of various kinds are to be readily obtained suited to this work, those designed for Turkish bath work being quite suitable. They are ingeniously designed stoves with cast-iron shells either gilled or broken up by convolutions, but in either case presenting surface that will make air as dry as could be desired, yet not dangerously hot or deficient in hygienic

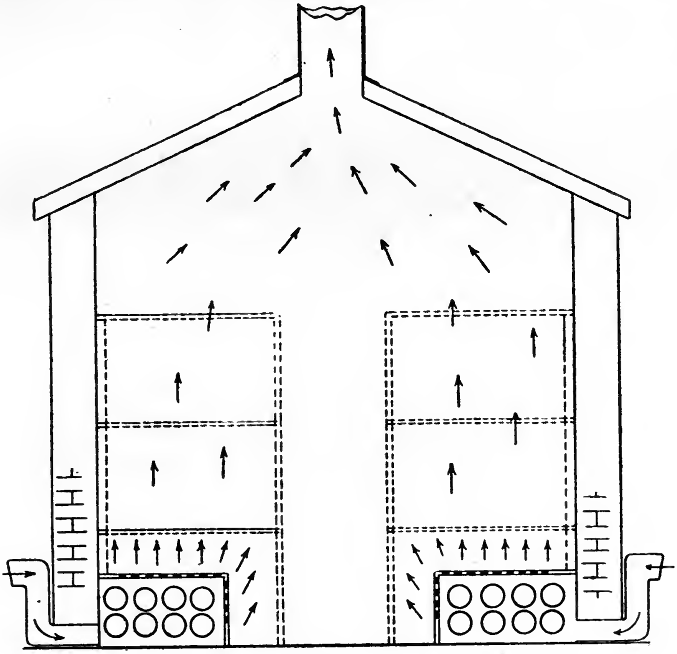

FIG. 86.—A Drying-Room.

qualities (except humidity). When using a stove it is fixed somewhere outside the drying-room, and the dry air is conveyed in metal or stoneware ducts (drain pipes) and discharged in the room where it will effect its purpose best. The same plan could be adopted with steam or hot-water pipes, if so desired. There is no need for them to be in the drying-room, if it is more convenient to put them elsewhere. They can be made into stacks in a heating chamber (see gilled pipes and radiators on pp. 4, 6), and from this source the heated air would be taken by ducts to the drying-room. In all these cases the extract ventilation is relied on to make the warmed air flow to and enter the room, for it will not enter otherwise. Extraction there must be, or the new air, warm or cold, will not enter the room.

The amount of heating surface required for this work is given in the table of quantities on page 154. With steam at 10 lb. pressure as the heating medium, the surface given in the table may be reduced one-third, while at higher pressures the area may be reduced one-half.

CHAPTER XV

TESTING HEATING PLANTS WHEN THE OUTDOOR TEMPERATURE IS ABOVE 32° FAHR.

BEING A PAPER READ BEFORE THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS, BY THE AUTHOR, AND FOR WHICH HE WAS AWARDED THEIR MEDAL

IN practically every case when a heating apparatus is erected, a certain rise in temperature is guaranteed or forms the basis of the order, and in the majority of instances this rise is from 32° to 60° Fahr. Occasionally the figures vary, though not to a great extent, and the conclusions arrived at in this paper will bear variation to meet any reasonable difference in the temperatures.

The engineer, having undertaken to afford a certain rise in temperature, it follows that, on the completion of the work, some sort of test takes place to show that the promised results are obtainable, and it is in this that a very real difficulty arises, for the outdoor temperature is so rarely at 32°, and when it is it cannot be relied on for many hours. Consequently, it is a very remote chance that the appointment to test finds the outdoor air at 32° and, failing some recognized rule or table, the test may amount either to nothing or a dispute. If an apparatus capable of affording a 28° rise of temperature from 32° to 60° would afford a 28° rise from any other outdoor temperature, say from 42° to 70° or 39° to 67°, then everything would be simple and satisfactory; but this is not the case by any means, for, when the outer air is above 32°, the increase that an apparatus can afford falls in a rapidly decreasing ratio. It will be seen from the table suggested that an apparatus capable of affording a 28° rise from 32° to 60°, can only cause a 14½° rise when the outer air is 56°, and a 2° rise from 32° to 34° finds an equivalent in half a degree rise from 69¼° to 69¾°. The sole purpose of this paper, therefore, is to propose a table that may be worked to with some degree of certainty and satisfaction when the outer air is above 32°, and if any argument for the need of such a table were required, then it can readily be provided by stating that, with some two hundred or more observations made during the past winter, the outdoor temperature was only once found to be 32°, and then for one hour only.

It is necessary to explain that the writer's house is warmed throughout—every room—by hot water, and the apparatus, always tended carefully, was stoked and looked after with proper care during the months the tests were on. Two rooms were chosen (the cooler room an unused bedroom), one with north aspect, on which the sun did not shine ; the other with a west aspect, on which the sun never shone until the tests were over—at noon. The morning hours were chosen as being the most reliable, for during the afternoon the results often varied, probably by reason of sunshine or other variable outdoor phenomena. Indoors, too, the phenomena varied by the rooms being used, cooking operations taking place and other variable factors. Each room had what may be considered a normal area of glass, and each had a chimney of equal area and height acting as extract ventilating shafts. Both rooms were about 12 feet from an outer entrance or source of outside air. Every effort, as will be understood, was made to get reliable normal results. On this account the temperatures, on many days, were discarded, or not taken, owing to some happening likely to cause uncertainty ; such domestic details as cleaning the rooms, etc., making a great difference in the warmth registered. Needless to say, also, the thermometers were carefully tested and all were hung in mid-air in positions where it was considered they would register the general temperature and not that of currents of air. Much more might be said regarding the different precautions taken and the pitfalls avoided, and it is hoped, therefore, that it will be taken for granted that everything possible was done to ensure reliable working results.

Hitherto the only attempts in this direction have resulted in algebraic formula, unsuited, I would submit, for general practice. In a paper read before an American Society the following rule appears :—

" Let T represent the temperature of the steam or hot water in the radiator, t the temperature of the air in the room, and t_0 the temperature of the outside air. Then

$$\frac{T - t}{t - t_0} = k$$

when k is a constant quantity for each building and plant.

" If as is usually the case,[1] t is 70° and t_0 is 0°, then the value of k will be

$$k = \frac{T - 70}{70}$$

From these equations we get

$$t = 70 \times \frac{(T - 70)\, t_0}{T}$$

This latter equation enables any one to determine the temperature, t, which should be maintained inside a building when the temperature outside, t_0, is higher than 0° (zero), and when the heat of the water or steam is T."

Professor Carpenter (of the Cornell University, U.S.A.) gives the following formula :—

" Let T be the temperature of the radiator, t' that of the room and t that of the outside air for the conditions corresponding to the guarantee. Let B equal loss from room for 1 degree difference of temperature ; let c equal the heat units from 1 square foot of radiator per 1 degree difference of temperature for conditions corresponding to the guarantee ; let c' denote the same values for other conditions ; let x equal resulting temperature of room, t'' outside air for the actual conditions, R equal square feet of radiation.

For guaranteed conditions,

$$(t' - t)\ B = c\ (T - t')\ R$$

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[1] In America.

For actual conditions,

$$(x - t'')\ \mathrm{B} = c'\,(\mathrm{T} - x)\ \mathrm{R}$$

Divided (1) by (2),

$$\frac{t' - t}{x - t''} = \frac{c\,(\mathrm{T} - t')}{c'\,(\mathrm{T} - x)}$$

When $t' = 70$, $\mathrm{T} = 220$, $t = 0$,
and $c = 1{\cdot}8$, we have

$$c'\left(\frac{\mathrm{T} - x}{x - t''}\right) = 3\ 86."$$

Professor Carpenter, in a note under this rule, states that the heat transmission grows less as the inside temperature rises, and that, therefore, the equations can only be solved in an approximate manner. In working out an example case, the author of this formula states that an apparatus which will give an increase of 70°, from 0° to 70°, will register $104\frac{3}{4}$° when the outer air is 60°. This, although having a genuine respect for Professor Carpenter, the writer feels compelled to doubt, especially as the radiation allowed to afford this temperature is seldom, if ever, more than 30 square feet of hot-water radiation or 20 square feet of steam radiation per 1,000 cubic feet of space.

Having had occasion to decide a test in this way, one that required to be settled beyond dispute (and such occasions, more or less important, must arise to all many times), it was thought that a series of tests would or should give figures that could not be doubted, and as the tests proceeded there was a feeling of conviction experienced that something in the nature of a problem was being solved. The following are the selected temperatures taken, only representing a rather small proportion of the whole, but the recording cards have, on so many days, marginal notes which throw a doubt upon the results being obtained under what may be termed test conditions. Negligence, or over-attention, at the furnace, alone spoiled many days' tests, and it will be seen in these selected that the temperature of the water was difficult to regulate with exactness. This was due to the boiler being fully powerful, requiring checking more than urging.

SELECTIONS FROM TEMPERATURES TAKEN

Arranged in approximate order of out-door coldness.

Hour	Outdoor Thermometers		Indoor Thermometers		Temperature of Water leaving boiler	Weather
	S.W. Aspect	N. Aspect	Room No. 1	Room No. 2		
	°F.	°F.	°F.	°F.	°F.	
10 a.m.	26	27½	59	54½	192	Bright, S.W. breeze
11 ,,	28	29	59½	55	204	,, ,,
12 ,,	30	32	60	56	206	,, ,,
10 ,,	27½	29½	59½	53½	180	Bright, S.E. breeze
11 ,,	30	31	60	54	184	,, ,,
12 ,,	30½	31½	61	55	200	,, ,,
10 ,,	28	30	61	54	190	Dull, E. breeze
11 ,,	30	32	62	55	190	,, ,,
12 ,,	32	34	62½	56½	200	,, ,,
10 ,,	29	30½	60	56	200	Bright, E. breeze
11 ,,	31	32½	60	56½	185	,, ,,
12 ,,	30	31½	60½	57	180	,, ,,
12 only	29	30	59½	56	182	Dull, N.E. breeze
10 a.m.	30½	30	62½	—	200	Bright, still
12 ,,	32½	33½	62	—	180	,, ,,
10 ,,	35	36	63	57	200	Raining, E. breeze
11 ,,	35	35	64	58	204	,, ,,
12 ,	36½	38	65	58½	210	,, ,,
10 ,,	35½	36½	66	58½	210	Bright, W. breeze
11 ,,	38	39	66	58	182	,, ,,
12 ,,	41	42	65½	58½	175	,, ,,
10 ,,	36½	36	64	58	190	Bright, S.W. breeze
11 ,,	41½	40	65	58½	185	,, ,,
12 ,,	43½	43	67	61	210	,, ,,
10 ,,	38	40	64	56	196	Bright, W. wind
11 ,,	40	41	65	56	189	,, ,,
12 ,,	41	42	66	58	196	,, ,,

SELECTIONS FROM TEMPERATURES TAKEN—*continued*

Hour	Outdoor Thermometers		Indoor Thermometers		Temperature of Water leaving boiler	Weather
	S.W. Aspect	N. Aspect	Room No. 1	Room No. 2		
	°F.	°F.	°F.	°F.	°F.	
10 a.m.	38	40	66	58	196	Mist, still
11 ,,	39	39½	66	59	291	,, ,,
12 ,,	39	40	67	61	202	,, ,,
10 ,,	38½	39	65	59	192	Bright, S. breeze
11 ,,	39½	39½	65	59	195	,, ,,
12 ,,	39	39½	65½	59½	204	,, ,,
10 ,,	39½	38½	60	58	192	Bright, N.E. wind
11 ,,	40½	41½	61½	58	182	,, ,,
12 ,,	40½	41½	63	59½	182	,, ,,
10 ,,	41½	42	68	60	200	Bright, S.W. breeze
11 ,,	43	43½	68½	60½	208	,, ,,
12 ,,	48	47½	69½	62	204	,, ,,
10 ,,	42	43	62½	57½	210	Wet, S.W. breeze
11 ,,	43	44	63½	58	185	,, ,,
12 ,,	44	44½	64	58	176	,, ,,
10 ,,	41½	42	59½	56	175	Dull, N.W. wind
11 ,,	41½	42½	64½	59½	193	,, ,,
12 ,,	41	42	65	60	192	,, ,,
11 ,,	44	42	—	61	198	Bright, W. wind
12 ,,	44	42	66	60	190	,, ,,
10 ,,	44	44	67	61	184	Bright, W. breeze
11 ,,	46	45	68	62	182	,, ,,
12 ,,	46	46	68	62½	180	,, ,,
10 ,,	45	45	66	59	183	Wet, W. breeze
11 ,,	45	45½	67½	60	178	,, ,,
12 ,,	45½	46	68	60	178	,, ,,
11 ,,	44	46	67	62½	175	Raining, S. breeze
12 ,,	44	46	68	62½	175	,, ,,

SELECTIONS FROM TEMPERATURES TAKEN—*continued*

Hour	Outdoor Thermometers		Indoor Thermometers		Temperature of Water leaving boiler	Weather
	S.W. Aspect	N. Aspect	Room No. 1	Room No. 2		
	°F.	°F.	°F.	°F.	°F.	
10 a.m.	45½	46	66	63	195	Wet, still
11 ,,	50	50	67	62½	175	,, ,,
12 ,,	52	52½	68	62½	180	,, ,,
10 ,,	47	47½	—	60½	188	Bright, S.W. wind
11 ,,	47	47½	67	61	182	Dull, W. wind
12 ,,	45½	46½	67	60	175	Wet, W. wind
10 ,,	47	47	66	61	175	Bright, W. wind
11 ,,	48½	48½	67½	61½	185	,, ,,
12 ,,	49½	49½	67	61	170	,, ,,
10 ,,	47	46	68	61	180	Dull, W. breeze
11 ,,	48	47	68	60	190	,, ,,
12 ,,	48	47	69½	62	190	,, ,,
11 ,,	48	48	67½	61	200	Dull, W. wind
12 ,,	48½	48½	68½	61	184	,, ,,
10 ,,	48	48	67	62½	190	Bright, E. breeze
11 ,,	46	45	67	63	193	,, ,,
12 ,,	49	49	68	63½	180	,, ,,
12 only	51½	51½	69	62	180	Dull, S.W. gale
10 a.m.	52	52	68½	63	175	Dull, S.W. wind
11 none						
12 a.m.	53	53	70	64	180	,, ,,
11 ,,	52	51½	69	63	190	Dull, S.W. gale
12 ,,	52	52	70½	63½	200	,, ,,
11 ,,	54	53	68½	63	185	Dull, W. wind
12 ,,	55	53½	69	63	176	,, ,,
10 ,,	56	56	71	64	186	Bright, W. breeze
11 ,,	57	56	70	65	180	,, ,,
12 ,,	57	56	71	64	184	,, ,,

From the foregoing temperatures the following table has been compiled. It is almost unnecessary to point out what a difference the temperature of the water makes to the internal temperature, and the tests illustrate this; and in arriving at the figures for the table it has been endeavoured to make correct allowance for the temperature prior to the figures being taken. It might have been mentioned earlier, that, although the figures are given for three different hours in a day, this was only done for the sake of the information it might afford, the actual test time being 12 o'clock (noon).

TABLE *of equivalent temperatures to enable heating works to be tested when the temperature of the outer air is higher than that given in the contract or guarantee.*

When the required rise in temperature is from 32° to 60° Fahr.

If outer air is	The internal temperature should be
32 degrees	60 degrees
34 ,,	61¾ ,,
36 ,,	63¼ ,,
38 ,,	64½ ,,
40 ,,	65½ ,,
42 ,,	66½ ,,
44 ,,	67¼ ,,
46 ,,	68 ,,
48 ,,	68¾ ,,
50 ,,	69¼ ,,
52 ,,	69¾ ,,
54 ,,	70¼ ,,
56 ,,	70½ ,,

It would seem desirable to suggest some rules or provisions when making tests.

In the first place, not less than two outside thermometers should be used, one on the sheltered and one on the exposed side of the building. In no case should the sun shine directly upon either of them, and the external temperature should be the mean of the two. As the external air is constantly changing in temperature (usually rising during the morning hours), it cannot be correct to take the external figures either at the beginning or end of the test, and it would appear best to take them when the test is half through.

As to the time to test, this should invariably be during the morning hours, as early as possible, for it may be supposed that an apparatus is installed with a view to giving the agreed warmth as soon as reasonably possible after the rooms or place may be occupied. In the case of factories and works, also in private residences, the apparatus would probably have the fire alight all night, for without this provision it would be well on in the morning before the boiler would be giving its full results, and this with many businesses and purposes would entail annoyance if not loss.[1] If a place is occupied an afternoon test is out of the question, as the heat from workers, from machines, or other sources, and many happenings, all go to give unreliable results, though usually in favour of the heating engineer.

There should be two or more indoor thermometers hung free in the air, and at about 5 feet from the ground; and, needless to say, the whole of those used should be exactly alike in their recording qualities.

It is always best to test when a place is fitted or furnished, occupied and in normal use, and what has already been said is based largely on this. Unfortunately such a test is not always possible, and there arises the question whether allowances, and what allowances, may be necessary when testing in new, unoccupied buildings of any kind. Few can have had experience sufficient for them to say that a certain allowance is strictly correct, but as the writer has lived in a house, not for a few days, but some months, with parts of it in both conditions, a degree of confidence is felt in saying 3° should be allowed when freezing; or equivalent when the outer air is warmer. It will be understood that this means that an apparatus intended to give an internal temperature of 60° when 32° outside should be considered satisfactory, if it gives a 57° warmth in an unfurnished, unoccupied building when 32° outside; or an internal tem-

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[1] In printing and lithographic works the ink will not flow properly until 58° to 60° is registered.

perature of say 62½° when 38° outside. This is a detail that will well bear discussion, being a source of many disputes of a serious nature. In some instances the internal temperature is specified as being that "when the building is empty and unoccupied," but a qualification of this kind is rare,[1] and the temperature mentioned is almost always that which is required (as being agreeable or suitable) when the place is regularly occupied and used.

As to the time occupied in making a test, if the fire has been alight a few days previously and the whole of the previous night, then two hours' brisk firing in the morning should suffice, whether the apparatus be small or large. This is based on the supposition, a reasonable one it is believed, that a place, whatever its kind, is required to be of a comfortable temperature within two hours after the attendant revives the fire in the morning. This needs consideration in erecting an apparatus, for in so many instances the night fire is essential to success, and, when no night watchman is employed, it requires a good boiler to keep some warmth in the place for 12 to 14 hours without attention. If by any chance a test for temperature is required without the fire being alight through the night, then the period of time to be allowed for the test is an uncertain quantity, for it must depend on the size of the installation and the conditions. It should, therefore, be stipulated in every possible case that the fire be lighted some days previously and be banked up each night, and then the test be made in the morning hours. This is only a fair provision for the heating engineer, while being equally fair to the client or his representative.

The upper limit of external temperature, 56°, is quite high enough, for above this temperature such an exceedingly small rise is obtained inside for one or two degrees outside. Even a quarter of a degree is not easily read off ordinary thermometers, nor are ordinary thermometers always correct to this extent.

[1] It is also important, when the test is to be in a new building, that the heating apparatus have its fire alight and all parts fully hot for several days before the test. To attempt to get a full temperature to the air while the walls are cold is more or less hopeless.

CHAPTER XVI

BOILERS

A NOVICE or beginner in heating work might suppose, on studying the different makers' catalogues, that amongst the great variety of makes and designs of boilers shown there must be at least a good number that serve special purposes, and included in the design of which must be some special detail or principle of construction to meet different specific requirements. It is scarcely so, however, and although there is generally some good reason for the variety it might all be summed up in saying that they represent heaters suited for installations of different magnitudes and exhibit the efforts that are continually being made by manufacturers to do better than their rivals, or better than they have previously done themselves.

The efficacy of a boiler lies chiefly in the area and disposition of its heating surface, and it would be wholly so if it were not that the area of fire grating or bars must bear some sufficient proportion to the heating surface, to ensure perfect combustion and effectual heating. Again it might be said that efficacy must also depend upon the chimney, which detail forms part of this chapter. The subject of boiler efficacy is, therefore, reduced to the question of heating surface, grate area and chimney, the more important of which is heating surface.

Primarily there are but two kinds of heating surface, the Direct and the Indirect, but these may vary much in heating effectiveness. The direct surface is that which faces the fire —what the fire shines upon, and which *radiant* heat from the glowing mass of fuel chiefly affects. This surface also receives heat by contact with the incandescent fuel that rests against those parts which are near the fire-bars. There can be no doubt whatever that direct surface is the most valuable a boiler can have, and it will be found that the newest boilers on the market give evidence of effort being made to increase this surface by the most ingenious means, while true flue surface is being largely abandoned.

The direct heating surface in a boiler may be said to be horizontal (over the fire) or vertical ; but between these two there are angles of many different degrees, and which would be given a degree of efficiency relative to the two. It is very generally contended that a horizontal direct surface over a fire is the most valuable that can be had, and the heating of the familiar kettle is used to illustrate this. A kettle placed over a fire will have its contents boil much sooner than a kettle placed in front of a fire, supposing the area of heating surface and the state of the fire to be the same in each case, while a kettle placed beneath the fire would be much the least effective of all. This is a strictly correct argument when applied to a kettle or any water-heating device which can be subjected to an incandescent fire on all sides ; but with the average boiler this will bear modifying. In the first place, the surface over the fire is only the most valuable when the top of the charge of fuel is in a glowing state. This is not always the condition of the fire, particularly in boilers constructed to take a charge of fuel to last several hours ; or in boilers which are tended by unskilled persons, who heap fuel in with the idea of making the fire go as long as possible without being looked after. This tells against the heating surface over a fire and brings it nearer to being no better (if as good in some cases) than vertical surface, for included in the latter we get that surface which the glowing fuel, whether it be little or much, rests against.

The foregoing is not intended to deprecate the usefulness of direct surface, for under all conditions it remains the best that can be had. It is to show how varying its efficacy can be, and how impossible it is to set any precise working value on horizontal compared to vertical, or any degree between, unless the boiler be under the care of a skilled stoker. The best that can be done is to consider direct surface as a whole and give it a general value accordingly, as is usually done. In all heating boilers effort is made by the manufacturers to increase the direct surface, for if any were sacrificed so as to gain more flue or indirect surface, then the latter would have to be at least three times as great to have a working value equal to the direct surface lost, and would, of course, need to be four times the area to show better results.

Indirect heating surface is that which the fire does not shine upon, and which receives no heat by radiation from or by contact with the glowing fuel. Indirect surface is flue surface, and is heated by the hot gases of which the products of combustion are composed. With coke fuel, which is so largely used, or anthracite, which is the finest fuel known (if the quality is good), there are no flames, and the flue surface is heated by hot but non-luminous and invisible gases, i.e. products of combustion.

Flame gives abundant evidence of two peculiar phenomena that have to be considered in boiler construction, and heated gases show the presence of like results also. Flame affords little heat unless it has actual contact with the surface or substance which is to be heated by it. Any one can obtain the most obvious proof of this with a small flame from a fire, or a gas flame, for the hand can be held quite close at the side of such a flame without feeling the heat at all painfully, but immediately the hand and flame come in contact, however little, the heat has an immediate intense effect. Flame, therefore, must have contact to be effective.

The other phenomenon peculiar to flames and heated gases is that they show a positive objection to having contact with surfaces cooler than themselves. If possible, which means if there is room, or the draught and formation of the flues admit of it, flame and gases will float and travel between surfaces without having contact with them. Flues have, therefore, to be of suitable sizes as to shape and smallness, yet not so small as to choke the draught, or have an ill effect on the general work of the boiler.

Although flame is more effective in heating than hot gases, yet the difference is not so very great, for both proceed from an equally hot source, in fact the gases in many cases come from incandescent fuel, while flames may be evolved when the fuel is at a less temperature ; but flames really represent a portion of the fuel still in a state of combustion, and this gives them a greater heating value than gases. Opposed to this is the fact that flames deposit soot, which gases do not. Soot is a poor heat conductor, and a very thin coat will cause flame to have no better heating effect than gases have on a clean surface. It is not intended to say that coke and anthracite produce no dirt in the flues, for they do, and the flues must be regularly cleaned, the surfaces being well brushed with a stiff *wire* brush, but the fouling of flues by non-bituminous fuels is much less than with a bituminous fuel (ordinary coal), and on this account and for general reasons the indirect surface is counted as of one heating value whatever fuel is used.

Flame Contact.—While on the subject of contact between flames with surfaces cooler than themselves, reference may be made to a paper read by the late Thomas Fletcher, as long ago as 1886, and which, while showing how better results could be obtained, does not appear to have been put to practical use to the full extent it might have been. Makers of cast boilers might with advantage give more consideration to it ; it is not so easily applicable to wrought boilers. It is not necessary to give the paper *in extenso*, as the substance of it may be explained quite briefly. From a series of experiments and observations, it was found that when flame is applied to heat a vessel of water, the flame does not have actual contact with the metal of which the vessel is composed. This is shown to be due to the fact that the metal, by reason of its having water in contact, can never be of a temperature equal to that of the flame itself nor near it. It matters not how hot the water may be, it is still far below the heat of the flame, and it follows that when the vessel contains cold water the conditions and results are still worse.

There appears to be a film, or space, between the flame and the metal, and while this exists the results are distinctly less satisfactory than when a more perfect contact is obtained. The purpose of the paper was to show how the film or space could be disposed of, and more effective heating obtained. What appeared to be necessary was some provision or means by which the metal of the water vessel could be made to more nearly approach the temperature of the flame; for, as will be understood, flame has better, if not perfect, contact with surfaces at much higher temperatures; and, when this contact is obtained, the good results noticed are quite out of ratio with the increase of temperature. In other words, there is the difference that might be expected between imperfect and perfect contact.

To obtain the desired effect a vessel was made, in the form of a kettle, with a large number of metal pins or *solid* projections on the bottom, as Fig. 87. The advantage gained by this arrangement was that the pins (about 1½ inch long) had their lower extremities too far removed from the cooling effect of the water to be kept at a low temperature, consequently they became highly heated and nearer the temperature of the flame. This being so, the flame had a more perfect contact, and parted with its heat more freely than it is ready to do to a cooler surface, and the result was that 40 ounces of water was boiled in one minute fifty seconds, whereas with a kettle of similar size, with a plain bottom, the same quantity of water took three minutes fifty seconds, or double the time.

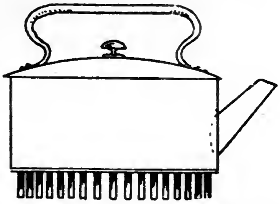

Fig. 87.—Kettle constructed to demonstrate the effect of flame contact.

Absorption of Heat by Water.—It is worthy of note that the idea of increasing the heat-receiving surfaces by solid projections was promoted very many years ago, with a view to increasing the efficacy of boilers, but the gain in effectiveness that was claimed had a different origin. It had been found, and is still recognized, that the water in a boiler can take up, i.e. absorb, heat over two and a half times (2·6 times) as fast as a given area of plain heating surface can convey it from the fire, and that, therefore, the water on one side of a plain boiler plate never receives one half the heat it is capable of taking, however hot the fire and plate may be. The idea of using projecting solid parts (it was solid flanges or gills in this case) was to offer an increased surface to the fire, of, approximately, two and a half times the metal heat-receiving surface to what the water contact surface was. Thus one foot of water surface would have about two and a half feet of heat-receiving metallic surface to supply it, and by this plan a considerable increase in results was hoped for. It was not expected that any particular economy in fuel would be effected, but that a small boiler could be given the effectiveness of a larger one at a very small extra outlay on the cost of the small one.

It will be seen, therefore, that solid projections on the heating surface of a boiler would have two quite distinct good effects. First, the securing of flame contact ; second, the increase of heating surface. The latter, it will be seen, would be actually of greater effectiveness than an equal increase of ordinary surface which has water close against it.

Value of Heating Surfaces in Boilers.—The writer's table of work values for heating surfaces in boilers, and which he first gave in his editions of *Hood on Warming Buildings* is as follows ; and although its original compilation occurred some years ago there has appeared no reason or arguments since to require an alteration to be made :—

TABLE OF WORK VALUES OF HEATING SURFACES IN BOILERS

DIRECT HEATING SURFACE. All that which faces the fire and receives heat by radiation from, and by contact with, the glowing fuel	One square foot will transmit 4050 B.Th.U. per hour equal to 30 square feet of ordinary direct radiating surface.[1]

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[1] For proportion of other heat-emitting surfaces, see page 147.

INDIRECT HEATING SURFACE.

Primary flue surface: that is, flues which receive flame and heat immediately on leaving the fire box, and which may be termed first flues	One square foot will transmit 1620 B.Th.U per hour, equal to 12 square feet of ordinary direct radiating surface.[1]
Secondary flue surface: that is, flues which receive flame and heat after it leaves the first flues . . .	One square foot will transmit 945 B.Th.U. per hour, equal to 7 square feet of ordinary direct radiating surface.[1]

Note.—The above figures only apply to the average, or the aggregate, of the surfaces which are either horizontal and over the source of heat, or are vertical, and receive the heat at the sides. Surface, whether direct or indirect, if beneath the fire bars, should not be included, as it cannot be given any useful value.

The above figures can only apply when the area of furnace bars is correct, i.e. not less than the area that is needed.

No allowance has been made for third flues. These occasionally appear when a chimney is high enough to admit of such a boiler being used. With a draught such as would carry a useful degree of heat to a third flue the other surfaces might be given a greater working value, but the total result would be a greater consumption of fuel than is customary. The tendency now is to work all boilers with a slow draught, and for all ordinary purposes the figures given in the table will be found to apply correctly, ignoring the possibility of boilers with third flues. Except with brick-set boilers even second flues are now seldom found.

Deciding the Size and Kind of Boiler to use for a proposed Heating Installation.—Following on this subject of working values of boiler surfaces may come the question of deciding what size of boiler to allow and order for any given installation. As to the most desirable make of

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[1] For proportion of other heat-emitting surfaces, see page 147.

boiler to use, it is not within the province of this work to recommend any one kind in preference to another, especially as there are now several different makes that may be rightly called good. The writer keeps to one particular manufacture, but doubtless others are as good, but once a make of boiler is used which causes no disappointments it is usual to find that engineers keep to that make to the exclusion of others.

It follows that almost first consideration must be given as to what kind of boiler can be accommodated, this in many cases meaning, can a boiler of normal or ordinary design be used or must a low one be chosen because of the available height being restricted. Even in new buildings architects will occasionally arrange for the boiler to be put away in some awkward place because that space cannot be used for anything else, while oftentimes everything points to boiler accommodation being more or less an afterthought. In brick buildings, from residences or small business premises to the largest structures, the independent boiler is almost invariably used, the brick-set boiler now seldom appearing in this work, while for horticultural requirements the brick-set boiler is still more evident than any other kind. In this latter case, whether it be glass-houses in a residence garden or a market grower's establishment, the choice very seldom lies with the heating engineer, the gardener in the former case, the master in the latter, almost always deciding what boiler they can do best work with.

Although the table just given (page 180) has been compiled to show the working values of surfaces, it is not customary for a heating engineer to specify the surface he needs in a boiler, nor to measure it up, or even to ask the manufacturer what surface a certain number or size of boiler has. Some makers now give this information in their catalogues, but the particularly good detail now appearing in catalogues is the published *efficiencies of the different sizes and designs of boilers given in British Thermal Units.* This, needless to say, is of the greatest service when the radiation and the general heat emission requirements have been calculated by the coefficient method. Allowance must be made for stoking, however, as is explained directly.

To find the suitable power of boiler that should be used for a proposed installation, it is first necessary to take the radiator surface, then add all exposed pipe surface, which, together, represent the heat-emitting surface that the boiler has to serve. If any pipes are covered it must be allowed that they lose a certain amount of heat, depending on the covering, and if well covered the heat emission can be calculated as one-fourth that of exposed pipes.

On arriving at the total heat emission, whether in B.Th.Us. or in square feet, there should be *at least one-fourth added to give the catalogue power of boiler that may be used,* so that if the surface represented 600 square feet of radiation, the least suitable size of boiler, catalogue rating, should be 750 square feet. It is by no means intended to convey that makers' catalogues are incorrect or unreliable, for the reverse of this really applies, but it is that the makers very properly publish the actual powers of boilers—the work they will do —under best conditions of stoking, draught, fuel, etc.

In just suggesting the 25 per cent. addition to all surface to find the least best catalogue power it is assumed that the stoking will be moderately well attended to, but unless a man is deputed to do this in a proper manner (as in large blocks of buildings, institutions, etc.) the allowance suggested is not always sufficient. In so many instances the attendance amounts to shovelling as much fuel into the fire-box as it will hold with the view to lengthening the periods between stoking—to save trouble. The upper part of the fuel is black for much of the time, the good direct heat-receiving surface has black fuel looking at it and the ash on the fire bars grows thicker and thicker.

Again there is the question of the fire keeping alight all night without attention. This necessarily means filling the fire-box with black fuel and closing the damper to a fair extent, and while this may result in the fire being alight in the morning the water in the radiation will not be hot then. As one of the important features of a hot-water apparatus is that of affording uniform warmth day and night or early morning till night, a boiler which will do fairly good heating work during a night of 8 to 10 hours is commonly the best size to instal. *To admit of this, and also of rather unskilled attention, the writer never adds less than one-third, and often one-half,* to the total heat-losing surface to decide the catalogue rating of boiler he shall put in.

When an engineer has studied and practised his work for some years, he discovers that a reputation for unfailing good results can almost be built up on using boilers of full power. They are quick, work with a slow draught, may be stoked carelessly or unskilfully, and prove distinctly economical. A boiler of bare power, even with a perfectly designed apparatus, will give poor results in many ways, results which are totally absent with a boiler of full power, and the latter will work in a way that one engineer describes by the word "sweet." In the writer's own house the boiler, one which has a proper catalogue rating, is 75 per cent. above power, that is, its catalogue power is three-fourths more than the actual heat-losing surface. The consequence is that after filling the fire-box with coke, closing the draught-damper and opening the check-damper, the fire will go for twelve hours and keep the water at 130° all the time. What this means is that the boiler only needs attention morning and night in moderately cold weather and is ready to give smart results directly the coldest weather comes, and it will do this with the draught-damper open only half-an-inch and the check-damper still half open. The general effect is a greatly appreciated economy in fuel and attention, while the apparatus generally works perfectly. It does seem as if a boiler of full power had some kind of mastery over many irritating results that appear with boilers of bare power.

Although a heating engineer may have no direct interest in the question of fuel consumption, yet he indirectly aids his business if economy in fuel is coupled with good results, and this is what a boiler of proper full power ensures. If a radiator can be given its required temperature with a slow fire (in the coldest weather), the economy compared to having to keep a fast fire to get the same results is most marked. It is more than this, for it is almost astonishing. The explanation that can be offered is that while a small surface in a boiler subjected to a fierce fire probably absorbs about the same number of heat units as a large surface subjected to a low heat, there is a great difference in the number of units that go up the chimney ; while in the hands of an attendant unskilled in stoking the fast fire can be made more wasteful than a slow fire. Such an attendant would not keep thin bright fires to get the best possible value from the fuel that a fast fire can give ; he would more likely fill the furnace with fuel, arrange the dampers for a full draught and remember that he must return in an hour to put more fuel on.

It is necessary to repeat again that the addition of one-fourth or one-third to catalogue boiler powers will give satisfaction in the ordinary way, but if there is the money to spend, a customer can be given a certain amount of extra satisfaction by increasing the boiler power a little more, and the engineer will most probably derive a certain degree of good advertisement by doing this.

Small Boilers.—When the apparatus is a quite small one it is, of course, equally important that the boiler be of full power, but even then it may not be large enough to take a charge of coke to last the night without attention. In such a case a boiler having a fuel hopper becomes necessary, or the boiler maker should be asked what he would recommend.

Fire Bars.—In regard to the most suitable area of fire-bars[1] for boilers, it may be explained that an insufficient area means an insufficient supply of air needed for combustion, while too great an area means, possibly, an unnecessary consumption of fuel. Neither conclusion is strictly correct, however, but there is no doubt that a boiler must have a certain area of bars to give best results when the fire is required to burn briskly ; but too great an area of bars does not cause a waste of fuel unless the damper is not regulated, and the fire is allowed to burn too rapidly. A large area of bars does not allow of the passage of a large volume of air, unless the damper is opened sufficiently to admit of this ; therefore, if an error is to be made, it is best to make it on the side of too great an area rather than too small. It is necessary to speak in this manner as no precise rule exists or can be made to give the exact area of bars needed by all makes and sizes

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[1] Area of fire bars includes the bars and the spaces between the bars.

of boilers. Makers of independent boilers—boilers which have the bars sent as part of their structure—may be relied on to send what is best, but it is doubtful whether any one could say the bars sent were of a precisely correct area. What is doubtless done is to estimate the correct area by tables or experience, or both, and then add a little to it to be on the safe side.

It is only with brick-set boilers that the heating engineer may have to choose the area of fire-bars he will use, as all independent boilers are provided with these and sent out complete, by the maker. The table which follows is therefore very brief, as it can refer only to the saddle boiler and boilers of somewhat similar character; and, it may be added, every boiler maker is prepared to send, with boilers of these kinds, a set of bars and furnace fittings of suitable size, if he is asked to do so. The area of furnace bars is therefore, at this date, more a subject for boiler makers than boiler fixers.

AREA OF FURNACE BARS REQUIRED BY BOILERS FOR EACH 100 FEET OF RADIATING SURFACE.[1]

	Square inches.
With a plain saddle boiler . . .	50
With a saddle boiler having one check or water-way end	46
With a saddle boiler having two water-way ends and a tubular flue . .	40
With a saddle boiler having two water-way ends and return tubular flues .	35
With boilers as above but having cross tubes, *reduce* the area for each cross tube	5 to 10

The foregoing areas will be found to exceed those of the bars which appear in modern wrought-iron boilers of powerful character, or the cast-iron sectional boilers. There are two reasons for this; one being the large area of heating surface within a small compass; the other, the greater height of chimney and keener draught usually associated with these latter boilers.

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[1] The areas given include the bars and spaces between the bars.

The areas given are not intended to apply to boilers below 400-foot size. With boilers of the "Star" type, ranging down to 65-foot capacity, the area must be larger, and the same applies to small saddle boilers.

Rocking Fire-Bars.—There at present appears to be doubt as to the durability and general utility of these, but there can be no doubt of the really great convenience they offer in dealing with the ash that collects on the fire bars. If a boiler is in a house or pit outside the building which is being warmed then the clearing of ash from the fire bars may cause no trouble, but when a boiler is in a basement room inside a house the disturbed ash is a source of real annoyance. The writer has used a boiler with rocking bars for eleven years without breakdown and without the bars giving any evidence of wanting renewal for some time to come. It is only a 700 square-foot boiler (catalogue rating) and may be carefully tended, but everything points to the rocking bars doing equal service to stationary bars. Certainly for personal use rocking bars will always be preferred in future, and it is felt that no hesitation need be felt in recommending them. To know that the fire can be cleared of ashes in less than a minute, with all doors on the boiler closed, is a very desirable thing.

Covering Boilers.—A large part of the external waterway of a boiler contains water at a higher temperature than the water in any part of the heating system. Water loses heat after it leaves the boiler; therefore the hottest water must be in the boiler. Largely on account of this it is important that the boiler be covered with composition to prevent, or at least reduce, heat-loss. Loss of heat is loss of fuel, loss of time and loss in results, but besides this there are very few boiler rooms or houses but what are seriously overheated if the boiler is not well covered. The foregoing is well recognized, but a note of warning requires to be given as to how thick the covering should be and how a proper thickness, when specified, is not always put. Boilers of fair to large size should have the covering 2 inches thick on all parts of the waterway (the top in particular if there is any difference), and this should be tested, when done, by pushing the blade of a penknife or an awl or a skewer in until it reaches the iron.

Fuel Consumption.—For general guidance, when the question is raised, it may be estimated that under reasonably good conditions the consumption of gas-coke for installations of moderate size averages one hundredweight (1 cwt.) per day for each 400 square feet of radiation. It requires an efficient boiler to do this, one of a size that can be worked without undue stoking, while this average consumption means a moderately greater quantity in severe weather, less in milder weather. The figure is given for a 24-hour day, the fire burning as may be necessary for say 14 day-hours, while a quite slow fire is kept for 10 night hours. With gas-coke costing 18*s*. to 20*s*. per ton an apparatus of moderate size (small installations cost a little more) will use no more than a pennyworth of fuel per room of about 2,000 cubic feet capacity (or the equivalent of this in larger or smaller rooms) per day of twenty-four hours. No other method of artificial warming is so cheap as this. It is, however, best not to promise this to intending customers, as while easily possible of attainment there are many things that may bring about disappointment, but if the figure is increased by 50 per cent., or even doubled, it still remains an exceedingly low one.

Flue Nozzles and Flue Pipes of Boilers.—(See subject of Chimneys also, page 139.) It is scarcely within the heating engineer's province to decide what size of flue nozzle an independent boiler should have, as this part is cast and fitted to the boiler by the maker, who presumably knows the best size and would find it difficult and expensive to make any alteration for one customer. It may be mentioned, however, that boilers require to have flue nozzles of suitable size, and indeed it is a rather vital part of a heater and can greatly lower efficiency if too small. It is doubtful if a flue nozzle has ever been too large.

In a paper read by the Chairman of the Beeston Foundry Co., Ltd., the following figures were suggested for modern sectional, cast-iron, independent boilers.

Smoke outlets (circular) for boilers up to

200	square feet	(of radiation)	capacity	5	inches	diameter
500	,,	,,	,,	6	,,	,,
1,000	,,	,,	,,	7	,,	,,
1,500	,,	,,	,,	8	,,	,,
2,500	,,	,,	,,	9	,,	,,
4,000	,,	,,	,,	12	,,	,,

In opinions which were offered after the reading of this paper the general idea was that these sizes should be considered the minimum, if they were not actually too small. It was suggested that, commencing at the 1,000 feet boiler a size larger nozzle should be adopted throughout. In some of the latest makes of boilers this is being done, for while the sizes just tabulated are nearly always found sufficient, there occur instances where a poor draught makes a full-sized nozzle highly desirable, in the same way that a chimney of low height and consequent low draught-power requires to be of greater diameter (area) to perform a given duty.

The Flue Pipes which extend from the boiler to the brick chimney have to be of the same diameter as the opening of the flue nozzle. It might be thought unnecessary to say this except that more than one instance has been experienced of reducing-pieces being put on the nozzle to admit of a smaller flue pipe being used. This was evidently thought permissible or believed to be a small thing, but any experienced man knows it is sufficient to spoil the results of the whole heating installation.

Chimneys.—See Chapter XI. page 139.

Further Sundry Details relating to Boilers.—For small works, of three or four radiators, the " Star " or similar type of upright independent boiler may be used, for they are cheap, and require no brickwork fixing. This boiler, however, after choosing one of full power, holds a comparatively small bulk of fuel, and if required to keep the water hot through the night without attention, should have a fuel hopper. Makers' catalogues show these.

The saddle type of boiler is not intended to bear pressure, and should not be put to an apparatus in which the cold cistern is more than about 25 feet above the boiler. For works in which a greater water pressure will be felt, a circular, i.e. cylindrical shape of wrought-iron boiler must be used, or a cast-iron boiler of any pattern.

For horticultural work the saddle boiler, or boilers of this type, do good service, as they are fully understood by gardeners; but in all glass-house work the gardener must be consulted as to the boiler to be installed.

In horticultural work it is not uncommonly found that the boiler pit cannot be sunk to a full usual depth, owing to surface water appearing. In such cases the deepening of a pit, and then making it water-tight, is an expensive task, and sometimes barely possible. To obviate the difficulty special makes of boilers can be had, designed for "shallow-drainage" as it is called. Examples of these are given in catalogues.

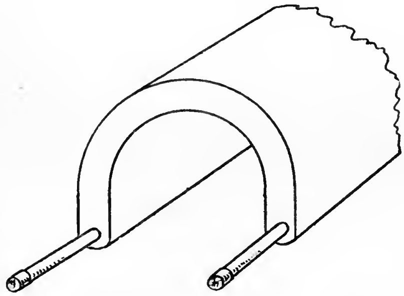
FIG. 88.—Means provided to disturb sediment in horticultural saddle boiler.

For greenhouse work on a limited scale the wall-setting type of boiler can be used with great advantage, as no pit need be made to receive the boiler (see page 101).

All boilers which are fed with water of doubtful purity—and this includes many horticultural boilers which have their water dipped from a rain-water tub, or a pond or ditch—should have mud-holes for flushing out the sedimentary dirt that must collect in the low parts of the boiler. Fig. 88 shows how these are best arranged with a brick-set boiler, the holes having pieces of 1¼-inch or 1½-inch tube screwed into them, these tubes coming through the front brickwork. A cane can then be inserted to disturb the sediment or mud, which is afterwards flushed out. The tubes, of course, have their ends capped off when the apparatus has water in it.

For heating buildings and places which are only warmed as required for use, and not every day (as churches, assembly rooms, etc.), a boiler known to have rapid heating qualities is the best to use. The saddle boiler is the reverse of this, while boilers having a large heating surface in a small compass usually fulfil the requirement successfully.

The independent boiler is, in a very general sense, preferable to a brick-set boiler, although its exterior cannot be used as heating surface.[1] Independent boilers are compact as to shape and size, take little room and require little fixing; and those now appearing in the makers' catalogues leave nothing to be desired as to effectiveness, without the need of using the exterior of the boiler as heating surface. Their first cost is certainly higher than a brick-set boiler, for a given power, but this difference is greatly reduced, if not extinguished in some cases, when the cost of fixing is compared.

What may be termed plain boilers should only be used when it is known that the draught is sluggish or will be suitably regulated. The saddle boiler is one, but a more pronounced instance is the upright cylindrical dome-top boiler, and its varieties, which are largely used. These consist of a plain upright shell, holding the fuel, with a flue nozzle at the top. Anything approaching a full draught will cause more heat units to go up the chimney than are absorbed by the water, and although such boilers may do the work they are said to do, equally with other makes, there is a strong likelihood that it will be done with an extravagant consumption of fuel. This is the ever-present doubtful feature in boilers—the fuel consumption for given results. One maker has claimed to get 92 per cent. of the heat units from the fuel into the water, while another authority considers 80 per cent. a full return. From this the percentage figures, as appear in papers read by able men, drop to 30 per cent., but in this latter extreme case it was the result of a test purposely made with fast combustion. Very little can be recommended as a remedy for this state of things except to say that a plain boiler may be chosen when the draught is poor, and a flued boiler, with full interior surface (direct and

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[1] The outsides of all independent boilers should be covered with composition to prevent loss of heat.

indirect), when it is anticipated that combustion will be effected with a good draught.

Setting Brick-set Saddle Boilers

The best known example of a brick-set boiler is the "Saddle," as Fig. 89. This is about the cheapest form of boiler we have, and it approaches nearest to what was once considered an ideal shape for a boiler, viz. a basin inverted over a fire. This ideal must be modified now, owing to the comparatively immense amount of heating surface that has to be got into a limited space; but for many purposes the saddle is still in demand, and does good service. Horticultural work takes most of them, as they are well adapted for low chimneys and a slow draught; and the average gardener or his assistant knows how to bank the fire up, and get the best results from them generally. Being of horizontal shape, they do not need a deep pit, and, in the majority of cases, surface water does not interfere with their use. This boiler will not bear pressure well, and should not be used when the pressure exceeds 25 feet head of water. This, of course, does not happen in glass-house work.

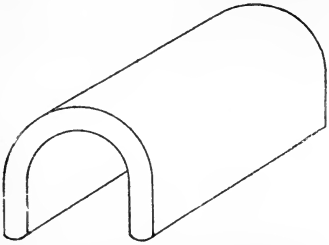

Fig. 89.—Plain Saddle Boiler.

It is a slow-heating boiler compared to the more modern designs, not that its surface shows reluctance in taking up heat, but because anything like a brisk fire leads to an excess of heat getting away without doing service. On this account it will be found that there are many purposes to which the saddle boiler is put with very poor results. Probably the heating of places of worship is the most noticeable instance. It has been a common practice, in provincial districts, to use the saddle boiler and 4-inch pipes for this work, a combination which gives the worst results in church work (see page 89). In all places where quick results—a quick response to the fire—are needed, then the saddle boiler should be avoided; but where the reverse of this applies, as in all horticultural and glass-house work, the saddle boiler does good service.

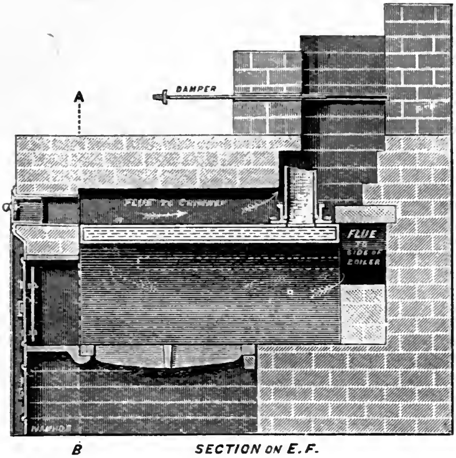

FIG. 90.—Setting of saddle boiler—Sectional elevation front to back.

The plain saddle boiler is best not put to heat more than about 800 to 1,000 feet of 4-inch pipe, as a boiler of greater length than 5 feet cannot be worked to advantage unless it is of a much more powerful character and greater fuel consumption. In large horticultural works the saddle boiler, when used, is put to heat a comparatively small quantity of pipe, the work being allotted in sets of houses, two, three or four houses (according to size) to each boiler. In such cases a large area of ground covered with glass quite bristles with low chimneys. In other cases the more powerful flued type of saddle is used, this working satisfactorily up to nearer 2,000 feet, but the writer learns that some large growers, particularly in the north of England, are using the most powerful sectional boilers, heating about 5,000 feet of 4-inch pipe from each boiler.

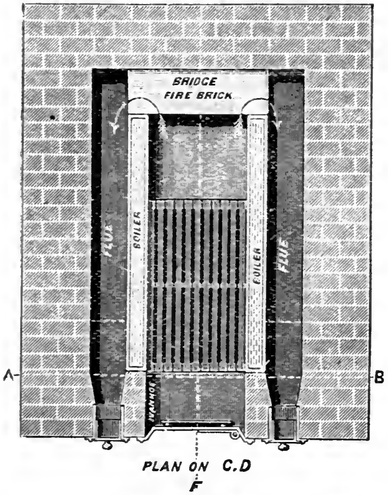

FIG. 91.—Setting of saddle boiler—Plan.

The customary method of fixing the saddle boiler can be described from Figs 90, 91, 92 and 93, the process being as follows: The brickwork base is first built up at sides and back to the level of the fire bars, the dead-plate and bearing-bar (for the fire bars) being then fixed in place. The height of this base will be according to the furnace-front (Fig. 93), it being arranged that the dead-plate comes just about level with the lower edge of the furnace door.[1] The space between the brickwork base, and which forms the ash pit, is made the same width as the interior of the boiler, and about two-thirds its length (that is the length of the bars and dead-plate combined). The boiler is then placed in position, and the pipe connections made.

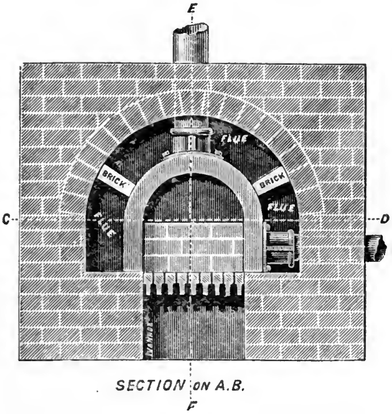

Fig. 92.—Setting of saddle boiler—Cross-section.

It will be seen that with the brickwork which follows, the boiler is arranged to come tight against that in front, while a flue space is left at each side and at the rear end. The side

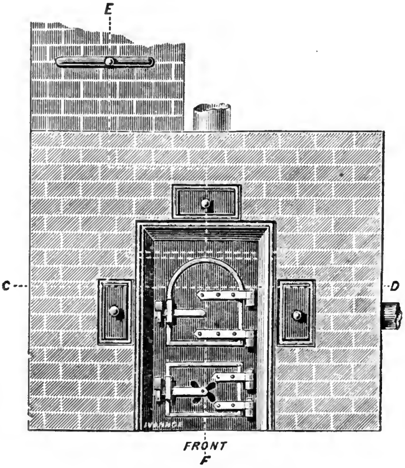

Fig. 93.—Setting of saddle boiler—Front elevation.

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[1] Instances occur in which the dead-plate is made to slope down from the furnace front to the fire bars, it being possible by this plan to save an inch or two in the depth of the boiler pit, though it reduces the height of the ash pit.

flues vary from $3\frac{1}{2}$ inches to 5 inches in width according to size of boiler, while the end flue is from 5 inches to 7 inches. The illustrations, it must be mentioned, are not to scale, and no judgment must be formed by comparing the parts or spaces shown in them.

Before throwing the arch over the boiler, to form the flue space, it may first be necessary to put in the brickwork "bridge" shown at the back of the boiler. This is usually built of fire-brick, reaching about half-way up the end of the boiler, as shown, but not so high as to come nearly level with the mid-feathers. It forms a boundary to the fire-box to prevent cinders and ashes from working into the flues, and tends to throw the flame up against the crown of the boiler. Above this another bridge has to be made, to prevent the flames taking a short cut to the chimney, instead of passing back along the horizontal flues. This will be seen in the form of a fire-brick resting on the top of the boiler (at the rear end), but more often it is a row of bricks, as Fig. 94 or 95, or occasionally a solid fire-brick lump is used, as Fig. 96. Fig. 94 is not a good plan, as the iron bar will probably fail and collapse at too early a date, and the brick arch, as Fig. 95, is more to be commended. This arch can rest on the mid-feathers, if preferred, but in this case the midfeathers should rest on at least one or more bricks gathered out from the back wall.

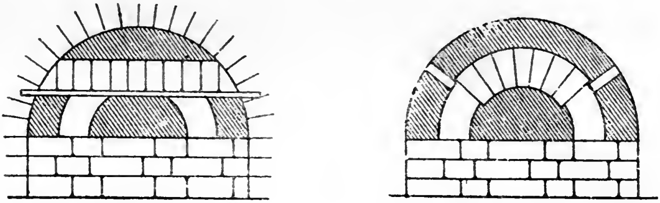

FIG. 94. FIG. 95.

Two methods of forming brick bridge at rear of saddle boiler.

Having arranged for the provision of the bridges, the arch can be thrown over the boiler, the midfeathers being provided at the points shown. There is a simple way of doing this. The brickwork can be carried up as far as the mid-feathers without difficulty, and from here it can be built on a bed of sand or ashes. The sand or ashes are strewn on top of the boiler until, when patted down, there is a thickness equal to what the flue is to be. The bricks are then laid on this, and the work completed, and after all is dry or set the sand or ashes can be raked out.

Three flue-cleaning doors are necessary, as Fig. 93 shows, and as appear in two of the other illustrations. The two lower ones come level with the bottom of the side flues, so as to facilitate scraping out all soot or dirt, and the upper one comes centrally over the boiler. This latter, however, though usual, does not admit of the soot or débris, which settles and heaps itself on the mid-feathers, being disturbed.

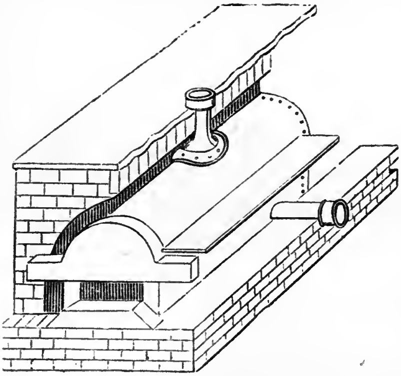
Fig. 96.—Bridge formed by shaped fire-lump.

In fixing the furnace-front, difficulty is often experienced in getting it to remain tight against the front brickwork. Ordinary cramps are not effectual for long, nor does the brickwork always remain in good condition. The only satisfactory method is to have two long rod cramps made to reach from the furnace-front to the rear end of the boiler, one on each side. Let one end (of each cramp) clip round the rear end of the boiler, while the front end comes through the furnace-front, and is threaded so as to be tightened up with a nut. They are really long bolts, nutted at one end as usual, but with hooks at the other ends where they usually have heads.

The doubt that enters into the rather elaborate fixing of a saddle boiler is whether the indirect or flue surface of these boilers is really worth the trouble. The two side flues, which first receive the heat that leaves the fire, are of some value, but the fact that only one side of these flues is heating surface reduces the usefulness of the fixing. The flue over the top of the boiler is practically useless, for surface beneath the source of heat, especially in a second flue, cannot be worth the trouble of throwing an arch over to obtain. The arch, however, is necessary to make a return for the side flues, and this brings forward the question why boiler makers have not made this type of boiler more square, as Fig. 97. With this no arch would be needed, and the fixing would be very simple. The brickwork could come tight down on top of the boiler, and the sides could be used for first and second flues by placing the mid-feather half-way up each side. These side surfaces, too, for the second flues, would have some better value than a flue across the top; and, lastly, this shape of boiler gives a greater direct surface, facing the fire, for a given length and width. It is peculiar to note that nearly all the more powerful relatives of the saddle boiler, those with internal flues, etc., are of a more square shape, and are not arranged for top flues, although external side flues are sometimes arranged for.

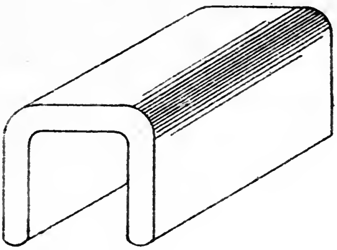

FIG. 97.

A different method that can be adopted for fixing small-sized saddle boilers is illustrated in Figs. 98 and 99. The brickwork is much the same as in the preceding example, except at the front and rear ends; and it will be seen that the boiler is raised above the level of the furnace bars three inches, by standing it on fire-bricks at its four corners. The flame and heat largely

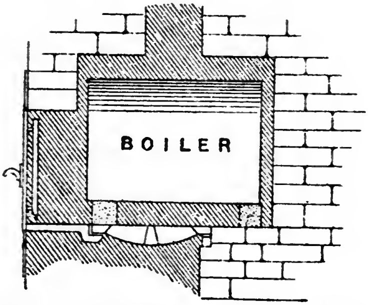

FIG. 98.—Setting of saddle boiler—Different method for small boilers; section front to back.

pass under the lower sides of the boiler, and affords an effectual degree of heat to the outer surface. The exception is when the bottom of the fire is thick with ash, but even then some heat passes. The spaces between the front and rear ends of the boiler and the brickwork there, are about 1½ inch, these spaces carrying away the products of combustion from the crown of the arch, and allowing of a sufficient draught when the lower openings are partially choked with ash. The front and rear 1½-inch flue-ways are arranged for a chimney coming centrally over the boiler, as shown. If the chimney came at the rear of the boiler the 1½-inch space there might be omitted, and a 2-inch space put in front only.

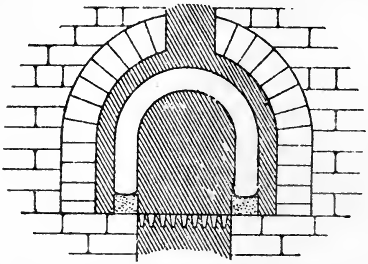

FIG. 99.—Setting of saddle boiler—Different method for small boilers; cross-section.

The writer has been told that a fault this method of fixing possesses is that it leads to the earlier destruction of the boiler if sedimentary dirt collects in it. The two lower edges, where the dirt must collect, come in the very hottest part of the fire, and it is well known that whenever there is a deposit of earthy mud in a boiler at such a point, the plate must become burnt, perished and fractured. It is not that the sediment does this of itself; it is that the deposit separates the plate from the water, and the plate, which then loses the cooling influence of the water, is injured in the same way as it would be if the boiler had no water in it at all. Wrought iron is ill able to bear the heat and effects of a fire, if it does not have water in close contact on the other side of it. Cast iron is much more serviceable in this respect, this being the reason that wrought-iron boilers have cast-iron fire-bars and furnace fittings. The point in this case, however, is not as bad as it may sound, if ordinary care is used. The care to be exercised is to use only clean water, or to clean the boiler at regular periods.

GAS-HEATED BOILERS

Since the last edition of this book was prepared the gas-heated boiler, as a practical means of heating the water in a hot-water apparatus, has become quite widely known and used.

At present the gas-boilers regularly made are not to be had in large size or high power, and there seems little likelihood of large sizes being made as it is found that a battery of moderate-sized heaters of this kind offers certain advantages which one large boiler would not possess. Perhaps the chief advantage of the battery is that—gas boilers having no dampers to regulate heat and combustion—the number of boilers put to use can be arranged exactly according to the weather or conditions. When first heating up, or in very severe weather, all the boilers have the gas lighted beneath them, while at other times the number of boilers actually heating is arranged to suit the day or hour. Very precise results are obtained this way, besides which the gas is economized more positively than by regulating the gas tap of one large boiler.

At present the largest boiler made and used in any numbers has a burner consuming 80 cubic feet of gas per hour when full on. These boilers have a high efficiency (nearly always over 80 per cent.) so that if the gas has 500 B.Th.U. per cubic foot then 400 B.Th.U. will be put into the water for each foot of gas burned or 32,000 B.Th.U. per hour from the 80 feet burner. Reference to the table of heat-emissions, page 147, will show that a cubic foot of gas (400 B.Th.U. into the water) will serve rather over 2½ square feet of radiator surface for one hour, or equivalent of pipe surface, etc.

It will thus be seen that with gas at 2*s*. 6*d*. per 1,000 cubic feet, a little more than 2,500 square feet of radiation can be served in coldest weather for 30*d*. per hour, or say 3,500 square feet for this sum as the average cost for mixed winter weather. This is 117 square feet of radiation served for 1*d*. per hour, which is about four times as much as coke fuel costs.

It has to be, and always is, frankly acknowledged by makers of gas boilers that for continuous day and night duty gas as a fuel costs more than coke. Yet there are numbers of instances, also certain trades or callings, in which a coke boiler simply cannot be used and the quantity of gas boilers being sent out is, to the writer's certain knowledge, quite large.

Although sounding contradictory it has to be stated that the gas boiler for quite small duties is not uneconomical in any noticeable degree, while it has at least one striking advantage compared to the very small coke boiler. For the pipes in amateurs' greenhouses, for a radiator in a garage and such duties as these, the gas boiler is becoming almost universally employed. A coke boiler for such places is commonly a source of annoyance, and, more particularly, the very small coke boiler is usually uncertain as to having its fire keep alight all night.

These boilers can be supplied with cast-iron enclosures, called "hutches," when the boilers have to be out of doors, these enclosures being quite storm and weather proof, allowing of the boiler doing its duty normally with the gas burning steadily, regardless of the weather and without a chimney.

It may be mentioned that gas boilers are used in literally enormous numbers for domestic hot water tap supply, and the cost of the gas for the duty performed is quite low. This is an intermittent duty, the demand for hot water at taps not occurring every minute, or even every hour of the day, and then a thermostat can be relied on to shut down the gas at all idle times.

CHAPTER XVII

RADIATORS, CAST PIPES AND FITTINGS, PIPE JOINTS, VALVES AND ACCESSORIES, ETC.

It may be best to commence the subject of radiators by describing how they differ from pipe-coils or runs of pipe in general advantages and effects.

The Cast-Iron Hot-Water Pipe.—It can be said in favour of the cast pipe, as radiating surface, that it still excels for horticultural requirements. It must afford a more uniform warmth to a glass-house than a radiator would, while it is cheap, easily run by comparatively inexperienced men,[1] and, rather importantly, the 4-inch cast pipe holds a fairly large quantity of water. Bulk of water has the advantage that it does not quickly show variations in the stoking, or the state of the fire, especially the night fire, and so ensures more uniformity in heat emission than any radiating surface holding less water would do. The gardener, or grower, too, knows his heat requirement better in pipe than in radiators ; that is he knows how many rows of pipe in a certain size or character of house will bring his plants or fruit to maturity at the time he wants them. Lastly the straight runs of large pipe ensure a swift circulation with hot returns even though the whole is only just above the level of the boiler.

Where the cast pipe, used as radiation, shows particularly bad qualities is when run in trenches—with gratings over—for warming places of worship and some other public buildings. Pipes in trenches have a reduced heat emission, but a

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[1] Market growers usually have the piping work done by their own men—gardeners, not engineers—who know just where to run the pipes to suit the purpose the glass-house is being put to.

worse feature is that they get loaded with dust and débris, which has the same effect as coating them with a certain amount of non-conducting material. Their efficiency is then reduced to a great extent, possibly to one half that of exposed clean pipes. It has been said that the attendants should keep the pipes clean, but this is scarcely practicable as it may involve lifting a ton or more of gratings and then causing a degree of dust-disturbance sufficient to make trouble. A further fault is that the large bulk of water held by cast pipes, while being a distinct advantage in horticultural buildings, makes it necessary to light the fire (in places not continuously warmed) so long before the place reaches a desirable temperature.

Pipe-Coils, which were once used for the purposes that radiators now fill, were originally a number of rows of horizontal cast pipes, the ends being joined up by syphons (return-bends or syphon-ends) so that the whole of the pipe was one endless run, or, as the name implied, a coil of pipe. Later on the pipe-coil was made up of two upright box-ends between which a number of horizontal pipes extended, either in a single row, as Fig. 100, or in double or triple lines. This detail would be governed by the surface required or the size or shape of the space provided for the coil. The first fault possessed by the coil as compared to the radiator is its size for a given area of surface or effectiveness. A coil as illustrated, to contain 50 feet of surface, would require to be about 7 feet long if the pipes were 4 inches ; while, if 2-inch pipes were used, there would require to be nearly double the number of pipes. The height would be about 40 inches ; projection 7 inches. A radiator 30 inches long, 38 inches high and 7 inches projection has the same surface. Another fault is the appearance. Coils are so unsightly that in almost all exposed positions they have to be covered with a coil-case, and this introduces several faults of quite new kinds. Firstly, there is the expense—for coil-cases are not cheap—the greater space occupied, the impossibility of cleaning the coil (for the parts of the case are *bolted* together), and the reduced heat diffusion occasioned by boxing the coil up. The horizontal pipes of the coil lend themselves to the collection of dust and floating matter, and on taking down coil-cases the coils are commonly found loaded with dirt in a peculiarly matted state. Practically all the materials of which this dirt is composed are poor conductors of heat—hair, cotton, wool, fibre, grit, etc.—and this is quite equivalent to wrapping the pipes in felt or cloth. Finally, the constant heating of this débris cannot be approved from a hygienic point of view, and it is possible, with enclosed coils, after a time, to have a faintly ill-smelling air rising from them.[1]

In stating the faulty qualities possessed by coils of horizontal pipes as compared with radiators, the improvement effected by the introduction of the latter will be seen. A further advantage the radiator has been made to possess is in the area of its tubes. They are never round, and directly a more flattened form is used the area, which means the quantity of water held, is lessened without lessening the external surface.

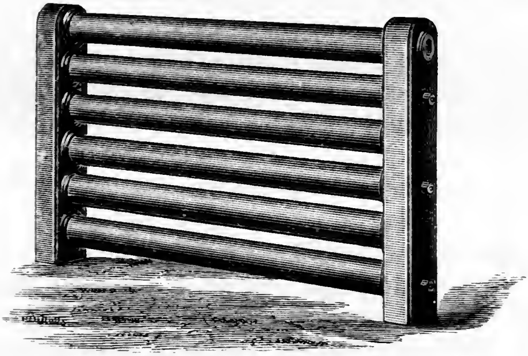

FIG. 100.—Pipe coil with box-ends.

The Water Contents of Radiators.—For a given surface a round tube holds more water than a tube of any other section, and although a large bulk of water is an advantage in horticultural heating, as already stated, it has no good features in heating brick buildings. A 4-inch pipe holds

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[1] These remarks apply to practically the same extent with pipes in trenches.

approximately two quarts per square foot of surface, a 2-inch pipe about one quart per square foot, while the best quantity for radiators is considered to average 1½ pint to 1¾ pint per square foot of surface. With this smaller quantity of water, more rapid results are obtained in heating the surface, the reason being that the bulk of water in the apparatus is less, and can be heated up more rapidly than a larger quantity. On the other hand, the larger the surface compared to the bulk of water the quicker the water must be cooled, but the average bulk-for-surface just given does not allow of the cooling being so rapid as to be a fault. To the best of the writer's belief the minimum in existence is 1 pint per foot, but this might be considered an extreme for satisfactory results; and in departing from the 1½ pint to 1¾ pint per foot standard it would be decidedly better to increase the quantity of water a little rather than decrease it.[1]

The Appearance of Radiators.—A few words may be said in regard to the appearance of radiators. In factories, business places and the like, a plain or severe looking radiator is always used; while in hospitals and institutions of the kind the plainest possible radiators are intentionally employed to facilitate cleaning, and offer no collecting places for dust or micro-organisms. In such places appearances count for little; but in places of entertainment, in shops, and particularly in our homes, it would be supposed that an ornamental radiator would be in demand. The fact is, however, that the ornamental designs as yet on the market do not appeal much to public taste, and in some of the most beautifully finished and furnished rooms imaginable the owners have preferred the quite plain radiator finished in white enamel. It is not that the ornamental radiator is not wanted, but that the ornamental kinds now produced do not quite meet the want. Something very much handsomer, and probably more expensive, is needed for good rooms,

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[1] If radiator tubes are clustered at all closely, they lose heat less rapidly, and the smaller bulk of water would then cool less quickly; but these tubes never should be clustered, if best results are desired, owing to the fact just stated that they do not so freely part with their heat, either to the air or by radiation.

otherwise the plain radiator, perfectly enamelled to give a porcelain effect, is thought as good as anything that can be obtained.

There can be no doubt that the radiator in all its forms has stimulated residence heating, and possibly the latter has stimulated the radiator manufacturer to make nice designs ; but better can be done yet, although much good has already been effected. The possibilities in the direction of making radiators of beautiful design are considerable, for there is nothing to prevent their being made a handsome adjunct to the furnishing of a room.

What we now have in the way of radiators is, however, something to be thankful for. Without doubt the very existence of the radiator has increased the business of the heating engineer enormously, and it only needs a moment's thought to show what a state the trade would be in if we had to revert to cast pipes and pipe-coils again.

Decorating Radiators.—Where a decorative radiator is required, the heating engineer should see that its appearance and general good effect are kept up, or improved, and not spoiled. The spoiling, when it is done, is in the painting. Broadly speaking, decorative radiators should be coloured in *light tints, as light as possible,* or in white. The latter is the writer's favourite paint, either matt or enamel, or one picked out with the other. On no account should the fitter's favourite colour, purple-brown, be used, nor deep green nor any sombre colour. Although this subject can only be given a brief paragraph, for it is of no use repeating the advice, it is a really important matter, having a strong bearing on the approval and progress of the work. It must be remembered, that, except in buildings devoted to work, or in institutions, a lady's likes or dislikes have to be fully considered, and only dainty schemes of decoration will be approved. If talent is expended in the designs and handsome appearance of fireplaces, joinery work and wall decorations, why not on radiators ? Failing this, the radiator may be a dull or ugly spot amidst handsome surroundings.

Jointing Radiator Sections.—Radiator sections are now jointed by nipples, but these are of two kinds. The rubber joint or the composition collar no longer has any existence in this work, for they were considered liable to perish and give trouble.[1] The push or taper nipple, as Fig. 101, and the screw nipple, as Fig. 102, are used, and although the exclusive user of one has arguments against the other, there are large firms which use both. The push-nipple was originally a piece of thin tube, a part of the completed radiator which proved a weakness by its rusting away too soon, but since then it has been found possible to use a heavier cast malleable nipple with success. This nipple is turned slightly taper each end so that when placed in the corresponding holes in the radiator sections, and the sections are drawn tightly together, a sound metal-to-metal joint results. The screw-nipple is tapped with a right-hand thread at one end and a left-hand thread at the other, so that when the ends are started in the radiator sections, and screwing up is commenced, the sections are drawn towards one another. The screwing up is done by a flat tool inserted inside the nipple, and engaging against the studs inside it. A wrench or tee head is put on the other end of this tool by which to turn it.

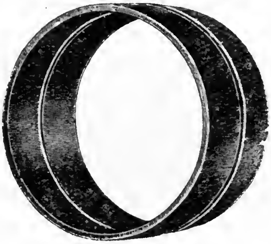

FIG. 101.

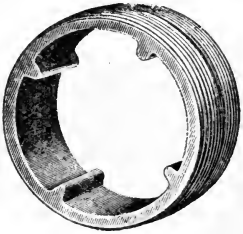

FIG. 102.

Jointing Radiator sections: Push nipple and screw nipple.

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[1] The writer put 72 rubber-jointed radiators into some large business premises about eighteen years ago, just before the nipple-jointed radiator was introduced, and up to this moment not a single joint has given trouble. The nipple joint is best, however.

In either case it is possible for a fitter on the job to take out or insert a section in a radiator ; or a faulty section, if one is unsound, can be as easily replaced. The radiators having push-nipple connections have bolts through from end to end to hold the sections tightly together ; this is not necessary when screw-nipples are used. The nipples are usually of cast malleable iron, this being found more lasting than wrought iron, particularly when the radiators are used for steam, and condense-water has contact with the nipples.

Those who use the screw-nipple exclusively consider it superior to the push-nipple, but the reason is not at all obvious. It will be found that the majority of cast sectional boilers are jointed with push-nipples, and if suited for this purpose they are surely suited for radiators. The only fault the writer had to find was that the push-nipple was rather light, but this has been remedied.

Space between Sections of Radiators.—The nipple-jointed sectional radiator was originally made with the sections closer together than is the rule at the present time. They measured 2½ inches from centre to centre, whereas the general rule now is to have them 3 inches. This gives an additional half-inch space between sections which has been found to admit of more successful heat emission. What are known as Hospital-radiators have a greater space, but this is provided for convenience of cleaning, not to secure greater heat emission, although the latter is doubtless experienced. Unfortunately when the space is increased the appearance suffers and there is a probability of 3 inch centres being the maximum for general requirements.

Makes and Designs of Radiators.—In previous issues the writer has devoted several pages to illustrating the different makes and designs of radiators obtainable, but it is now felt that, with the common knowledge every fitter has of these goods, the pages look too much like a trade catalogue. Needless to say the makers' catalogues illustrate and describe all kinds most fully; and as catalogues are gladly supplied gratis a set of them should be in every engineer's or fitter's possession for reference.

Valves.—One of the most useful radiator fittings we have is (when the circulating pipes are beneath the radiator) the Angle Valve, which is shown in Figs. 103 and 104. Previous to the introduction of this the straight valve had to be used, and made a comparatively unsightly piece of work at this end of the radiator. By means of the angle valve, no pipe or pipe-fittings need be visible above the floor, and the general appearance, on the floor where the radiator is, leaves nothing to be desired. Fig. 35, page 70, will give an idea of this. The valve has an ebonized wood wheel-head, and the body can be had in polished gun-metal or nickel-plated. The second of the two valves illustrated is described as "with union," the union being the radiator connection. The majority of engineers never use this valve without the union (together with a union-elbow, see page 212), for, as explained on page 59, it is quite the common thing to have to remove the radiators for the convenience of decorators or other tradesmen, apart from the possibility of disconnection being required by reason of a leak or for the engineer's own purposes. The small extra expense for the union is a profitable outlay as a rule, and it simplifies the work to some

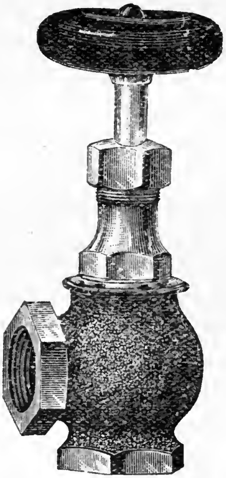
FIG. 103.

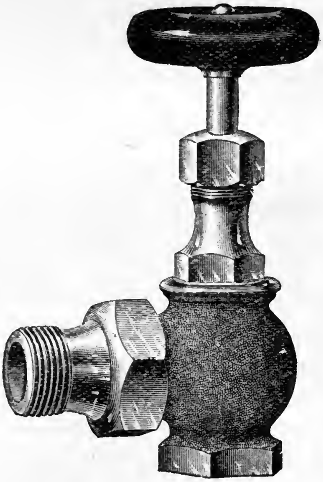
FIG. 104.

extent. This valve, in its angle form, has a nearly full way through it.[1]

Fig. 105 illustrates another valve, one of more modern make and having the advantage of being quick-opening and closing. It is not a screw-down, a centre plug being turned by the crank handle, much the same as the plug in an old-fashioned plug-cock is turned. This inner plug is open at the bottom, so that the water comes up through it, and then passes to the radiator by way of an opening in the side of the plug. It is an angle plug-cock in fact, but has a full way. The indicator shows at a glance how far the valve is open. See also page 98.

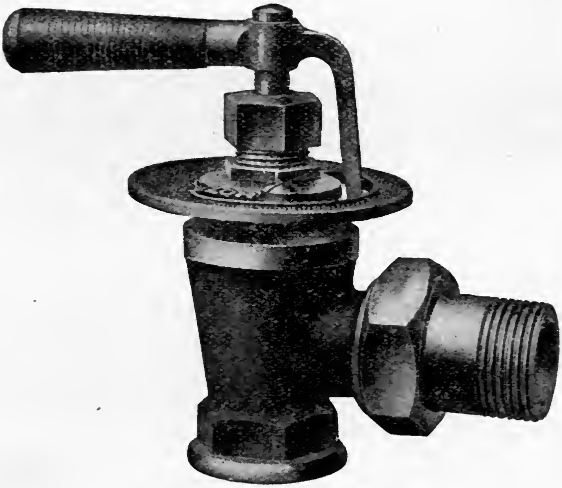

FIG. 105.

The valve first described, Figs. 103 and 104 is of the screw-down kind, and to open it full, or close it, takes quite twenty

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[1] It will be found mentioned more than once, that for, say, a 1-inch valve to have only a $\frac{3}{4}$-inch or $\frac{5}{8}$-inch way through it is unreasonable. If a 1-inch service is required for any purpose, why choke it with a valve which is quite foreign to a 1-inch measurement except at the tapping—the screwed part? If a valve is described by a certain size, then its way—the passage through it—should be equal to the area of the pipe to which it is attached; otherwise, it is much like paying, say, a 1-inch price for a $\frac{3}{4}$-inch article, so far as results are concerned.

hand turns. (The hand turns the wheel-head about one-fourth to one-third of a complete revolution with each movement.) This is often found to be something of an annoyance, and the quick-opening (and closing) valve has been introduced to overcome it. It was this fault, the many turns of the handle to open or close and the difficulty of knowing how far open or closed the valve might be when partially turned on, that caused the writer to introduce his improved valve described on page 59 and again illustrated here,[1] Fig. 106. This valve opens or closes with one turn and has the marked advantage of being at the top of the radiator, so as to be used without stooping. No external or visible pipe is needed to the valve as the first section of the radiator is made to serve this purpose and the pipe connections can be at the bottom in the usual way, or be made invisible as Fig. 28 page 59 shows.

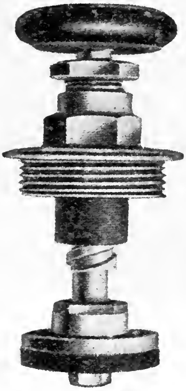

FIG. 106.

A near relation to the angle valve is the Corner valve illustrated at Fig. 107. This is of service when a pipe is brought through the wall against which the radiator stands, and in a line with the radiator connection. An ordinary angle valve could be used, but it would require to be fixed on its side, or horizontally, as it is called, with the stem of the wheel-head in a line with the floor, instead of being upright. The corner valve fills the purpose with an upright stem, and the wheel-head in its proper place, but it must be explained that in most cases it is without the full-way and clear air-way which the angle valve has. If reference is made to Fig. 109 it will be seen that the corner valve is in reality a globe valve,

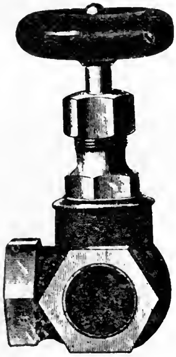

FIG. 107.

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[1] Made by The Beeston Foundry Co., Ltd., Beeston, Nottingham.

but with one opening at right angles to the other, and it can possess all the faults that the globe valve has. What, therefore, has to be ordered when corner valves are required, is that they have a full-way, and that their internal construction does not admit of air being locked in. The writer knows that a full-way corner valve is made, but has not yet seen one quite free from the air-lockage fault.

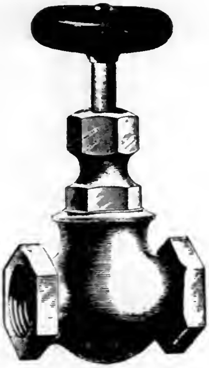

FIG. 108.

The screw-down Globe Valve has an external appearance as Fig. 108, while its water-way is indicated by Fig. 109. A fault the writer referred to in the footnote to page 133 is always present in this valve, and it is commonly found that the water-ways are contracted to about one-half the area of the pipe the valve is attached to. Added to this the way is very crooked, and the total result in this respect is as bad as it can be. This by itself would be sufficient to condemn the valve for most purposes, but there is another fault, this being the certainty of air being locked in on one side or the other, if the valve is fixed in a pipe which runs horizontally. This latter difficulty can be overcome by fixing the valve on its side, but although this may prevent air being locked in, it does not straighten the water-way nor increase its area.

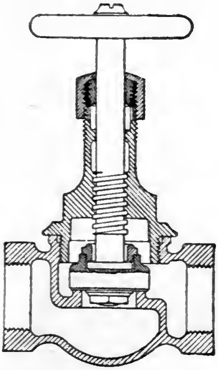

FIG. 109.—Screw-down Globe or compression valve (not recommended).

The Peet's pattern or the Gate Valve should always be used in straight runs of hot-water pipes, whether mains or branches, horizontal or vertical. The interior of one such valve is illustrated in Fig. 110. Not all valves of this type are constructed exactly as shown, but the working principle remains the same, this being to raise or lower one or a pair of discs, the gate as it is termed, which, when raised, leaves a straight clear way through the valve of a size quite equal to the bore of the pipe the valve is attached to.

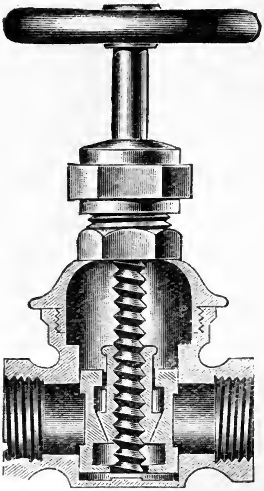

FIG. 110.—Type of Gate or fullway valve.

Lock-Shield Valves.—All the valves just described pages 208–212, can be had with what are termed "lock-shields," a means of using the valve with a loose key or handle, as is sometimes necessary in institutions and public places.

The Union Elbow.—A fitting which, as a radiator connection, is about as useful as the angle valve, is the Union-Elbow, illustrated at Fig. 111. The purpose of this is to admit of the end of the radiator which comes opposite to the valve, being connected up with the least visible amount of pipe, and having as good an appearance as the valve end. Fig. 35, page 70, shows this, and as the elbow is made of gun-metal, and can be had polished or nickel-plated, the general effect is very good. When speaking of the advantage of having a union to the valve to allow of easy disconnection, it will be understood that a union at the other end of the radiator is equally necessary, and this elbow provides it.

Air-Cocks.—A radiator usually requires an Air-Cock, and Fig. 112 shows two of these. These are not the only designs made, but they represent those most generally in use. The one with a wheel-head matches the angle-valve, as the head is of black wood; the body is nickel-plated. The other valve has a similar body, but the key is loose, which makes it better suited for shops, public places, schools, children's nurseries, etc.

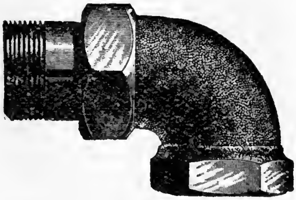

FIG. 111.—Union Elbow.

Automatic Air-Valves, for hot-water work, have not been in demand to any great extent in the past, a possible reason being their high price, compared to that of an air-cock, while, in ordinary circumstances, they are scarcely needed. Once a hot water installation is charged up and heated in the autumn and the air then discharged by the cocks, there is little attention needed to discharge air afterwards.

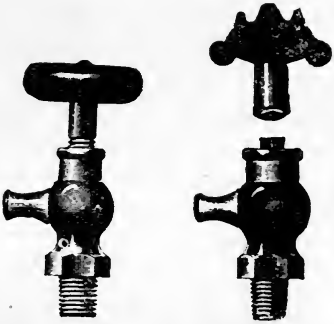

FIG. 112.—Air-cocks with wheel head and with loose key.

Safety Valves.—A fitting which must be put on *every boiler*, or on a flow pipe near the boiler, is a Safety-Valve. A table of sizes best suited for apparatus of various extent is given on page 52, and it is only necessary to describe the valves here.

The least expensive safety valve for general use—and there need be no hesitation in using it—is the weighted lever valve as Fig. 113. This might be likened to the angle radiator valve, described on page 208, only that the seating is held down by a weighted lever, instead of being screwed down. The screwed outlet to this safety-valve is to admit of a pipe being connected to carry away any water that might issue, should the valve come into operation. This pipe need not be fitted, however, nor is it always recommended, as these valves very rarely come into operation; and when they do, it should be plainly seen and promptly attended to. It is different when the valve is

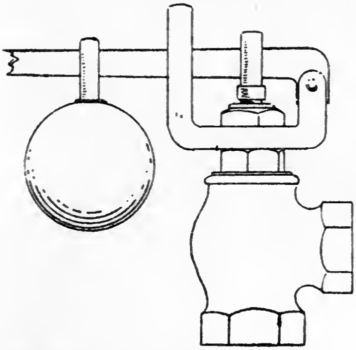

FIG. 113.—Safety-valve. Weighted-lever kind.

put upon a steam boiler, as it may be blowing-off quite frequently, and the issuing steam can make the boiler-house unbearable, if it happens to be a small one; a pipe is then used to discharge the steam outside.

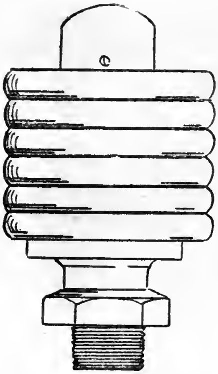

FIG. 114. — Safety-valve. Dead-weight kind.

Figs. 114 and 115 illustrate the dead-weight type of safety-valve. This valve is adjusted to bear different pressures, or heads of water, by removing, or adding to, the ring weights shown. The interior construction of the valve differs in some makes, but the one illustrated is considered reliable and sensitive. It has what is termed a knife-edge seating, this being obtained by a spherical upper piece resting in the end of a tube, as shown. It follows that a ball, very accurately turned, resting in an annular opening, also accurately turned, will make a water-tight joint, yet where the two surfaces meet, the contact is little more than a knife edge. It is a very sensitive valve, as will be understood, and if by long disuse the parts " grow " together (get stuck together) it requires but a very little force to separate them. A trifling fault, if it can be called such, that this valve possesses, is that its seating can be so readily injured. The finest particle of grit, or a scratch, will usually lead to leakage, but the likelihood of this happening can be lessened, if not obviated, by putting the valve in a less conspicuous place than usual, where it will not get knocked or played with.

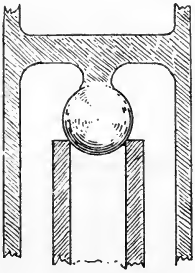

FIG. 115.—" Knife-edge " seating of dead-weight safety valve.

Thermometers.—Fig. 116 illustrates a hot-water thermometer, specially designed for use in a heating apparatus. This screws into the outlet of a tee, and the projecting hollow stem at the bottom comes into the full current of the water in the pipe the tee forms part of. As illustrated, the thermometer is suited for a tee with the outlet looking upwards, and this would be in a horizontal pipe. For vertical pipes the bottom stem of the thermometer is at right angles, so as to screw into a tee with horizontal outlet. The ingenious detail of this thermometer lies in the bottom stem. This is easily removed, and is found to be a short length of very thin tube, closed at the bottom, and quite half-full of mercury, and is spoken of as the mercury bath. This stem comes away at the joint just where the arrow points (being usually held by a small set-screw), so that it can be inserted into the tee, and made sound before the thermometer itself is fixed. When the stem is away the thermometer is found to have a bulb of mercury at the bottom of its tube, the same as ordinary thermometers have, only that the bulb is a little more than an inch below the bottom. This makes the bulb dip deeply into the mercury bath when the thermometer is in position, and thus a mercurial contact, and a correct transference of heat, is obtained between the water and the bulb.

FIG. 116. — Thermometer for hot-water circulating pipes.

The object of the hollow stem is to admit of the thermometer being repaired, a new glass tube put in if necessary, without emptying the apparatus of water, and it also prevents leakage in case the thermometer is broken. The bulb of the thermometer might go direct down into the water, without using the hollow stem and its bath of mercury, but as a thermometer tube is a fragile thing, the mercury-bath has been devised to admit of breakage occurring without leakage or even inconvenience. It will be understood that it would not do to let the bulb come down into the hollow stem without the latter containing mercury. If the stem was empty, that is, containing air only, the thermometer could not register the temperature of the water correctly. The loose mercury in the stem makes a perfect metallic contact between the water and the bulb, and the results obtained are the same as if the bulb rested in the water.

Temperature Regulation.—The writer seldom erects a hot-water heating apparatus without a thermometer, and sometimes uses two or more on the same installation. It can be made to nearly approach an automatic regulating device, for in any case it automatically indicates the temperature of the water, and the attendant can by this means keep a proper degree of warmth in a building without going inside it, or having anything to directly indicate what the temperature is there. The plan adopted is, after having the apparatus in regular use a few days, to write out on a card what the heat of the water is to be, according to the outdoor temperature. Three of the lines from the card hanging in the writer's boiler-house read thus :

When the outdoor temperature is :	Keep. the flow pipe thermometer at :
32°	165°
38°	145°
45°	130°

The attendant, a youth, has a thermometer hanging conveniently outside the boiler-house, and there is a thermometer in the chief flow main, facing him, as he stokes the fire, and although he never enters the warmed part of the house, it is exceptional that he has to be told to increase or decrease the heat. He tends the fire and keeps the indoor thermometers within about one degree of the warmth wanted without seeing them or being told. In one instance, where two hot-water thermometers were used, one was at the boiler, while one was on a main flow pipe that passed near the manager's room (in large club), and this enabled the manager to see if the stoker was attending to his boilers carefully, and keeping the water temperature according to the card. Failing some such arrangement as this, it is to be wondered at how a proper warmth is obtained and kept. The stoker cannot be running into the rooms to ascertain how they feel, nor can he have messages sent to him continually. If he is skilled he can doubtless guess it cleverly, but taking heating works for all purposes, how many are tended by clever stokers ?

Water-level Indicator.—Fig. 117 illustrates an appliance that serves a useful purpose, and helps to make the boiler look business-like. It is an Altitude Gauge, its purpose being to indicate head of water, though it will indicate any increase or decrease of pressure in the boiler, whatever the cause. The figures represent the head of water in feet, and the hand or indicator extending across the dial is the one that moves with any alteration in pressure. The shorter spear-pointed hand is coloured red, and is stationary except when moved by the fingers. Supposing an apparatus, when filled and in use, indicates a head of water of 25 feet. The ringed pointer would point there, and the red hand would be moved by the fingers until it came beneath the other, and only showed a disc of red through the hole above it. This would be the normal state of the gauge ; and only upon an abnormal pressure, high or low, being felt would the red hand be exposed, and it would then be considered as a danger signal indicating something wrong. It will be understood that this gauge will indicate a reduced pressure due to loss of head of water, a thing that is not so quickly discovered in the ordinary way.

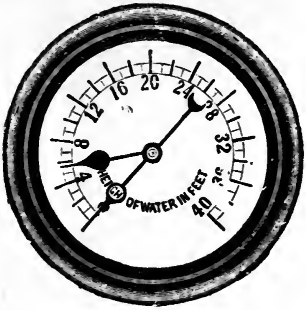

Fig. 117.—Altitude Gauge, or Water-level Indicator.

Automatic Damper-Control.—While an automatic damper-regulator, which controls fuel consumption and the general work performed by the boiler, is considered essential with all low pressure *steam* boilers, the use of such an appliance with hot-water boilers is more exceptional. With the former there is, of course, steam pressure which can be utilized as the controlling force, while with the latter the heat of the water has to be relied on, and this a variable factor as the temperature (of the water) has to be varied with the weather. As will be seen in a following paragraph, the most effectual control is obtained by a thermostat which governs the work of the boiler by the temperature of the air of the room or house.

On occasions where there is an excessive draught at all times an automatic control or means of limiting the draught is an advantage regardless of weather changes, but there is also a means of regulation to suit all weathers if the attendant will do what is needed. Fig. 118 shows the National Radiation Company's "Sylphon" damper regulator with which, by shifting the counterpoise weight, any desired change of temperature can be maintained. This regulator has for its active force a sensitive metallic bellows charged with a volatile liquid which evaporates at a proper temperature, the vapour, acting like steam would do, exerting force on the operative parts.

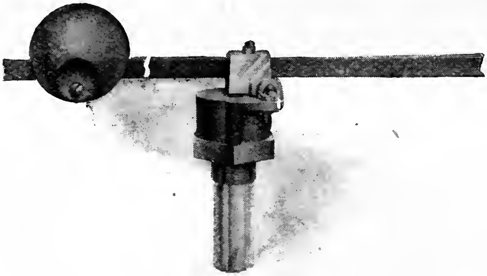

FIG. 118.—Automatic Damper-regulator.

Automatic Temperature Control.—The ideal means of controlling the work of a boiler is that of utilizing the air temperature of the house to do it. When the house is at a comfortable warmth this warmth is employed to govern the fire so that the temperature is maintained with more or less exactness. In saying that the warmth of the house is utilized, this has to be qualified by explaining that no arrangement can be suggested for all rooms in a building to control the boiler at once, consequently one room or point is chosen as representing the general requirements of the building, or representing the normal or average warmth of all rooms, and the control is effected from this point. This is spoken of and understood as automatically controlling the warmth of the building, which is correct in a broad sense, but it would be almost more correct to say that when the air of the place has reached a certain temperature it commences to control the fire and this, in turn, keeps the air temperature from rising beyond the desired warmth. Briefly, the air by its warmth causes an appliance to act which prevents the warmth becoming much greater. It does not prevent the fire going down and the warmth then decreasing if fuel is not put on in time and proper quantity.

Fig. 119 illustrates the National Radiator Company's "Ideal Sylphon Regitherm." The active part consists of a metallic bellows chamber containing a volatile liquid, this being of a sensitive character, so that a change of temperature to the air surrounding the bellows of only one degree will bring the parts into action. The area of the head of the bellows is 30 inches and a rise in temperature of one degree will cause a force of 15 lbs. to be felt inside, this expanding the bellows by half an inch. When this or any expansion occurs the force is exerted on a short lever arm which is connected by a wire cord with a balanced lever on the boiler. As the lever arm rises or falls, therefore, the lever on the boiler is made to operate the dampers which, needless to say, control combustion and the heating of the water accordingly.

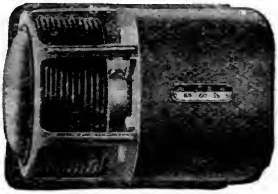

FIG. 119.—Automatic Temperature-regulator.

As already stated the foregoing type of automatic temperature-control device is placed in a room or part of the building which is considered to have a normally satisfactory temperature, and the warmth of this room or part will control the boiler fire and, consequently, the warmth of all the other rooms, or parts which are served by the same boiler. It must be fixed with proper thought as to its position, as it must not, for instance, be over or near a radiator, or where the sun will shine on it; it must receive warmth from the air at its regular temperature in the room.

For the interest it may afford Fig. 120 is given to show the working operation of an American auto-controlling device. This may be described as a Damper Regulator, which may be used alone, with additional parts to make the whole an automatic Temperature Regulator. The sketch shows the parts in section and it is known as Power's Regulator and Thermostat.

To explain the damper regulating portion first, let it be supposed that the parts marked " thermostat " are absent. It will be seen that the largest piece of the complete appliance is an upright cylindrical casting with a water-way shell having a top and bottom pipe connection. This part is inserted in a flow pipe, or a branch flow circulation arranged for it. The water that passes through the shell is to be representative of that in the whole apparatus, as its heat will control the fire and the temperature everywhere. In the middle of this shell is a space containing a volatile fluid or alcohol, this being filled in by the small plug shown. This inner chamber has direct communication with the underside of a sheet rubber diaphragm, shown in the part which extends from the chamber. When the heated water circulates through the shell, it immediately heats the liquid in the inner chamber and causes it to expand. The expansion of the confined liquid causes a pressure to be exerted beneath the diaphragm, tending to lift it, and thus operates the lever above, which has direct communication with the boiler dampers.[1] The dampers, it is needless to say, require to be balanced to allow of this operation occurring with precision.

It will be seen from the foregoing that the " Regulator " portion of Fig. 120 provides for the automatic control of the dampers by the heat of the water in the flow pipe, but it makes no provision for automatically varying the heat of the water according to the warmth of the rooms or the weather. This can be done by hand, by manipulating a pointer at the end of the lever (not shown in detail) which will cause the dampers to be opened more or less, according to the position of the pointer. This, however, is not automatic, and to have

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[1] Many boilers are now provided with two dampers, one the " draught-damper " in front of the ash pit; the other, the " check-damper," in the flue nozzle. A cord or light chain extending from one to the other, passing over pulleys in the ceiling, allows of both being worked together.

the heat of the water regulated by the warmth of the house the Thermostat portion is added. The upper part of this is circular—a disc, but shown in section in this illustration (Fig. 120). The outer convex plates are stiff, but extending right across, in the centre, is a corrugated flexible division as shown (in section). On one side of this division is a small quantity of liquid that boils, and gives off a vapour (equivalent to steam), when it reaches a temperature of about 60° F.,

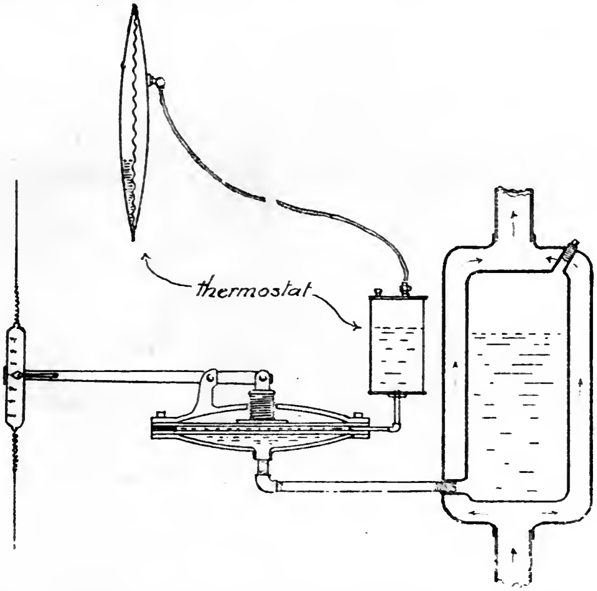


FIG. 120.—Combined Automatic Damper-regulator and Temperature-regulator.

so that when the air of a room becomes of a comfortable warmth, this liquid begins to steam. The effect of the steam is to force the flexible division over towards the other side, and this exerts a pressure on the air contained there. This air space communicates by a metal tube with the small vessel shown, this vessel containing water, and having communication with the diaphragm. It will be noticed that the diaphragm is double, that is, consisting of two sheets of rubber with a space between. This is only necessary when the thermostat is used, as the regulator needs but one. The effect of the air pressure described is to cause a pressure to be exerted on the surface of the liquid in the small upright vessel, and this pressure is transmitted to the space between the rubber diaphragms, causing the upper one to rise and operate the lever.

Provision for Expansion and Contraction of long straight runs of Main Circulating Pipes.—Fig. 121 shows a group of four Expansion Joints. When long and perfectly straight runs of pipe occur, it is usually necessary to make some provision for the expansion and contraction (lengthening and shortening), that occurs in the pipes when the water is heated or cooled. In horticultural work, where water-pressure is scarcely felt, provision is made for expansion by either a loose long-socket, packed so as to act as a stuffing-box, or by using plain rubber ring joints as explained later, but these are not possible in buildings where the pressure is always too great for such simple expedients. When cast pipe is used for mains, it is a common practice to use a rubber-jointed pipe, particulars of which are given later, and each joint, although drawn up tight, makes sufficient provision for expansion in itself. These are always known as expansion joints, but they have no relation to the joints just illustrated.

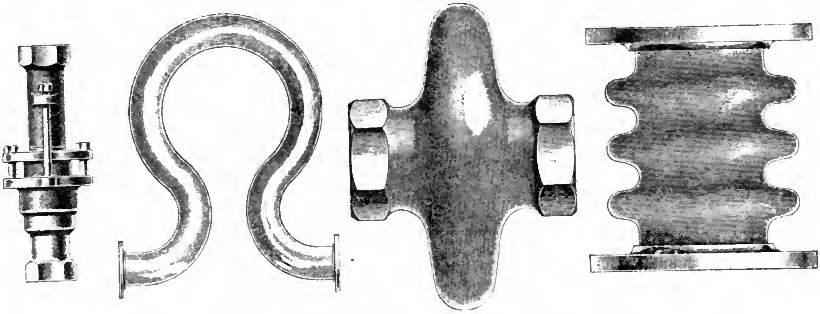


Fig. 121.—Expansion joints for long straight runs of rigidly jointed pipes.

When flanged cast pipe, or wrought pipe, or any tube having rigid joints, is used for long runs, then every effort should be made to break the direct line of the run, so as to make a natural provision for expansion; for however well a specially made expansion-joint is constructed, it is always better to do without it. In running mains along a long corridor, or culvert, for instance, it may be possible to let them cross from one side to the other every forty to fifty feet, for, as stated, it is only necessary to break the direct run to make a natural provision for expansion and contraction. Some judgment is needed in this, however, for a break of only two feet would not be sufficient for any size of pipe; in fact, it is scarcely sufficient for a 1½-inch pipe, as there is no spring in such a short break, unless the pipe is small. It might be roughly calculated, for wrought pipe, that the least break should be, for 1½-inch pipe, 36 inches; 2-inch pipe, 48 inches; 2½-inch pipe, 66 inches; 3-inch pipe, 84 inches, and so on. In case the term "break" is not quite clear Fig. 122 is given to show what is meant.

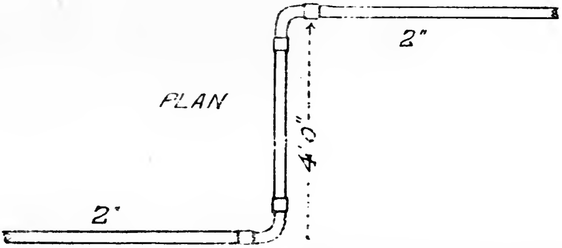


FIG. 122.—"Breaking" a straight run of pipe to provide for movement of expansion and contraction.

The expansion joints, shown in Fig. 121 are named as follows: from left to right, "stuffing-box," "loop" or "horse-shoe," "bellows" and "concertina." The first of these is made up of one tube sliding within another, both accurately turned, but relying chiefly on a stuffing-box to keep the joint water-tight. It is not liked so well as a joint without a stuffing-box, but it takes the least room of any. The loop or horse-shoe joint is liked best by most engineers, while the bellows pattern comes next in approval. Any of them can be had with screwed or flanged ends. Copper is the metal used for all except the stuffing-box joint, and this is made either wholly of gun-metal, or with an iron casing and gun-metal working parts.

To lengthen the life of copper expansion joints they should be taken out and sent to be re-annealed every five to six years.

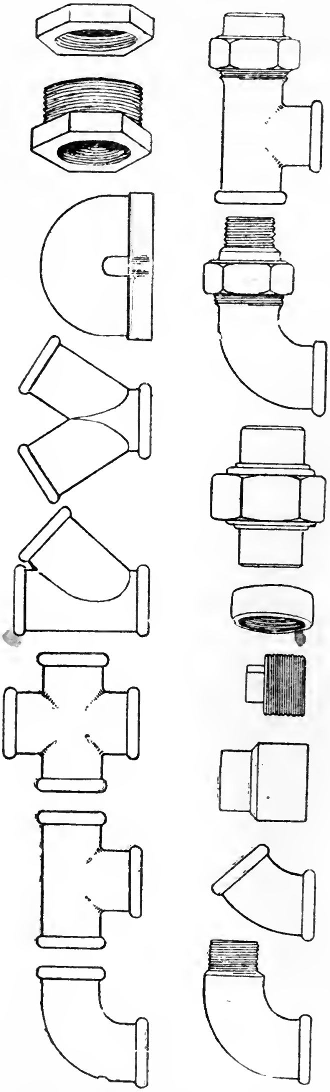
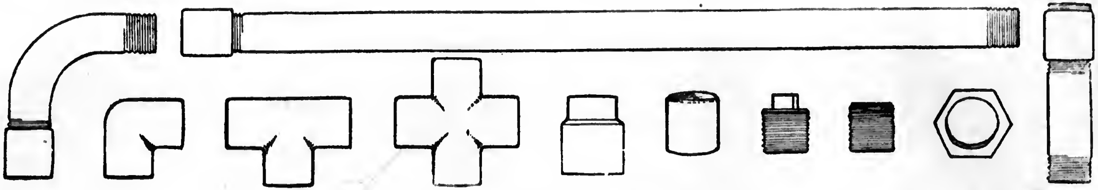


FIG. 123.—Malleable iron fittings for wrought pipe.

WROUGHT TUBE AND TUBE FITTINGS

On the next page are given some illustrations and the universal English price list of wrought-iron tube and fittings, this price list being given for convenience of reference in making up estimates. The list stands for tubes of all qualities, viz. gas tube, plain or galvanized, water-tube, plain or galvanized, and steam tube, plain or galvanised. The difference in cost is arranged by a difference in the trade discount allowed in each case.

Fig. 123 represents a group of malleable cast-iron pipe fittings, for use with wrought tube. These are of more elegant form and finish than the wrought fittings, while in certain details they excel also. The elbows are so cleanly and evenly rounded that bends (as we know them) are unnecessary.



PRICE LIST OF WROUGHT-IRON TUBES AND FITTINGS.

This is the universal list of English Manufacturers, and is subject to a trade discount.

	Nominal Internal Diameter in inches.		⅜		½		¾		1		1¼		1½		2		2½		3	
			s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
TUBES.	Tubes, 2 feet long and over	per foot	0	4	0	5	0	6½	0	9	1	1	1	4	1	10	2	9	3	3
	Pieces, 12 to 23½ inches long	each	0	10	1	1	1	4	1	10	2	6	3	4	4	9	8	0	10	0
	,, 4 to 11½ inches long	,,	0	6	0	8	0	10	1	2	1	6	2	0	3	0	5	3	6	9
	Long Screws, 12 to 23½ inches long	,,	0	11	1	2	1	5	2	0	2	8	3	7	5	3	9	0	11	6
	,, ,, 3 to 11½ inches	,,	0	7	0	9	0	11	1	3	1	8	2	3	3	3	6	3	8	0
	Barrel Nipples	,,	0	5	0	6	0	7	0	9	1	0	1	4	1	9	3	0	4	0
	Bends	,,	0	8	0	10	1	0	1	6	2	6	3	0	5	0	12	0	18	0
FITTINGS.	Elbows, Square	,,	0	9	0	10	1	0	1	4	1	10	2	5	3	10	9	0	14	0
	,, Round	,,	0	11	1	0	1	3	1	6	2	1	2	7	4	6	10	0	17	0
	Tees	,,	0	10	0	11	1	2	1	5	2	0	2	6	4	3	9	6	16	6
	Crosses	,,	1	6	1	11	2	4	3	0	4	0	4	10	7	9	21	4	40	0
	Sockets, Plain	,,	0	2	0	3	0	3½	0	4½	0	6½	0	8½	1	1	2	6	3	6
	,, Diminished	,,	0	4	0	5	0	6	0	7	0	9	0	11	1	4	3	3	5	0
	Flanges	,,	0	10	1	0	1	2	1	4	1	9	2	0	2	9	5	0	8	6
	Caps	,,	0	3½	0	5	0	6	0	8	1	0	1	3	2	0	4	4	6	0
	Plugs	,,	0	3	0	4	0	5	0	6	0	8	0	10	1	3	2	6	4	9
	Backnuts	,,	0	2	0	3	0	3½	0	5	0	6	0	8	1	1	2	3	3	6
	Nipples	,,	0	2	0	3	0	3½	0	4	0	6	0	8	1	0	2	3	3	6

The threads, too, are tapped slightly taper, so that as the pipe is screwed up it makes a good metal-to-metal joint. Again, the threads in these fittings stand up clear of the metal which is beyond the threads, so that instead of the end of a fully threaded pipe coming abruptly against solid metal at the end of the thread in the fitting, it can go on until a full thread-to-thread joint is obtained. These fittings are now stocked by several English factors, and they have a large sale, but in the past there were complaints of the castings being faulty, which was a considerable cause of annoyance, owing to the fault being undiscoverable until the apparatus was complete, charged with water and tested. There are now reliable makes and there is no doubt that the malleable cast fitting has come to stay, for it is cheap and offers distinct advantages.

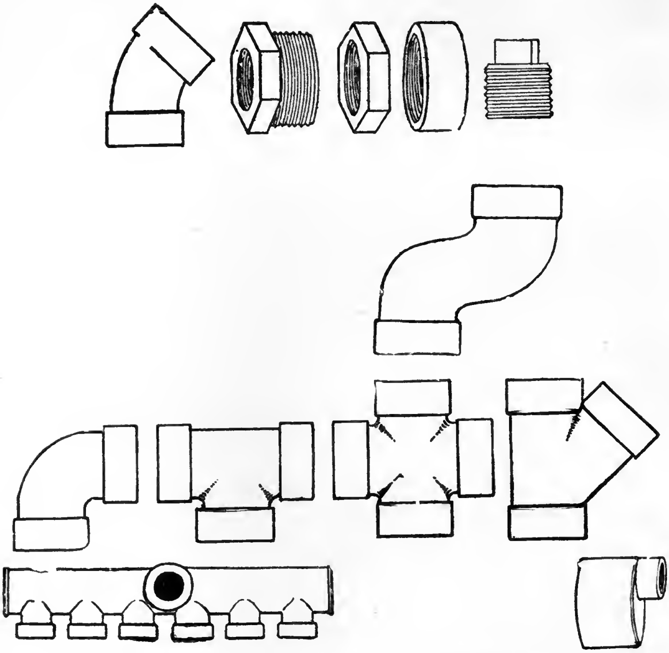


Fig. 124.—Soft cast-iron fittings for wrought pipe.

Fig. 124 is a group of soft-cast fittings. They are intended more for large wrought pipe, 2 inches upwards, and while their appearance is heavy, they possess all the good detail of design and construction that the malleable fittings have.

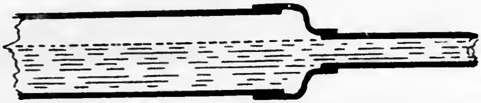


FIG. 125.—Air locked in horizontal pipe by ordinary reducing socket.

The illustrations given are by no means complete as to the variety of fittings made.

There are certain ingenious special fittings which can be referred to here. One is the reducing fittings which are made with eccentric outlets. Both reducing sockets and bushings can be had made in this way, also tees, though the latter are not always stocked. An eccentric reducing socket is shown in the group of soft cast fittings, Fig. 124, it being a reducing socket with the small opening out of centre and near the edge. To show its use let Fig. 125 illustrate a horizontal pipe reduced in its straight run with an ordinary reducing socket, while Fig. 126 shows the same pipe with an eccentric reducing socket. In the former air is locked along the top of the pipe; while in the latter the upper line of the pipes is level and unbroken.

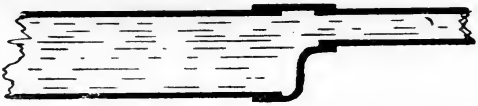


FIG. 126.—Air collection prevented by the use of eccentric reducing fittings.

Another special fitting is the tongued or diverting tee, shown in section by Fig. 127. This is intended to divert a portion of the flowing water from a main into a branch service, one that otherwise might be passed or neglected. Considerable care has to be exercised

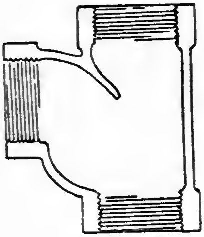


FIG. 127.—Tongued tee (section).

in the use of these fittings, or they may divert the water too successfully, and it is only in rare cases that a more normal way of getting the required result cannot be obtained.

CAST-IRON HOT-WATER PIPE AND FITTINGS

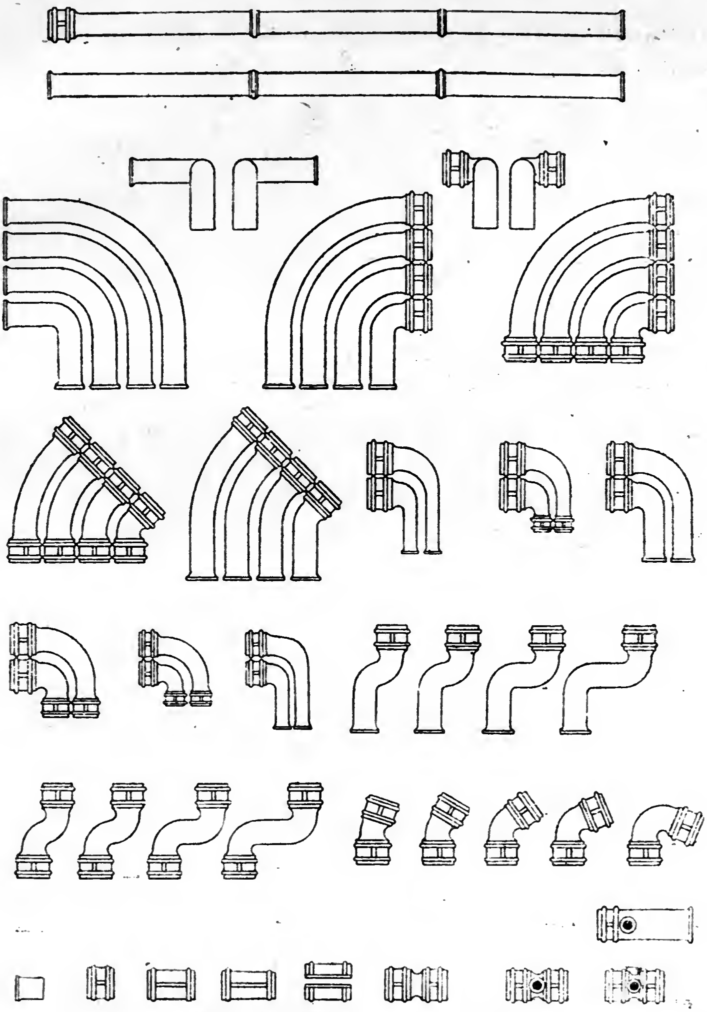
On the five following pages appear practically all the ordinary fittings that are made and stocked for cast-iron socketed hot-water pipes. These illustrations are given to enable the student or engineer to see the fittings ordinarily made, also what he can get ready made to meet special or urgent requirements. A peculiar source of trouble is sometimes experienced with these goods by reason of the varying thickness of the metal. It is usually noticeable as between pipes and fittings, and it has been stated that the difference is due to the moulders being paid by the piece for one and by weight for the other. In any case it is desirable, when settling on a maker who is to be bought from regularly, to see that this trouble does not exist, or is not too pronounced.

Cast-iron hot-water pipe is made in 9-foot, 6-foot, and 3-foot stock lengths (except the 2-inch size, which is not made in greater length than 6 feet). It usually has a socket at one end and a small rim at the other—termed the "spigot" end; but it can be had with two spigot ends, if required. The pipe can also be had with a trough cast upon each length, this trough being provided to receive water and make the air humid in horticultural work (see page 107), or loose troughs can be had to rest upon the ordinary plain pipes. The pipe is heavier than either rain-water or cast smoke-pipe, and the sockets are strengthened with cast rings. The sockets, too, are fully large to allow of a caulked joint being properly made.

JOINTING CAST-IRON HOT-WATER PIPES

There are several ways of jointing the ordinary cast hot-water pipe, the cheapest lasting joint being made with iron borings and known as the rust joint.

Rust Joint, Ordinary quick-setting.—Take 80 to 100



Cast-iron socketed pipes and fittings.

parts, by weight, of iron borings,[1] 2 parts of powdered (flour) sulphur, and 1 part of powdered sal-ammoniac ; thus, to 1

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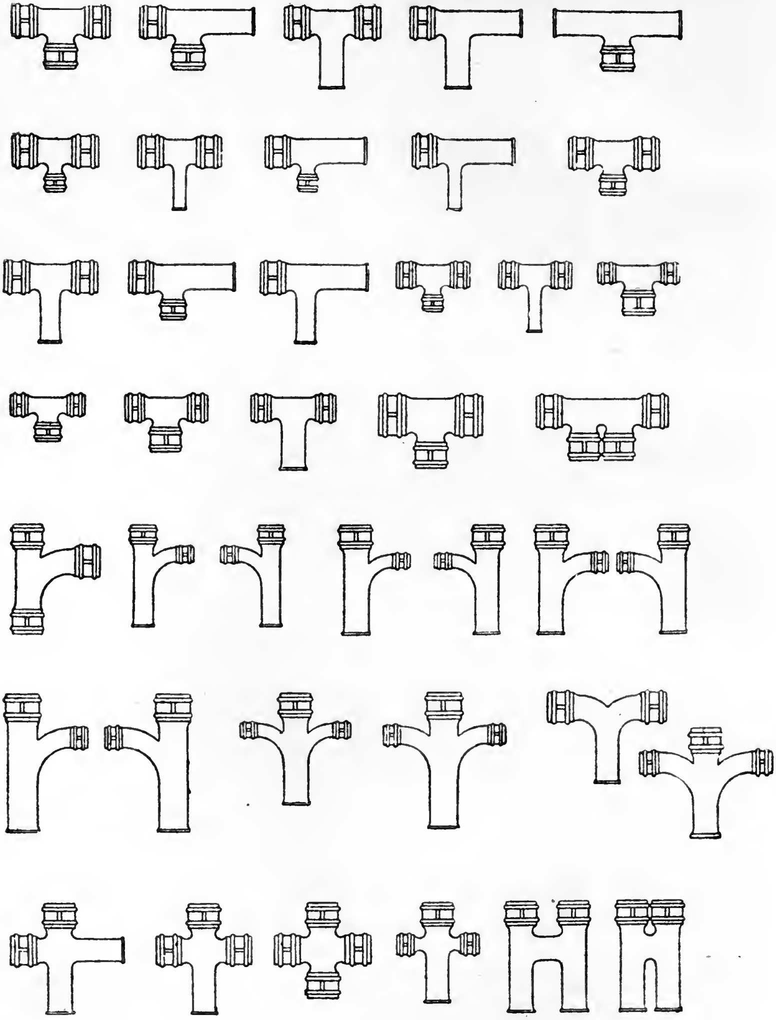
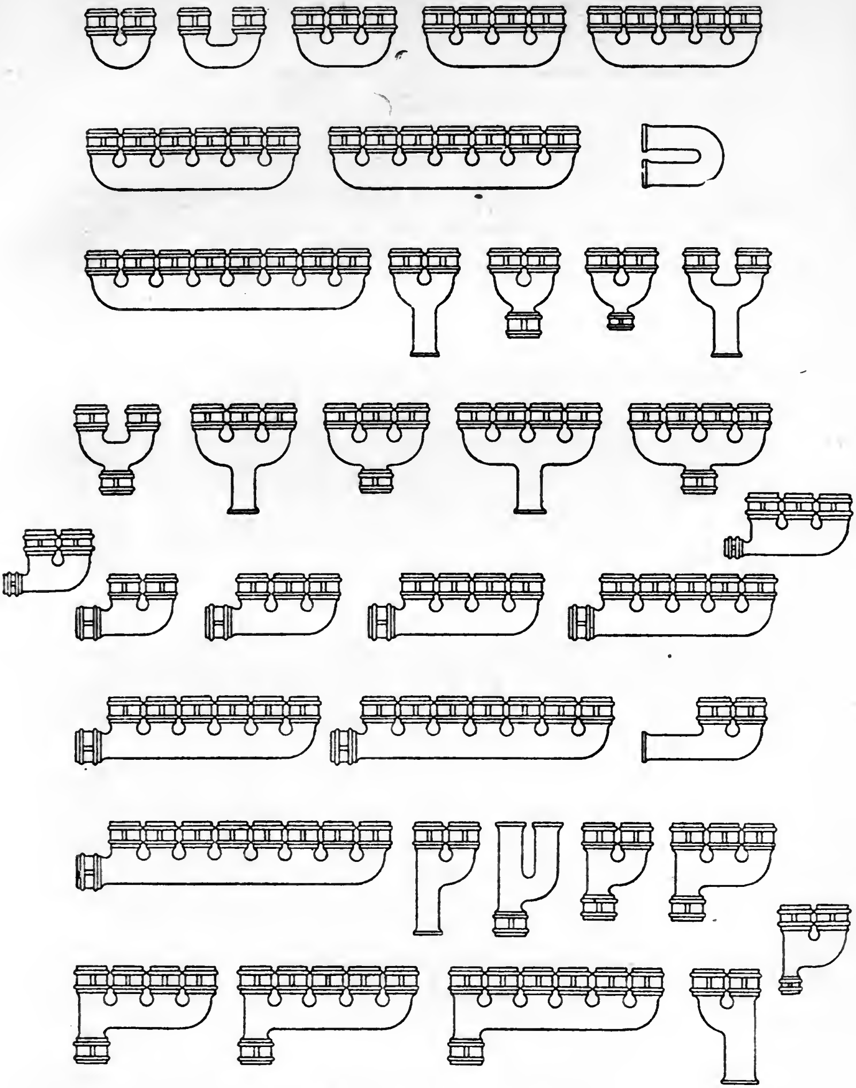
[1] Iron borings are supplied cheaply (3*s.* 6*d.* to 4*s.* per cwt.) by those firms who deal in cast hot-water pipes. Borings should be well pounded if they appear to be too coarse. On no account must the borings be oily as they will not then rust properly. Oily borings must be strongly heated to drive the oil off.

hundredweight of borings there would require to be about 2¼ lbs. of sulphur and, say, 18 oz. of sal-ammoniac. These must be well mixed in a dry state, then have water added and mixed until the mass is of a uniform moistness. This should be done from one to two hours before the material is



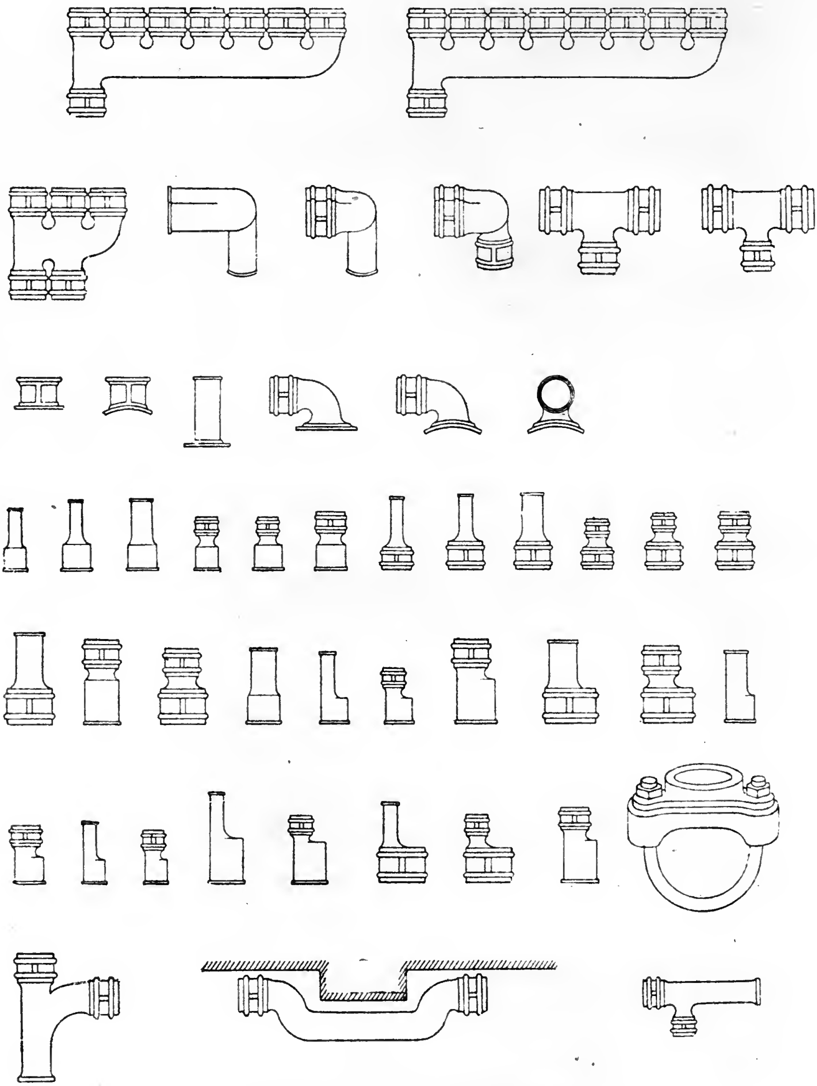
Fittings for cast socketed pipes.



Fittings for cast socketed pipes.

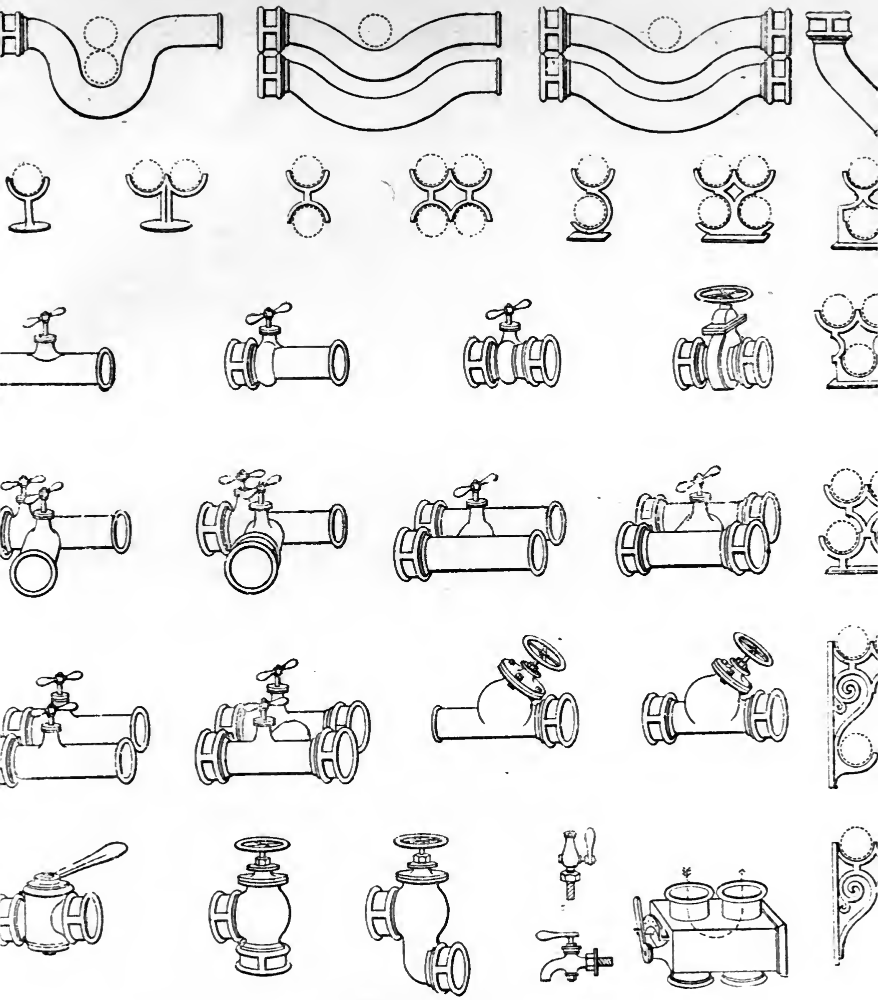
required for use. This joint will usually set hard enough to allow water to be run into the pipes the day following.

Rust Joint, Slow Setting.—200 parts, by weight, of

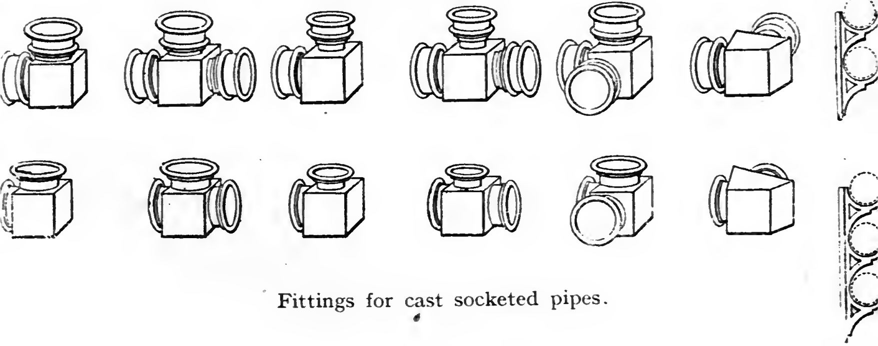


Fittings for cast socketed pipes.

borings, 1 part of powdered (flour) sulphur, and 2 parts of powdered sal-ammoniac. Mix as already described. Will set in two to three days.



JUNCTION BOXES.



Fittings for cast socketed pipes.

In making the rust-joint it must be understood that the yarn, or gaskin, first caulked in, is the actual joint-making material, and the boring mixture, when it has set hard, only serves to back this up and keep it sound.[1] On this account the water should not be turned into the pipes until the borings have set, and although very little thought is given to this in glass-house work, in which the pressure is so light, yet even in this case the joints should be allowed the longest time possible, for setting.

In making the joint a length of yarn, making about three turns round the pipe, is first caulked soundly in, and this is followed by other lengths until the socket is a little more than half-full. As regards the precise quantity, various fitters have different ideas, and while some consider the joint should be half yarn and half borings, others caulk in yarn until only half-an-inch space is left for the borings. Doubtless, this is sufficient if so small a quantity can be got to set well, and on the latter account about three-quarters of an inch of borings, and from this to 1 inch may be found best for the larger pipes (3-inch, 4-inch, or larger).

The chief reason for limiting the quantity of borings is its liability to crack the socket owing to its expanding a little as it sets. If it were not for this, the borings might be used liberally, as it is a cheap material, and would reduce the quantity of yarn required. It must be plainly stated that a man's capability in joint-making with this material is quickly known by whether he gets cracked sockets or not, and many tons of pipe have been rendered useless through this. The best advice that can be given is to use only a reasonably small quantity of borings, and to caulk or press them in evenly, but not too hard. They should not be used too fresh, yet no more must be mixed (that is, moistened) than can be used within a few hours, as they will not keep long without commencing to set.

The chief fault of the rust-joint is its liability to crack the socket of the pipe if the fitter is not skilled or has not been

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[1] In case of emergency some old tarred rope was once used to make caulked joints with, and this, without any backing, lasted well and had to be burnt out when the pipes were removed.

shown by a skilled man. *The mass of borings swells as it rusts and sets*, and the pipe socket, though very strong, will not stand much of this without injury. On this account the slow-setting recipe is adopted whenever possible as the material appears to accommodate itself to the space it is in in a better manner if longer time is given.

An American recipe for a rust-joint provides for the borings being moistened with plain water (so that they will cake slightly when squeezed up in the hand) and then caulk in with alternate layers of yarn, well caulking the whole. This would be fatal to the pipe if sulphur and sal-ammoniac were used, but, by using plain water, the rusting is much less active, though apparently sufficient.

When a few joints only are required, and borings are not readily obtainable, red and white lead putty may be used. With this a length of yarn is first caulked in, then a layer of the putty, then yarn and putty alternately until the socket is full. To make a good job of this some of the putty should first be thinned with boiled oil, and the socket and spigot painted with this on the surfaces where the packing material is about to come. This joint is not a cheap one, nor does it set quickly. It is very reliable.

A good substitute for the red and white lead joint is a mixture of six parts dry slaked lime or whitening, one part of litharge and two parts clean sand, these being mixed with raw linseed oil to make a putty. A $\frac{1}{4}$ lb. of driers may be added if required to set quicker. This is caulked in alternate layers with yarn as last described.

Portland Cement Joint.—There is a growing practice of using Portland cement for jointing socket and spigot hot-water pipes, and while this material does not appeal to the average hot-water engineer, there is no disguising that it is doing considerable service in horticultural work. It is not supposed that any one would use Portland cement for jointing pipes which have to withstand much pressure, or pipes which act as mains beneath large buildings. If Portland cement is used at all it would be best to confine it to glass-houses, or buildings of one floor of the warehouse or factory kind.

For quite unimportant requirements the sockets are half-filled with yarn, well caulked in, the remaining half with neat cement well tucked in and trowel-finished at top. Another way, a little more elaborate and which is being used to a large extent (with satisfaction) in market growing districts is as follows :—Two turns of gaskin are first caulked in to properly close the space at the bottom of the socket. Then (with horizontal pipe) a rope of clay is put round the open end of the socket, not quite meeting at top so as to leave an aperture. Into the aperture Portland cement is poured, it having been first mixed to a cream with water. When the cement is set the clay is removed and the joint finished with some more cement trowelled over. If clay is not available a ring of gaskin, one turn round the pipe, can be just tucked in the edge, leaving the ends out to make the pouring aperture. Before the cement is quite set the ring of gaskin is pressed in as far as it will go and cemented over ; or the ring can be drawn out when the cement is set sufficiently and the joint finished with more cement.

Rubber-ring Joints.—A joint that is largely used when the conditions will admit is made with a plain rubber ring.[1] A ring of round cord rubber, of bare ½-inch thickness, is stretched over the spigot end of the pipe, and this is then thrust into the socket. If the socket is an even casting, and the ring of proper thickness, a water-tight joint is obtained without doing anything else. Where rubber-ring joints are used no other provision for expansion is needed, but it will be seen that full provision must be made for supporting the pipes, as the joint has no rigidity whatever. Sometimes the ring is backed up with cement to keep it firm. A rubber ring makes a good provision for expansion if used here and there on long runs of rigidly jointed pipes.

A form of joint that is now being used largely with every success for moderately low pressures consists of two rubber rings which are compressed when the joint is tightened up,

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[1] The rubber ring joint is largely used in the glass-houses of market growers, as the men employed on the grounds can readily put up new runs of pipe, or alter old ones, with this joint. The rings are stocked by all firms supplying the pipe.

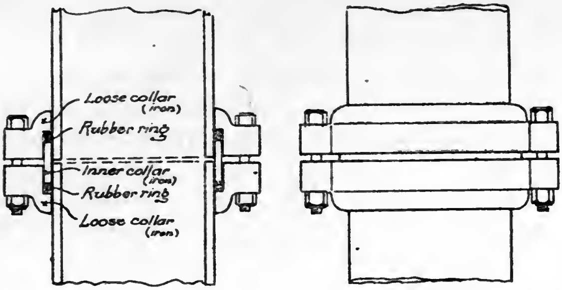

FIG. 128.—Rubber-ring compression joint for cast pipes; low pressure.

the tightening being done by bolts and nuts. The two illustrations of Fig. 128 show this joint, the particularly good feature being that both ends of the pipe are quite plain so that any cut lengths can be used. This is the joint sent out with the complete apparatus which is sold for amateurs' own erection, as illustrated at Fig. 47, page 101, for any one with but a slight knowledge of tools can make up this joint. It consists of three iron collars and two rings of square rubber. The two outer collars, as will be seen, when drawn together compress the rubber rings on to the inner metal ring, and this makes a perfectly sound joint. It is not intended that this joint be used for works in which a high pressure is felt, consequently it is not suited for the basement mains of a heating apparatus in a high building.

A joint designed for bearing high pressures is illustrated by Fig. 129. This necessitates the use of specially designed ends to the pipes and fittings, these ends, when drawn together, compressing a rubber ring on an interior iron collar as shown.

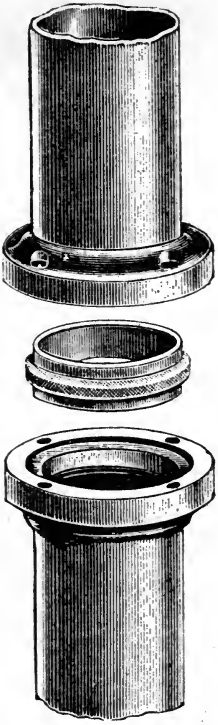

FIG. 129.—Rubber-ring compression joint for cast pipes; high pressure.

The two illustrations of Fig. 130 show Richardson's Patent Universal joint, as made by the Meadow Foundry Co. This is a reliable joint for high pressures, and it will be seen that, as one end of each bolt is a hook, bearing on a shoulder, a pipe or fitting can be twisted round and fixed at any precise angle required.

The illustration Fig. 131 [1] shows a simple joint for medium pressures, this possessing the advantage of only requiring one end of the pipe to be of special design, while the other end is plain. By this means a pipe can be cut on the job, whereas with joints requiring two specially designed ends to the pipes and fittings there usually have to be some odd lengths cast to order to finish a job with. It may be explained, however, that the makers of joints requiring two special ends always keep a fitting or joint that can be used on a cut pipe, and so save the time that would be taken by casting an odd dead length; or, as special lengths are a common demand, the makers hold themselves in readiness to cast these at short notice, and when a high pressure has to be withstood, it is better to wait a day or two for this than use a plain-ended cut pipe. When fair pressures have to be borne, say 30 feet and upwards, the writer prefers that both ends of pipes and fittings be specially moulded.

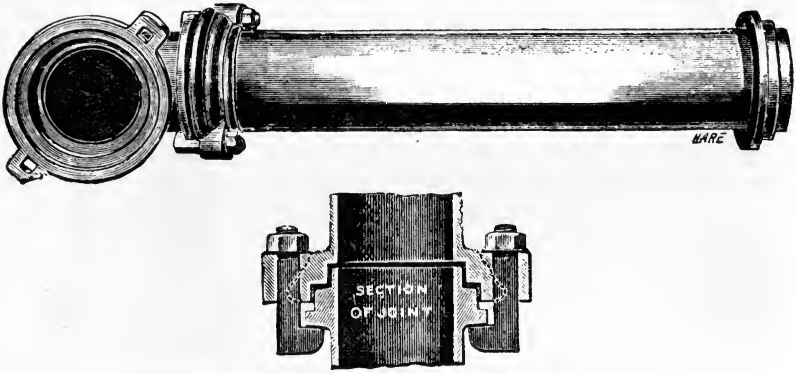

FIG. 130.—Rubber-ring compression joint for cast pipes; high pressure.

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[1] The Beeston Foundry Co., Ltd, Beeston, nr. Nottingham.

A fitting that is associated with cast pipes, and which will bear description, is the "saddle" shown on the sheet of illustrations, page 232, on the extreme right side, the second line from the bottom. This is to enable a wrought pipe branch connection to be made, when the cast pipes cannot be drilled or taken down for the insertion of a tee. A hole is cut in the pipe with a diamond-point chisel, and when it is of suitable size the saddle is bedded on with red lead putty and hemp, and then drawn down tight on to the pipe by the nuts shown. The hole in the pipe need only be of a fair shape, and does not need to be carefully finished or tapped with a thread. The tapping for the wrought pipe is in the hole shown in the saddle.

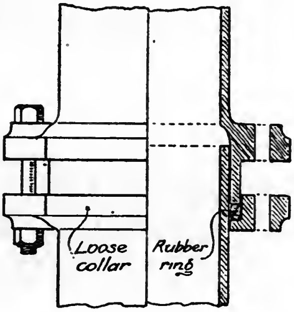

FIG. 131.—Rubber-ring compression joint for cast pipes; medium pressures.

Finally it may be stated that when a number of small branch connections have to be made on cast mains, the majority of makers are prepared to cast bosses or stubs on some of the lengths of pipe, as Fig. 132, these bosses being drilled and tapped for wrought pipe. This comes much cheaper than inserting a pair of tees for each small branch, for the tees must be provided and fitted with blank ends to the outlets, these ends being drilled and tapped for wrought pipe. Where, say, a 3-inch one-pipe cast main is run round a basement to carry about a dozen radiators, the insertion of two dozen tees is a real trouble and expense compared to having the bosses just described.

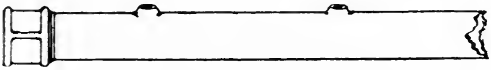

FIG. 132.—Cast pipe with bosses to receive wrought branch connections.

Tees, when used for this purpose and fixed with horizontal outlets, should have the blank ends to the outlets drilled eccentric ; that is, the hole for the wrought pipe should come out of the centre and close to the upper edge of the blank end (see page 227).

CHAPTER XVIII

THE HIGH-PRESSURE SYSTEM

THE high-pressure system of heating by hot water has its principle based on the fact that if, when water is heated, ebullition or boiling is prevented, the temperature that the water can attain is very high, and considerably above the generally recognized boiling point of water, which is 212° Fahrenheit. This latter temperature is that at which water boils when heated in open vessels (or vessels with loose lids), at sea level, at which level the pressure or weight of the atmosphere is 14·7 lb., or nearly 15 lb., to the square inch. If we ascend a mountain (where the pressure is less), or descend a deep mine, below sea-level (where the atmospheric pressure must be greater), the boiling point of water will be found to be less or greater than 212° F. On the summits of many high mountains water boils at a temperature which is insufficient to cook most foods.

When water reaches its boiling point and ebullition occurs, it ceases to rise in temperature, as the heat which would go to continue the rise passes away with the steam. This being so, it will be seen that if the pressure on the water can be increased, by some means, then a proportionately higher temperature can be had before boiling occurs, and by a simple arrangement it is possible to prevent boiling entirely.

It might be thought from the foregoing that if pressure and temperature worked together when heating water, the temperature would have no reasonable limit. This, however, is not correct, but it is possible and easy to have a hot-water heating apparatus in which the temperature of the water ranges from 300° to 400° F. At these temperatures the pipes will do much more work than surfaces heated by low-pressure hot water or steam, and yet not be dangerous. The writer has heard that a temperature of 600° F. has been attained, but this may have been an assumed temperature, for it could not be obtained without an exceedingly powerful boiler coil—or an accidental circumstance—and then it is doubtful whether the trouble was taken to test the heat with a suitable heat-measuring instrument. There is no obvious reason, however, why 600° F. should not be got in a sealed apparatus, with an excessively disproportionate boiler coil, and then the conditions would be dangerous in most cases. In properly erected works, the average temperature is 300° F., which, with good stoking, may rise a little higher.

If the water is not to boil, then the apparatus must be sealed, and all ordinary atmospheric influences excluded. This could be done with any hot-water apparatus by sealing off the expansion pipe and the cold supply; but it would result in the destruction of the apparatus, as the tubes and appliances ordinarily used will not stand the pressure. Even with the tube specially made for the purpose, there has to be provision for the expansion of the water, as will be seen presently.

In Fig. 133 is illustrated a high-pressure apparatus in a simple form which will afford a means of describing the details that have to appear in works of this kind.

The apparatus has to consist wholly of tube. No boiler or radiator is possible, on account of the pressure. A coil of tube is used as the heater in the furnace, and coils or rows of tube distribute the heat. The tube is all of similar size and strength, the apparatus being in fact an endless line of tubing except for the short and larger piece of tube shown at top, and two other small connections. To withstand the maximum strain that may occur, the tube is made of unusual strength, being of $\frac{1}{4}$-inch metal, lap-welded. The bore is $\frac{13}{16}$ inch (usually called $\frac{7}{8}$-inch), while the external diameter is $1\frac{5}{16}$-inch. Instead of the tube having the usual right-hand thread at each end, one end has a right, the other a left hand thread, and the socket is threaded right and left accordingly. It follows, therefore, that when the ends of the tube are put into the socket and the socket screwed up, the ends are drawn together until they meet in the centre of the socket.

The pipe joint is a very important detail in high-pressure work, and the only reliable method is that of making a metal-to-metal joint, as shown in Fig. 134. In this it will be seen that the end of one pipe is finished flat, while the other is coned all round. When the socket is screwed up and the ends of the pipe come together, it follows that the coned edge embeds itself in the flat end, and this, if properly done, makes a sound pressure-resisting joint, without any jointing material, such as red lead or hemp. No packing or jointing material is used in this work.

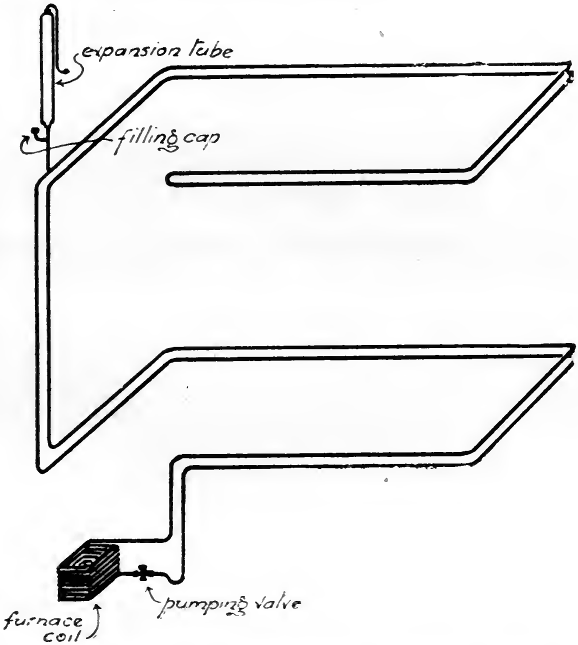

FIG. 133.—High-pressure hot-water heating. A simple example apparatus.

The tools used for preparing the ends of the tubes are usually shop-made, and, correctly speaking, there should be one for the coned end and one for the flat-faced end of each tube. Quite commonly the fitter considers a file sufficient for the flat-end, also for the outside bevel of the coned end, while he provides a tool resembling a countersink for the inner coned surface. The flat end is then filed true, and the outer surface of the coned end is filed also ; the inner surface is made with the tool just mentioned, worked by a brace. It is very important that both ends shall be at true right angles to the length of the pipe (or the ends would not meet true when drawn together), and this is generally tested by means of a small steel square.

The threads on the pipe ends, both right and left, are finer than the ordinary iron pipe thread, viz., fifteen threads to the inch, this being necessary to effect the best joint when screwing up. Special stocks and dies, also special tongs or grips, are sold for this work, the latter being, as will be understood, very requisite. The stocks only require two dies, one of each hand, as the size of the pipe seldom varies now. A $\frac{5}{8}$-inch pipe was largely used at first, but the $\frac{7}{8}$-inch size seems now to be generally preferred. The smaller size, and the tools required, may often be needed by any one undertaking repairs. The necessity for securing a very sound joint will be apparent when it is stated that every apparatus erected has to be tested (cold hydraulic pressure) to 1,800 lb. or 2,000 lb. to the square inch, before lighting the fire. The

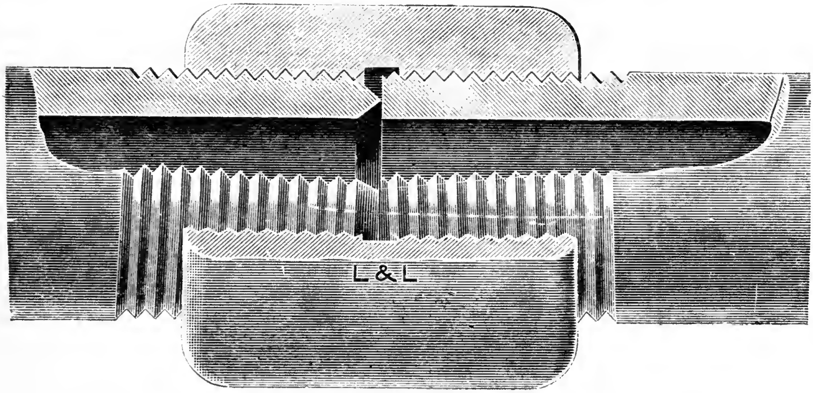

FIG. 134.—Showing how high-pressure pipe ends are jointed.

pressure is put into the apparatus by a suitable force pump (with pressure gauge) which is part of the outfit of tools.

The fire coil or heater is composed of the same tube as the circulation, and the quantity of tube used for this always bears a fairly exact relation to the length outside the furnace. This will be referred to again, but it may be here stated that in a general way the tube in the fire coil for ordinary warming is equal to one-tenth of that outside the furnace.

In constructing the furnace coil, whether it be large or small, the pipe is usually bent round to an oblong shape, one pipe above the other, as Fig. 133 shows; and although this is by no means an ideal economical means of utilizing the fuel, yet it is the form of heater most commonly used. The coil is either set in brickwork or placed in an iron case, the latter making it independent of brick-setting. The rule is to put large coils in brickwork and make the small ones independent.

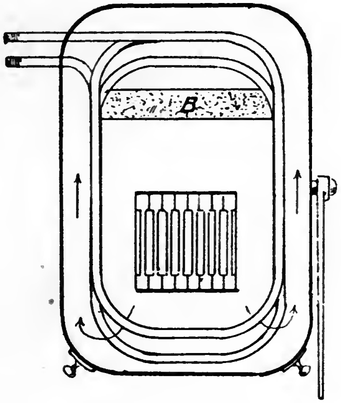

Fig. 135.—Plan of independent furnace coil for high-pressure work.

Fig. 135 shows, in plan, a coil in an iron case. The coil has its tubes, at the front and rear, projecting and receding alternately, as may be seen with the front of the four-pipe coil on page 250, this hit-and-miss arrangement being provided that the flame and heated gases may pass to the flues outside the coil and from thence to the chimney. The arrows (Fig. 135) show the passage of the flames and gases. The barrier marked B is a brick bridge extending across inside the coil, and so preventing the flame and gases making a short cut to the rear of the coil where the chimney is. This bridge extends up to the top and quite cuts off communication from the front to the rear of the coil, except by the flueways outside the coil. The flame and gases after coming through the side flues pass up between the tubes at the rear and then into the chimney, and by this means the interior and exterior of the coil are heated as well as is possible.

At the bottom of the furnace is a grating which is hinged at the rear, and, by means of a lever handle outside, this grating can either be rocked to clear the fire of ash, or it can be dropped to let the cinders and ash fall out when the furnace has to be cleared out entirely. This provision is necessary, as no stoking door can be provided in front, the coil proving a barrier to any access to the fire at this point. If the iron casing extends to the ground, then an ashpit door (with means to regulate the draught) is put in front below the level of the fire bars; and there have to be provided two flue doors for cleaning the side flues outside the coil. The top of the furnace is usually composed of firebrick slabs resting on the top of the coil, and above these the iron top to the case comes. In this top is a feeding-hole and cover, all fuel being passed in this way. Fig. 136 shows an independent heater, as made by Wontner Smith, Gray & Co., and although the description just given may not, perhaps, apply to this heater in every particular, it will be found to have a general application.

A variation to the ordinary form of coil boiler is that patented and made by Renton Gibbs & Co., of Liverpool. Fig. 137 illustrates this, and it will be seen to consist of a number of lengths of larger tubes running from front to rear of the furnace, and arranged in the form of an arch from side to side over the fire. The ends of the large tubes are reduced and connected together by the smaller size of tubing used in this work; and when the extent of the installation requires it, the arch of tubes is divided into groups for whatever number of separate circulations may be decided on. This arrangement is fully explained with the four-pipe coil shown on page 251.

A detail that may next be explained is the piece of large pipe shown at the highest point of the apparatus, Fig. 133. This is known as the expansion tube, and it fulfils a very important purpose. It must first be explained that water is a non-elastic, incompressible substance, yet it expands with some freedom when heated. Therefore, if an apparatus as Fig. 133 was erected, minus the expansion tube, and, after being filled with water, was sealed up, it could not long remain unfractured after lighting the fire. It could not fail to burst notwithstanding the great strength of its tubes, The purpose of the expansion tube, therefore, is to prevent fracture, which purpose it fulfils quite perfectly, as will be explained.

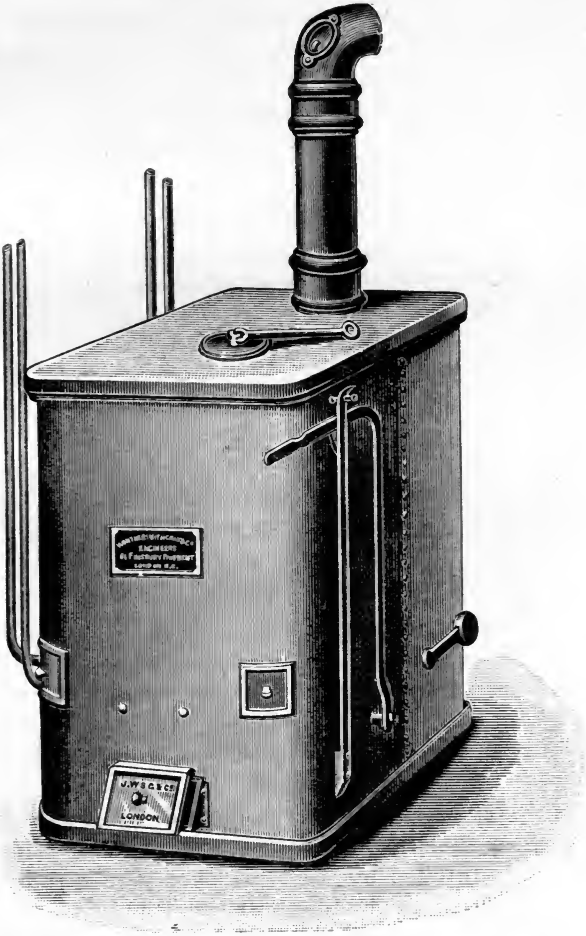

FIG. 136.—Independent heater for high-pressure work.

By referring to Fig. 133 it will be seen that a tee is inserted just below the expansion tube, and the outlet of this tee is closed with a cap and marked "filling-cap." This cap is the highest point to which the apparatus is filled with water (when cold), the tube above this containing air only. When the apparatus is charged and sealed, and the fire lighted, the water commences to expand, and starts compressing the air in the expansion tube, the water partly filling the tube. Air is highly elastic, and permits the water to expand into its greater bulk with no more force than that which is necessary to compress the air, this strain being insufficient to rupture the apparatus at any point, if the parts are properly proportioned.

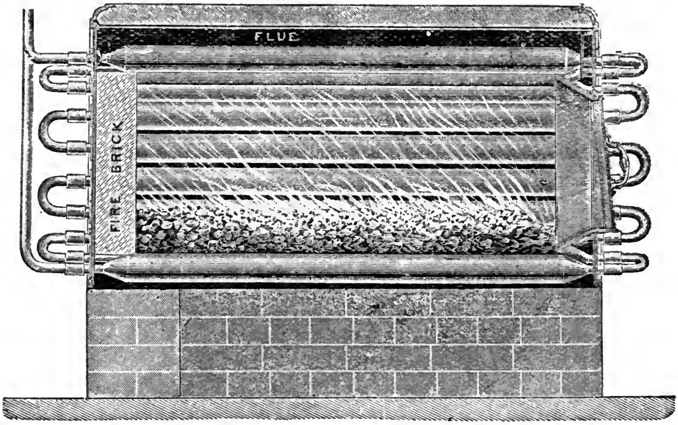

FIG. 137.—Special design of brick-set heater for high pressure work.

The air in the expansion tube is therefore an elastic cushion, against which the expanding water can exert its force ; but another office fulfilled by the expansion tube is that of preventing ebullition or boiling. It was explained that, by increasing the pressure on water, the temperature at which it boils or ceases to become hotter is increased proportionately. It will be seen that, as the water heats and expands, it causes a pressure to be exerted on itself by the fact that the air is compressed inside the expansion tube. The compressed air exerts a pressure back upon the water equal to the pressure the water has exerted in compressing it. In other words the expansion of the water compresses the air, but the air is, all the time, pressing back on the water. As the water becomes still hotter, seeking to reach its boiling point, it expands still more and increases the pressure in the expansion tube. Therefore the hotter the water becomes the greater the pressure it makes on itself in the expansion tube, and thus it is doubtful whether boiling could ever occur. The expansion tube, therefore, serves the double purpose of preventing rupture, and permitting of high temperatures being readily attained by the pressure its contained air exerts on the water.[1]

The apparatus, illustrated by Fig. 133 would only be suited for small purposes in which the run of radiating pipe would not exceed about 500 feet. It is never desirable to attach a great length of tube to one heating coil for the simple reason that, with so small a pipe, the cooling is so rapid that the greater part of the return pipe would be comparatively cold. By referring to any of the tables in this book giving the sizes of main pipes for low-pressure work, it will be found that a pipe of a certain size can only carry a certain amount of radiation, and the reason is that a given size of pipe can only allow of a certain amount of heated water coming through it to replace that which is cooled. In low-pressure work a pipe of $\frac{7}{8}$ inch diameter (if such were made) would only be given about 45 square feet of radiation or, say, at the utmost, 200 lineal feet of pipe of its own size. With high-pressure work the circulatory movement is stronger and the temperature is higher and, therefore, a furnace coil can be given as much as 500 lineal feet of $\frac{7}{8}$-inch pipe, but this should be the outside limit, and any less quantity will be more beneficial than otherwise in results.

Assuming the foregoing argument to be correct, and there

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[1] This may be a suitable moment to state that, when it appears desirable, two or more expansion tubes may be used on one apparatus, in which case they would be smaller ones, as the aggregate capacity need only be that required by the table on page 291. In an apparatus the writer saw, which consisted of three large coils or stacks of pipe, there was an expansion tube and filling cap to the top of each, and the periodical attention to the filling cap kept the coils full of water.

can be no doubt about this, it may be asked how it happens that many works exist in which thousands of feet of radiating pipe are doing good work, yet one furnace heats the whole. This is easily explained by saying that the furnace contains what appears to be one large coil, but which is, in reality, several distinct coils, intercoiled and heated by one fire ; and, strange as it may appear to the uninformed, these several coils, and the different sets of radiating pipes outside the furnace, are all one continuous endless tube.

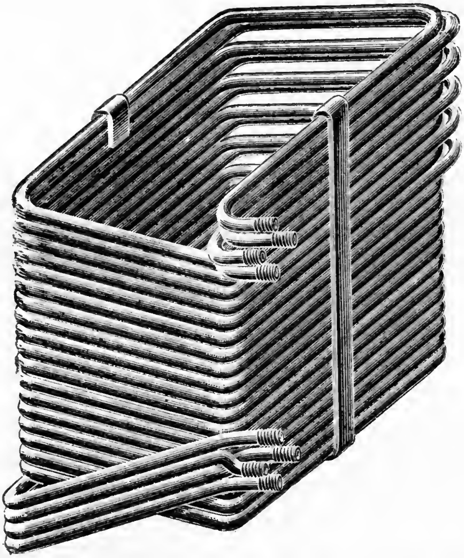

FIG. 138.—High-pressure multiple-pipe furnace coil.

It is always claimed for the high-pressure apparatus that it is quicker in doing its work than the low-pressure, and moderately short circulations are essential to secure this speed, otherwise the high-pressure system might take as long as the low in giving a certain degree of warmth. When, therefore, an apparatus exceeds 500 feet, some plan has to be adopted for dividing the piping scheme into two or more circulations, each starting out from and returning home to the furnace coil separately and without branching. This has also to be done without breaking the continuity of the pipe—that is, still leaving it one endless run of tube. This to the inexperienced may appear to be a difficult task, yet in practice it is very simple.

Supposing the apparatus consisted of 1,600 feet or 1,800 feet of pipe, and this was divided into four (or more) circuits as it should be, the furnace coil would then be made up of four distinct pipes, as indicated by Fig. 138 presenting four flow ends and four return ends to be connected on to, as shown. In connecting up it is important not to let the pipe going out from one flow come home to the corresponding return, as this would give each circulation a distinct furnace coil, and each one would require a distinct expansion tube and other details. Furthermore, unless each circuit and coil had the same length of pipe and the same work to deal with, there would be trouble owing to the fire affording more heat to one than another, causing great irregularity in general working.

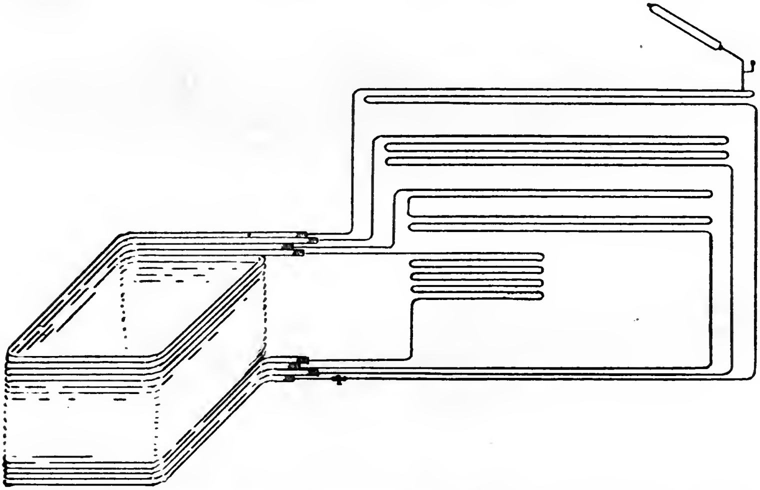

FIG. 139.—Showing circuit connections to multiple-pipe furnace coil, the whole remaining one endless tube.

The plan of connection that has to be adopted is to let the circuit going out from the flow of one coil come home to the return of another. Fig. 139 will show how this is done, but to make it quite clear Fig. 140 is given, this illustrating the four coils separated. It will be noticed first that the whole apparatus remains one endless pipe, which is a very necessary detail, as will be explained directly; secondly, that as the water goes round one circuit and becomes cooled, it is soon back at the furnace to be re-heated. Thirdly, although the apparatus consists of four circuits and coils, only one expansion tube and filling device is needed to the whole.

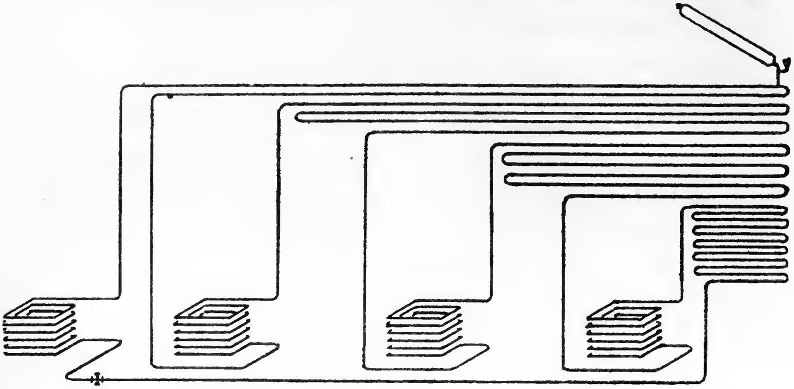

FIG. 140.—To make the description of Fig. 139 clearer.

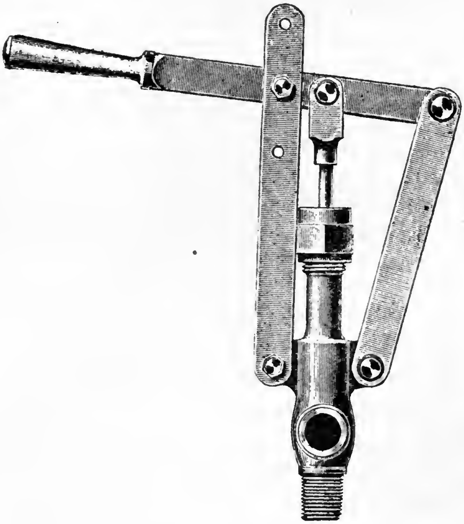

FIG. 141.—Pumping through cock; high pressure system.

In making the apparatus consist of one endless tube one chief result aimed at is to admit of proper filling. The filling is invariably done with a pump connected at the bottom of the apparatus, generally in the lowest return pipe near the furnace coil. Some engineers use the "pumping-through cock," as Fig. 141,[1] while others prefer the "pumping valve," which is usually of their own private design. In either case the device admits of pumping water into and through the pipe in one direction, and continuing the process until the tubing is full and water arrives back at the pump from the other direction. Only by this means is there any assurance that all air is swept out of the circulations. Occasional instances occur in which branches are necessary, and then trouble—little or much—may be experienced in the filling. Only well-skilled men should attempt branching an apparatus of this kind, and it will be found that the more experienced the man is the more anxious he will be to avoid branches.

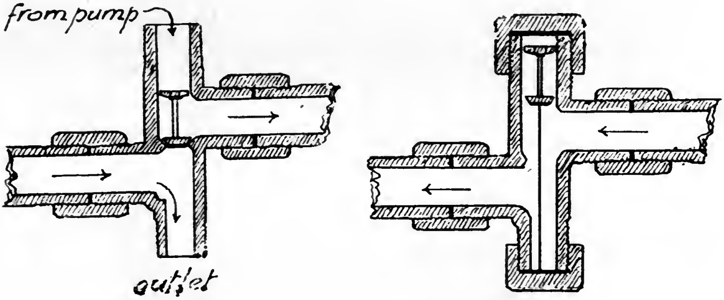

FIG. 142. FIG. 143.

Pumping valve for filling high-pressure circulations.

In Figs. 142 and 143 are given the working principle of a pumping valve made by W. Stainton, of King's Cross Road, London. This may be considered as a specially formed four-way or cross-piece, and the illustrations show the valve, the first one while pumping, i.e. filling, is proceeding, the second one, when closed and the water circulating.

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[1] This device is not a pump in itself, but only a peculiar form of plug cock which is used to divert the direction of the water when pumping is to be done. The plug of the cock is raised or lowered by the lever arm shown.

Figs. 144, 145 and 146 illustrate a pumping valve made by Renton Gibbs and Co., of Liverpool. The two first show the valve with hose connected at bottom from the filling pump, while the third shows the valve closed and the direction in which the water circulates.

The writer does not believe that the pumping valve is considered to be superior to the pumping-through cock in doing its work, but it is neater and is a preventive of trouble due to people meddling with the fittings. There may also be something in the fact that the pumping-through cock admits of a local man being called in to do the periodical re-pumping, whereas, with the valve, this is not quite so likely. Engineers undertaking this work, usually, on completion of an apparatus, ask if they may book an order to attend to the installation regularly, and send their man to re-pump it before lighting the fire each autumn, and at the same time do any repairs to the furnace, etc., that may be necessary. It is a regular job some one has to do, and it is highly desirable that only an experienced man should do it. The pumping valve is rather an assistance in this, as it is a device an

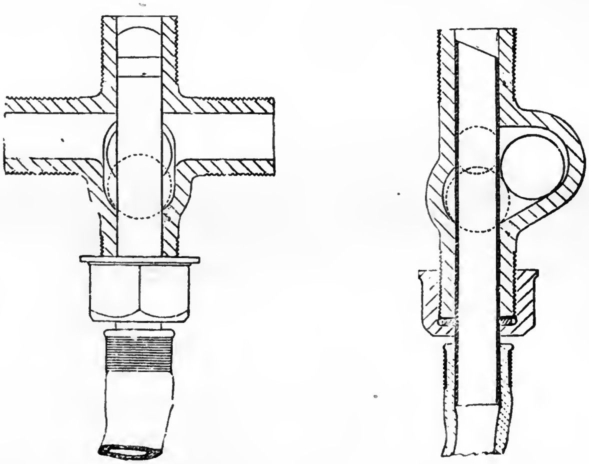

FIG. 144. FIG. 145.

Another pumping valve while filling is proceeding.

inexperienced man would not understand, and would hesitate to meddle with.

It will be noticed that there is a tee just under the expansion tube (Fig. 133), this tee being capped off and marked "filling cap." It might reasonably be supposed that this was the point at which the apparatus was filled with water, but it is not so. It should be called the "replenishing cap," for although it plays no part in the actual filling of the apparatus, the cap has to be removed about once a month and a little water put in, if there is need of any. This is the highest point to which the water reaches, when the apparatus is cold, and a moment has to be chosen when the apparatus is cool to remove the cap and do any replenishment needed. This is not done by the heating engineer, unless he should have his business premises quite close to the job. As a rule the engineer leaves a strong wrench with the caretaker, or whoever will be the attendant to the fire, with instructions how to remove the cap and replace it, this being done about once a month (during the time the apparatus is in use) as stated. It is needless to say that this filling cap is always a few feet above the highest point in the circulation, as it is important that any little shortage of water shall not exist in the circulating pipe.[1] It may seem peculiar that a shortage of water can possibly occur in an apparatus that is first pumped full and then sealed, yet a small shortage does occur,

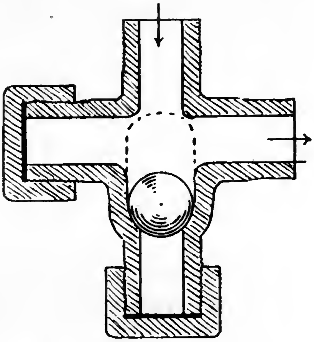

Fig. 146.—Pumping valve as Fig. 144 when filling is completed.

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[1] There is usually an air hole or tube on the upper extremity of the expansion tube, this outlet also being securely plugged or capped. When this exists it should be opened before the filling cap is removed, and closed again after the filling cap is replaced. Some firms who carry out this work leave a Card of Directions for the attendant which suggests that the fire shall be let out and the cap be removed weekly. The water in the apparatus must be quite cold at the time of replenishment.

and this is why the regular replenishment is required during the winter, and the thorough re-pumping once a year before the fire is lighted for the winter season.

The foregoing particulars describe what is usually known as the high-pressure or Perkins' system, and it has been considered that in the hands of workmen who do not correctly proportion the heating coil and the expansion tube to the radiating pipe, or in the hands of an attendant who allows the fire to become too fierce, alarming pressures may be obtained in the apparatus, accompanied by the possibility of dangerous results.

Limiting the Pressure.—With a view to preventing excessively high pressures being obtained an ingenious form of valve has been introduced to limit the pressure, this valve taking the place of the expansion tube and filling cap, and although the apparatus remains the same in all other particulars, a new name is given when the valve is used. There does not appear to be any decided name, nor a good name, but the apparatus is then said to be on the "moderate pressure system," or "limited pressure," or "high-pressure system with valve, or valve cistern," or is given some title conveying the fact that the pressure is under control so far as having an upper limit. This modified form of high-pressure apparatus is now in regular use, but it has not superseded the system which has an expansion tube, and the engineer practising this work will find that there is a regular demand for both.

Let it be assumed that a simple form of apparatus is erected, as Fig. 133, but the upright branch which carries the filling cap and expansion tube has, instead, a valve, fixed in a cistern, as Fig. 147, on its upper extremity, The valve, the principle of which is shown in section in Fig. 148, both discharges and takes in water at times, and this is the reason that it is fitted in a cistern. On examining the valve it will be seen that the major part of it, all the upper part, is no more nor less than a weighted-lever safety valve. Any pressure greater than the inner spindle can withstand must lift the valve end of this spindle from its seat and discharge whatever is beneath it. At the lower part of the valve will be seen a small unweighted spindle valve. This has its seating and seat so arranged that the spindle lifts with quite a light pressure from the outside, but closes if a pressure is exerted from the inside. It is a kind of check valve in this detail, but the whole complete valve is a device that can act as an outlet valve or an inlet valve, according as the pressure on it is greater inside or outside.

Supposing, therefore, that the outlet part of the valve is weighted at top to allow of its opening when the pressure inside is about 70 lb. to the square inch. This will mean a temperature of 316° F., which should be the highest limit in this work when put to ordinary uses (see page 242). Should the fire be urged, or carelessly tended, so that a pressure beyond this figure might be reached, then, at the correct moment, the valve opens and discharges a little water. This instantly checks the rise of pressure (and temperature), and however the fire might be urged the only result would be the possible discharge of a little more water. It will be seen that this safety valve—for that is what it really is—totally prevents any pressure being attained beyond that at which it is weighted or set to open at, and this quite obviates all the supposed risks a sealed apparatus is given credit for possessing.

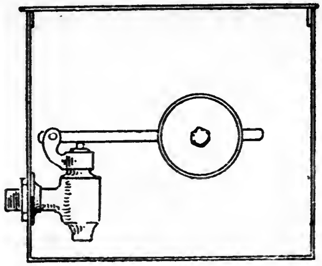

FIG. 147.

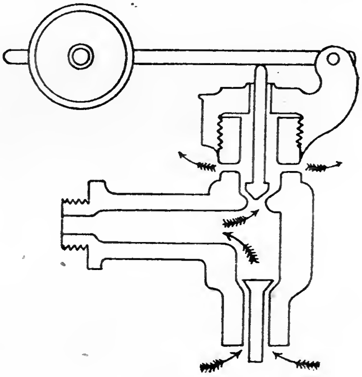

FIG. 148.

The valve-cistern and detail of valve, used to limit pressure in a high-pressure system.

The inlet part of the valve is provided to admit of water being carried back into the apparatus, when the pressure falls. It is necessary that the apparatus be always full of water and the inlet valve sees to this whenever anything like a vacuum is being formed in the pipes. From this it will be seen how necessary it is that the valve be fitted inside a cistern, and it is equally necessary that the lower part of the valve, at least, be always under water. It would not do for air to be sucked into the apparatus, when the inlet valve opened.[1] It will also be seen that no filling cap is needed for periodical replenishment, and the expansion tube finds a perfect substitute in the weighted valve. The only fault urged against the valve is that, like all valves, it can get out of order. The valve is in almost constant operation when the fire is alight, as every change in temperature means either a discharge or a taking in of water.

Even when an apparatus has this valve it is a good plan to put a pressure gauge on a flow pipe in the stokehole, where the attendant can readily see it. Although the valve may be set to open at the pressure accompanying 316° F., it is not always desirable to work up to this temperature in the ordinary way and the pressure gauge will indicate what pressure the apparatus is running at.

It will be understood that the existence of the valve makes no difference to the use of the regular pump-filling device, which is shown in the return pipe near the furnace coil in Figs. 133 and 140. The valve only displaces the expansion tube and the filling cap, the remainder of the apparatus being alike in general principle and detail.

In running the pipes in this work (whether the apparatus has an expansion tube or a valve cistern), it is customary and proper to observe the rule followed with low-pressure pipes, in giving them a rise from the furnace coil, and avoiding dips and irregularities of this kind. But where dips require to be made they can be put with less risk of failure than with low-pressure work, as the circulation is stronger,

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[1] As a rule the valve is more or less submerged as there must be sufficient water in the cistern to allow for evaporation. The valve should be looked at every two weeks in winter to see that it is operating.

and, most importantly, the higher parts do not become air-locked. The absence of air makes air-cocks unnecessary, and on this account coils of pipe, as Figs. 149 and 150 are quite admissible. Long runs of pipe up and down the side walls of a hall or place of worship, as Fig. 151, are also quite regular, and no provision for air exit is needed. Pipes can also be carried over doorways or window-heads, but the rule remains that irregularities should be avoided when possible, and not introduced as having no ill effect whatever. There is a too common feeling that the pipes can be run anyhow and anywhere in this work, but it is an incorrect idea, for the motive power which causes the heated water to move through the pipes is brought about by precisely the same natural action as it is in low-pressure pipes, but the higher temperature gives it a little more strength and ability to overcome obstacles. The total absence of air, too, is of assistance, as the pumping quite scours it out, or should do, while with other hot-water pipes there is always some gathered here and there.

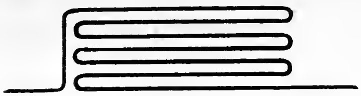

FIG. 149.

FIG. 150.

Pipe coils permissible with high-pressure work.

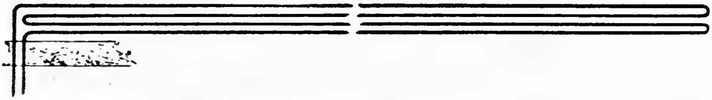

FIG. 151.—Long runs of horizontal coiled piping as commonly arranged in high-pressure installations.

Every effort should be made to keep these pipes exposed in the places to be warmed. The writer has had to run them in trenches, with gratings over, and behind grated skirtings and such other places, but it has always produced a very unsatisfactory feeling. They are, of course, less effective, even when new; they get loaded with dirt (see church work, page 89); and, what does not so plainly appear with pipes of a less temperature, the dirt gets heated up sufficiently to give a faintly tainted quality to the air. The dirt being composed of so many materials, such as wool, hair etc., which give off a little odour when resting on a 300° F. surface must produce noticeable results. Therefore, endeavour always to have the pipes exposed, so that they may keep clean, or be kept clean, without trouble. They may be under wall seats, if necessary; but not seats with closed or grated fronts, as the pipes will not then be dusted. Coils under coil cases should be avoided, if possible.

An awkward clause in the London Building Act (which most provincial authorities work to) is that which requires these pipes to be at least 3 inches away from woodwork and all inflammable material, and this applies whether the apparatus has a valve or not. Doubtless the authorities use their discretion in regard to this, otherwise brackets have to project to this extent, if on a wood backing, and pipes through wood floors must come through holes fully 7 inches in diameter.

It is customary when filling an apparatus of this kind, should it be installed in a place of worship or any building which is not heated every day in the winter, to charge it with "frost-defying" liquid. This was originally introduced, and can still be obtained from the firm of W. Stainton, King's Cross Road, London. It is supplied in a concentrated form to admit of its being heavily diluted with water.[1] Although there are firms undertaking this work who do not consider the use of a non-freezing liquid necessary, yet, remembering the smallness of the pipe and the extreme coldness of these large interiors when left unwarmed for three or four days in wintry weather, it cannot be ignored that frost is very likely to do injury somewhere, if the pipes contain plain water. The greater bulk of water in a low-pressure apparatus affords more resistance to the effects of frost, but even these do not escape always.

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[1] For calculations as to the liquid contents of an apparatus of this kind it may be taken that 100 lineal feet of $\frac{7}{8}$-inch high-pressure pipe holds a little over $2\frac{1}{2}$ gallons.

Every newly-erected apparatus on completion, whether with expansion pipe or valve, must be tested cold with a suitable hydraulic proving pump and pressure gauge, to 1,800 lb. or 2,000 lb. to the square inch. This is essential, and no apparatus should have the fire lighted until it has shown itself to hold sound under this test. It is a quite reasonable one, and ordinary good work will easily stand it.

A final detail to be explained is the possibility of heating low-pressure radiators by means of high-pressure pipes. This is a plan adopted when the appearance of the pipes of the general apparatus, passing through rooms or places, would be objected to, and where coils in cases, or pipes behind grated skirtings, are equally objectionable. When the heating of radiators by this means was first attempted, the method adopted was to run a high-pressure pipe directly through them, as Fig. 152, but later a better appearance was obtained by the use of a piece of cast tube, through which the heating pipe was carried, as Fig. 153. The radiators are heated by steam, as only a little water is put in them, and the high-pressure pipe brings this to the boil. On first heating up, an air-cock (having a loose key) on the radiator, is opened until all air is expelled, then it is closed permanently and replenishment is not needed for long periods. As the

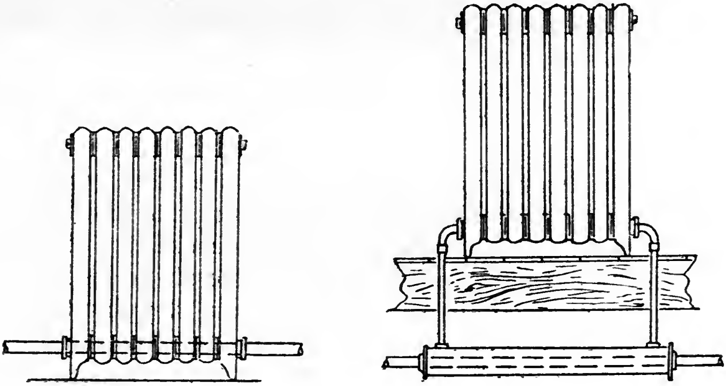

FIG. 152. FIG. 153.

Heating radiators indirectly by high-pressure pipes.

interior of the radiator must be in a state of vacuum when cool, the boiling of the small quantity of contained water readily occurs at a comparatively low temperature. Of course, if desired, the radiators could be filled with water, if reasonable provision were made for its expanding and for replenishment as it wasted.

The Advantages and Disadvantages of the High-pressure Apparatus.—The advantages are: Cheapness in first cost, provided the pipes do not have to be cased in. It is cheaper than low-pressure hot water, or steam.

Rapidity in heating up (if the circuits are not too long). This is of advantage in churches, and wherever the apparatus has to be heated up each time the place is used.

Its non-liability to freeze if left out of use in frosty weather; provided, of course, that it is charged with "frost-defying" solution.

The high temperatures obtainable for trade purposes, as in drying-rooms, etc. Japanning can be done in suitably fitted ovens.

The disadvantages that may have an existence are: the absence of any simple means of regulating the temperature of any section of the apparatus. Being an endless tube, stop valves are out of the question, as a valve of the kind could not be closed partially or wholly without stopping the circulation partially or wholly at every point. The absence of stop valves is no objection whatever in large interiors; but in a set of rooms or offices a difficulty might be experienced in getting every room at a temperature that suited the occupants. The sun shining on one room, or a larger number of people being in it, would make it warmer than the others. In a large business premises the writer was once interested in, the pipes were of full proper quantity everywhere, but in those rooms where the temperature occasionally got too high covers were provided to lay over a part of the pipes and thus reduce the radiating surface temporarily. A kind of regulating valve, known as a diverting valve, can be obtained, this being a three-way or four-way cock (very heavily constructed for this work) by which the circulation may be diverted more or less (shut off more or less, in fact) without stopping the main circulation. The use of this valve, however, introduces the necessity of branch circulations, and for the proper filling and maintenance of the apparatus these are best avoided until the fitter is well experienced in the work.

As already stated, the London Building Act, which practically all provincial authorities follow, requires that the pipes be kept at least 3 inches from all woodwork and inflammable material.

The pipes must, or should be, visible. This makes them unsuited for residence work or places where appearance has to be studied. As previously stated, the pipes may be hidden behind gratings and under cases, but this leads to their becoming loaded with dust, which, in turn, reduces efficiency and may make an odour or give a taint to the air. It is not quite so bad as some express it, viz. that the pipes if they reach 350° to 400° F. literally fry the dirt, but woollen and hair débris, carrying oils, must be affected.

The apparatus does not admit of alteration, repair, or extension by any ordinary hot-water fitter, unless he is experienced and actually trained in the work. Even the re-pumping requires a man who knows exactly what is to be done and why he is doing it.

Tables and Rules relating to High-pressure Heating Systems

QUANTITIES

References should be made to the Subject of **Quantities** for Low-pressure work, commencing on page 150. The remarks and general rules there laid down regarding the co-efficients for heat-losses by buildings and structural materials of different kinds apply equally to high-pressure heating. The detail (in finding quantities) in which high-pressure radiating surfaces differ to low-pressure is in the value of K. For this see next page, also the general subject of Heat Emission, page 145.

With a high-pressure heating installation it has been stated, more than once, that the length of any circuit extending out from the furnace coil should be limited to 500 feet run of pipe, for if this length is exceeded the temperature of some part of the return pipe will be too low to be serviceable. But even if the length does not exceed 500 feet the temperature of the pipe must vary considerably at its two extremities, consequently it is sometimes very difficult to find with any precision what length of pipe will be required to make good the heat losses which calculation shows will occur from a room or place. If the apparatus is required to warm a large open interior, like a place of worship, town-hall, etc., then the heat emitted by the pipe—or the temperature of the pipe—can be averaged; but if the piping runs through a series of rooms it may be felt with some assurance that the pipe in one room will not be at the same temperature as that in another room.

About the best that can be done is to assume a mean or average temperature for the whole of the pipe in the rooms, the temperature being based on the pressure it is proposed to have in the apparatus in coldest weather. If the cold weather pressure is to be 70 lb. per square inch, this will admit of a temperature of 316° F., but the water could only be at this heat in the flow pipe or pipes near the furnace coil. It would in such a case be proper to average the temperature for the whole circuit as 240° F.

When the average maximum pipe temperature is decided on then :—

The value of K is 2·5 (see Heat Emission, page 145).

For those who prefer to work to a simple table based on cubic contents the following is here given. It will be seen that two of the columns relate one to the length of pipe required in the furnace coil, the other to the proportionate capacity of the expansion tube.

Note: 3-inch pipe, a size commonly employed for expansion tubes, has 11¾ times the area of a ⅞ inch tube, so that 1 foot of 3 inch expansion pipe will represent 11 feet 9 inches of the smaller pipe.

The third and fourth columns are worked to after the total length of radiating pipe is found.

Temperature required when it is 30° outside. Degrees Fahrenheit	Length of ⅞ in. pipe required to each 1,000 cubic feet of space in a brick-built room or place	Length of pipe in furnace coil, in proportion to the radiating pipe	Size of expansion tube in proportion to the whole of the other pipes in the apparatus
50	16	1/12	1/9
55	20	1/10	
60	24		1/8
62	26		
65	30		
70	38		
80	55	1/9	1/6
90	85		
100	125	1/8	1/4
110	170		
120	225		

Notes and Working Allowances for above Table—

Add 10 per cent. for rooms having outer walls facing north or east. This applies to rooms of moderate size, not halls or other large interiors.

Add a further 10 per cent. for each outside wall more than one. This again applies to rooms of moderate size, not halls or large interiors.

Add 1 foot extra length of pipe for each 6 square feet of glass more than 20 square feet per 1,000 cubic feet of space. (It is considered that the normal amount of glass in a room is 20 square feet per 1,000 cubic feet of space, and when this is exceeded additional radiation is required to deal with it. In the same way when rooms have less than the normal area of glass the radiation may be reduced.

Places of worship and other high interiors need only be measured to 15 feet height (see Church Heating, page 89).

See the subject of Heat Emission, page 145, as to losses if pipes are cased in.

The reason for increasing the proportionate length of the furnace coil for the higher temperatures is to obtain a greater heat in the water. While water at 300° F. is sufficiently hot for the temperatures required in places occupied by human beings, it is not sufficient to economically afford the higher temperatures required for trade purposes. It may therefore be considered that 300° F. is the maximum for churches and public places, while from 350° to 450° F. will be required for drying-rooms, etc.

The sizes of the expansion tubes, too, have to rise in a fixed degree, for although the heat of the room does not affect them, nor is it affected by them, yet they must increase in size with any increase of heat in the water. As their name implies, these tubes are provided to allow for the expansion of the water and, this being so, they would be useless if not large enough. In Box's standard work on Heat the expansion of water is very clearly set out, and giving water at 40° Fahr. the unit figure of 1·00, the following increases in bulk are shown :—

Temperature Fahr.	Volume.	Roughly over its volume at 40° F.
°		
250	1·06	$\frac{1}{17}$
275	1·07	$\frac{1}{14}$
300	1·09	$\frac{1}{11}$
350	1·12	$\frac{1}{8}$ (full)
400	1·15	$\frac{1}{7}$ to $\frac{1}{6}$ ($\frac{2}{13}$ths full)
450	1·18	$\frac{1}{6}$ to $\frac{1}{5}$ ($\frac{2}{11}$ths)
500	1·22	$\frac{1}{4}$ to $\frac{1}{5}$ ($\frac{2}{9}$ths)
600	1·31	nearly $\frac{1}{3}$rd

These figures show that with water heated to 300° F. (the maximum for public places) the expansion tube must be large enough to allow of an increase in bulk of one-eleventh at least, and there must be, beyond this, enough space for a further increase of temperature due to careless stoking and then still have space for the cushion of compressed air. This is why the size of expansion tube for 300° F. work is given as one-eighth the tube, including the furnace coil; for what has to be allowed for is an increase in bulk of the whole of the water in the apparatus. It will also be seen that there is good reason for recommending that a pressure gauge be fitted somewhere in sight of the stoker, so that he may regulate his fire with reasonable nicety.

The temperatures and volumes given on page 266 will show what size expansion tank or cistern should be used when the valve-cistern is adopted in place of the expansion tube. In calculating, allow that each 100 feet of tube holds a little over 2½ gallons, and that therefore with 300° F. work the tank should hold one quart for each 100 feet of pipe, this quantity not filling the tank more than about two-thirds or three-fourths full, as some water should be put in the cistern to cover the valve at the commencement and allow for evaporation.

It may be added to the foregoing that for the high temperatures and pressures that exist with drying-room circulations the expansion tube is always used and not the valve cistern; and it should be the rule to mention the proposed pressure when ordering the expansion tube, as this is the weakest part of an apparatus and it must be of heavier metal when the furnace coil exceeds the one-tenth proportion. It is also customary at these times to test to about 3,000 lb. to the square inch instead of 2,000 lb. The piping will bear this if the work is properly done.

The tools required for this work have already been partially enumerated, but a list may be given here.

A set of stocks and dies. There is but one size of die, but right-hand and left-hand threads must be provided. The stocks are therefore made to carry the two dies at once, so that either may be used, as required, without changing.

At least three pairs of tongs, two for pipe and one for socket. These tongs are specially long and strong for the work, but what are known as dog-grips may be used if a piece of tube is slipped on the handle to lengthen it.

A tube cutter.

For finishing the ends of the tube, one flat, the other coned,[1] a common practice is to file the flat or faced end, also to file the outer edge of the coned end. The inner surface of the cone is made with a shop-made tool like a countersink. A small metal square is used for proving the ends of the pipes true.

A forge is needed for all bends, and, of course, a pipe-vice must be provided.

A force pump for filling.

A proving pump, with pressure gauge, for testing.

The usual bag tools, such as a hammer, screw-wrench, and screw-driver are often needed, also the tools for the brick-setting of the furnace coil.

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[1] It is customary to face the end with the right-hand, and cone the end which has the left-hand, thread.

CHAPTER XIX

WARMING BUILDINGS BY HEATED AIR

Warming by "Indirect" Hot-water Radiators.—It must first be explained, as clearly as possible, that in indirect heating the radiators or heating surface do nothing towards re-heating the air that is already in the room, and they afford no direct heat by radiation. When radiators are fixed in rooms they give some heat by radiation and still more by warming and re-warming the air already in the room, while in "indirect" work neither of these heating effects exist. Indirect work is the warming of fresh air in a suitable chamber or enclosed space and the subsequent delivery of this air into the room. The enclosed space may be near or a distance away, and the air may pass to a single room or several apartments.

It naturally follows that if the warmed air, which is to make a room comfortable, receives its heat away from the room, some power must exist or be provided to bring the air to the room, and to bring it in an unfailing stream. This is the important detail in connection with indirect heating, as the desired warmth can only be had by causing the air to flow through the room continuously. There must be new warmed air always entering and a corresponding volume of cooled and vitiated air departing, and this means—provision for effective ventilation. Indirect work is therefore little more than ventilating work with a means of warming the incoming air; but as the fresh air is relied on to bring warmth, its flow must be positive and regular, which requires that the ventilating scheme must be quite reliable in its operation. It follows that if the air movement is more or less a failure or uncertain, the warming of the place must suffer accordingly.

Fig. 154 [1] illustrates an indirect radiator, built up of sections nippled together, and its size may be anything according to the work to be done. The ordinary type of radiator is not used for this work, as the spaces between the sections are too open to admit of the air being properly warmed as it passes through. To effect the warming of the air the radiator sections are given gills (or webs or pins), so that the finished article may be said to resemble a strainer or filter, as the air spaces, while allowing a fully sufficient flow of air, are so contracted as to cause practically all the air to rub against the hot surfaces. These gills, too, are extensions of the heating surface, so that the space occupied is less than it would be if the radiator were built up of tubes with plain surfaces. As stated, some indirect radiators have the tubes gilled, as shown, while others are thickly pinned or have short ribs arranged on the surfaces. In all cases the results aimed at are alike.

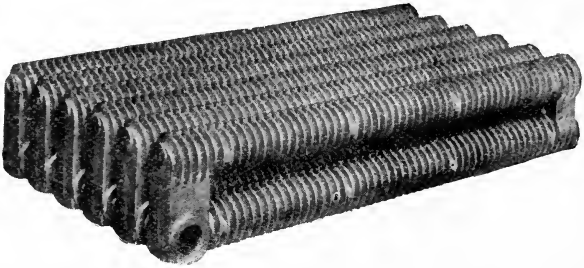

FIG. 154.—Indirect radiator.

Fig. 155 shows a single radiator fixed in position. Four rods of ½-inch iron, with screw holes at the ends which are secured to the joists, and hooks at their lower ends, carry two pieces of ½-inch or ¾-inch tube placed horizontally, and on these the radiator will securely rest. Suspended in this way it will, too, give to the movements of expansion and contraction, should there be any. The whole is encased with a

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[1] National Radiator Company, Ltd.

wooden box casing, this being lined with zinc or galvanized sheet iron. Occasionally a surrounding of wire netting is adopted, this being plastered over, but there is not such a certainty of this remaining sound and air-tight. In many instances it is important that the casing be air-tight, as its situation may be at a point where the surrounding air is not sweet. In one instance the writer had to make such a casing at the ceiling of a kitchen, and it followed that had there been a fissure the odours of cooking would have been delivered with the warmed air.

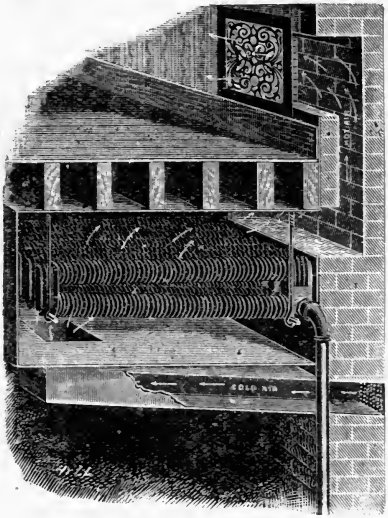

FIG. 155.—Indirect radiator in position.

The fresh air is brought by an air-tight tube (of any shape) from the nearest source where it can be had pure and untainted, and it should enter the radiator chamber at a point as remote as possible from the warm air outlet.

The warm air outlet is customarily arranged to come in the wall as illustrated, the air entering the room through an adjustable grating known as a "register." These registers can now be had in very good designs and in every required size. The mechanism which controls the flow of air through the register too, is ingenious, yet simple and not likely to get out of order. Occasionally the warm air outlet and its register are arranged to come in the floor, over the middle of the radiator or thereabouts. This is a cheaper arrangement as a rule, but has the great disadvantage of causing the radiator to become loaded with dirt in a short time. Servants have even been known to purposely sweep dirt through floor registers to save the trouble of using a dust pan.

It was just stated that the warm-air register had mechanism to adjust the flow of air, but, although there may be occasions when it is desirable to use this, it is not a good plan to reduce the warmth of the room by it. If a room should be too warm, by reason of the water being too hot, or the sun shining on the room, or an extra number of people being in it, then it is better to reduce the temperature of the incoming air rather than reduce its volume. To effect this a "mixing damper" may be used, this being a simple device by which part of the new air can come through the radiator chamber without passing through the radiator, and mixing with the warmer air as it flows through the register into the room. Fig. 156 illustrates this, and it will be seen how simply the valve can be controlled from the room.

Radiators used in this work are connected up on any of the piping systems described in this book, and each radiator should be provided with stop-valve and air-cock, both these coming outside the casing. All radiator cases or chambers should have a door or similar opening by which access to the radiator may be had for brushing and cleaning the heating surfaces.

It will be understood that one radiator, if of suitable size, can be arranged to heat two or more rooms. When this is done rooms are generally chosen which come over one another, so that a warm-air tube or duct may go straight up the wall (on the face of the wall or chased in) with registers opening into the rooms on the different floors. The duct in this case commences in a full size and is reduced as it passes each register.

In making warm-air chambers, as just described, the sides may come fairly close to the radiator, but beneath the radiator the least depth should be 6 inches, while the space above should not be less than 8 inches.

Quantities for Indirect Heating.—When rooms are warmed wholly by air passing over hot-water radiators which are not in the rooms, the radiators being of proper "indirect" design, the calculation for area of radiation resolves itself into finding the volume of air that will pass through the rooms per hour and then ascertaining the number of B.Th.Us. required to give it the necessary temperature. This plan is supposed to cover all losses by walls, window glass, ceilings, etc.

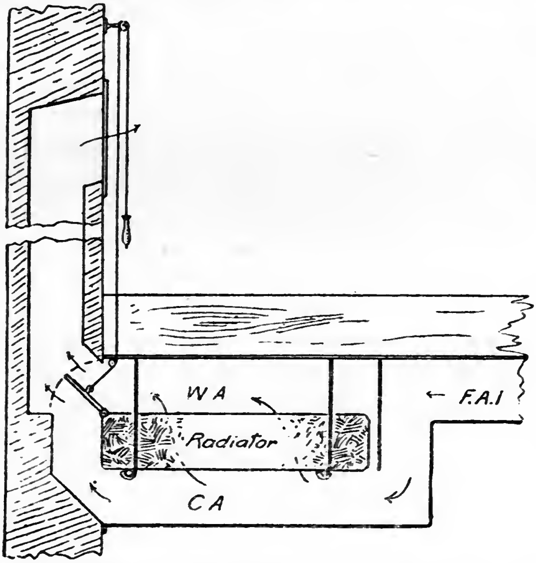

FIG. 156.—Valve in indirect radiator chamber, to admit of cold air being mixed with the heated air, as required.

On page 153 it is shown that for common purposes it is allowed that 1 B.Th.U. will raise the temperature of 50 cubic feet of air 1° Fah., therefore if the volume is ascertained and the required rise in temperature known, the calculation is a simple one. It is generally better to ask the radiator makers what heat emission their particular make of radiator will afford per square foot or per section, rather than work on one fixed figure for all makes of these, as much depends on the area of gills or pins or other extensions of the surfaces, also the grouping of the loops, etc.

In finding the rise in temperature for the air it has to be remembered that it will be outdoor air that comes to the radiators and this, for coldest weather, is assumed to be 30° F.

The air leaving the radiator has to be much warmer than the required general air temperature of the room, and assuming that the room gets no warmth by other means then the air leaving the radiator chamber (for ordinary average temperature in the room) has to be 100° F.

The volume of air allowed per person in public rooms, schools, hospitals, etc., is given on page 276, but for ordinary living-rooms, offices and the like, three changes of air per hour is considered sufficient.

As an example calculation on the foregoing basis let it be supposed that a fairly large room has 10,000 cubic feet of space in it, which changed three times per hour makes 30,000 cubic feet of air to be warmed per hour. The rise in temperature is from 30° (outside) to 100° (leaving the radiator) which amounts to 70°. 30,000 cubic feet of air raised 70° requires ($30{,}000 \div 50 \times 80 =$) 42,000 B.Th.U. required per hour.

Finally it has to be mentioned that for indirect heating the water is kept at a higher temperature than ordinary direct work. Calculations for indirect heating are based on the water being of a mean temperature in the radiators of about 180° F. when doing duty in coldest weather.

Sizes of Warm and Cold Air-ducts.—For indirect hot-water work the warm-air delivery tubes or ducts should have an area of 2 square inches for each square foot of surface in the radiator; thus a 50-foot radiator would have a delivery duct of 100 square inches, equal to, say, a 12½-inch by 8-inch tube. At the point of delivery the warm-air duct should open out and be fitted with a register (grating) which has a clear space through it of about one-fourth greater area than the duct. Registers, as a rule, have a clear opening of about one-third less than the face measurement of the grating. A good make of register (examined by the writer), measuring

12 inches by 16 inches across the grating, had 128 inches of clear space, and this would be the size for the 100 square inch duct just mentioned.

When a radiator and its warm-air chamber are arranged to heat more than one room, then the size of the duct and its reductions in size may be calculated on the following basis. For the area of radiation allowed to the ground floor the duct should have an area of 2 square inches per foot of radiation (as already stated); for the first floor, 1¼ to 1½ square inch per foot; while for a second floor, 1 square inch per foot is sufficient. A duct, like a chimney, has the velocity of its draught increase rapidly with its height, and the reduction in area this admits of is not only a saving in cost, but is necessary to prevent the upper floors taking an undue share of the heated air.

The cold-air supply duct or tube should be three-fourths the area of the warm-air duct, or three-fourths the total area of all warm-air ducts if there is more than one. The reason for making the fresh-air duct of this area, the warm-air duct larger, and the register opening still larger, is partly to allow for the warmed air becoming expanded and being of greater bulk; but, more important, it is to reduce velocity of discharge through the warm-air registers. The flow of warmed air into the rooms should be gentle and unnoticeable.

There are no obstacles to the fixing of indirect hot-water radiators as regards their proximity to woodwork or inflammable material; nor are the warm-air ducts from these subject to any vexatious regulations by local or other authorities, nor are Fire Insurance policies affected in any way. These things are mentioned, as quite the reverse applies with warm-air works when the heater is a stove (see extracts from London Building Act, in Appendix).

Air Extraction from Rooms.—It will be understood that while indirect radiators may be properly fixed, the cold and warm air ducts provided of suitable size, and general details arranged correctly, the whole must fail if provision for ensuring a sufficient and continuous air movement is not made. The mere fact of enclosing the radiator—even at the foot of a vertical delivery duct—will not cause the warmed air to enter and pass through the room in a satisfactory manner, if at all. There has to be some distinct active force at work independently of any movement to the air that contact with the radiator might create.

As a rule, with indirect hot-water installations of moderate size, the air movement arranged for is that of extraction —a provision for extracting the vitiated air from the room or rooms, this bringing about a corresponding inflow of new air which, of course, is arranged to come through the ducts from the radiator chamber.

Air extraction for moderate requirements is best obtained by brickwork flues (like chimneys) the chimney of a room often being made to do duty, as, assuming it has a normally good up-draught in it, it will extract air from a room in fully sufficient volume for general requirements. If a house or place was built expressly to be warmed by heated air, and chimneys were dispensed with, then ventilating shafts would have to be provided as a detail in the building construction, and the rule that is given on page 277 should be worked to. Ordinary chimneys may be said never to err on the side of being too small to ventilate any room in a residence, and it is only when ducts for the vitiated air have to be made or built expressly that their size must be calculated.

When the extraction of cooled and vitiated air and the supply of new warmed air has to be calculated at per head, then the following table must be worked to :—

CUSTOMARY VOLUMES OF AIR ALLOWED PER PERSON IN INSTITUTIONS AND PUBLIC PLACES

	Cubic feet per minute.
Schools, infants	28 to 30
,, scholars of full age . .	30 to 32
,, dormitories	25 to 28
Workrooms, slight exertion, air not vitiated by the trade followed	35 to 40
,, full exertion . . .	45 to 50
Public halls, meeting-rooms . .	35
Ballrooms	45
Theatres, dining-halls . . .	35
Hospitals, ordinary wards and rooms .	45

Volume of Air in Cubic Feet Extracted per Minute by a Ventilating Shaft of One Square Foot Area

No allowance made for friction; deduct 35 to 50 per cent. for this, according to height and size of shaft.

Height of Ventilating Shaft in Feet	Excess of Temperature of Air entering the Ventilating Shaft, above the External Air					
	5°	10°	15°	20°	25°	30°
10	116	164	200	235	260	284
15	142	202	245	284	318	348
20	164	232	285	330	368	404
25	184	260	318	368	410	450
30	201	284	347	403	450	493
35	218	306	376	436	486	531
40	235	329	403	465	518	570
45	248	348	427	493	551	605
50	260	367	450	518	579	635

It is requisite to mention that a ventilating shaft must have the same consideration as a smoke flue in regard to its upper termination. Although the table may show that a short shaft will meet the requirements, still it must go to the top of the building and up above its highest ridge. If not, it will suffer with down-blow or retarded up-draught (when certain winds are blowing), the same as a fireplace chimney. A ventilating shaft must be considered as a chimney in regard to its height and those conditions which ensure its having a permanent up-draught of regular speed.

If these shafts are built in brick-work during the construction of the building, they may be carried up separately and terminate either singly or in stacks as brick chimneys do, but if a hot-air apparatus is installed in an existing building and the heating engineer has to provide metal ventilating shafts, then it is the custom to connect several, or all of them, into one main shaft (which usually runs along or through the attic or roof space), and carry this up and out like a chimney.

It would not be possible, nor sightly, to carry a number of single metal tubes up through a roof. In certain necessary cases a gas ring is put in the base of the main shaft (to stimulate the draught) or a mechanically driven air propellor.

Direct-Indirect or Ventilating Radiators.—In concluding the subject of warming air by hot-water radiators, a short description may be given of the "direct-indirect" or "ventilating" radiator. This is a radiator devoted to warming a current of fresh air which is continually passing through it, but the radiator itself is fixed and visible in the room, and affords radiant heat and does something towards re-heating the air contained in the room. In nearly all cases the air inlet to the radiator is so arranged that the flow of fresh air can be partially or wholly shut off, and the radiator

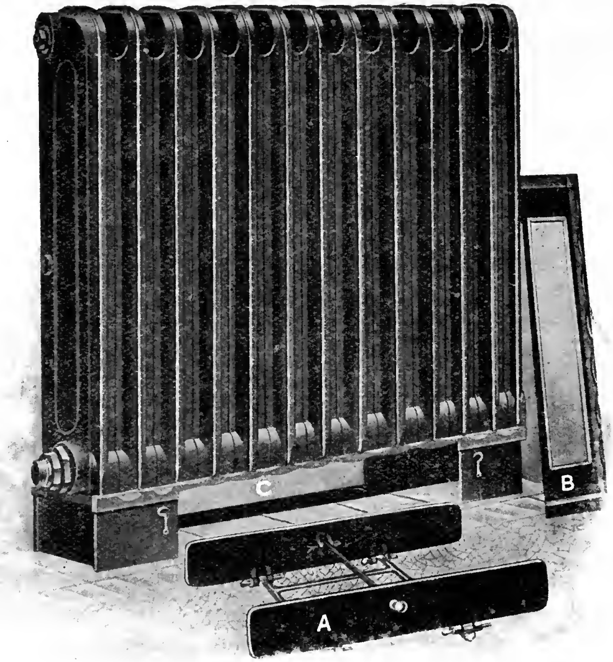

Fig. 157.—Ventilating radiator.

made to partially or wholly heat and re-heat the air already in the room. It is the practice in some places to nearly or quite close the fresh-air inlets in very severe weather.

Fig. 157 illustrates a radiator of this kind, with its fresh-air inlet at the back close to the floor. They can also be had

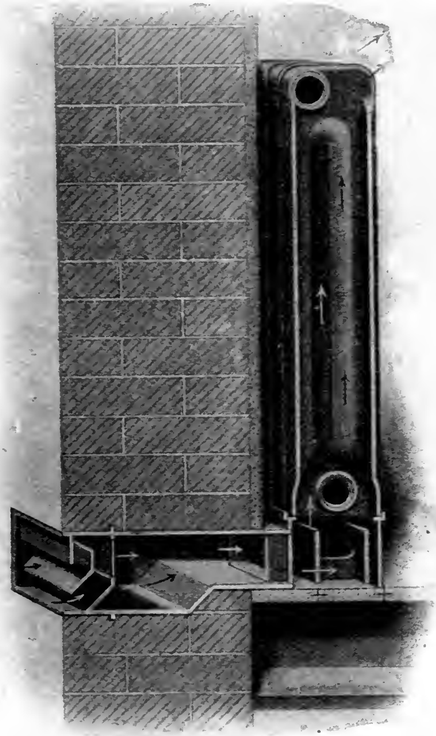

FIG. 158.—Ventilating radiator (section) to show passage of air.

with extreme bottom inlets for the air to come up vertically from below. The sections of these radiators are of a design that, when connected up, forms a number of vertical air flues up through the radiator, so that the incoming air cannot pass into the room by any short route, but must be warmed by intimate contact with the heated surfaces. Fig. 158 is a section of the radiator, showing the front and rear valves, which, as previously stated, allow either new air, or the air of the room, to partially or wholly pass up through the radiator.

Fig. 159 illustrates a means by which an ordinary radiator is made to do partially indirect duty. There is an air inlet through the wall, as just illustrated (though usually a few inches higher) and the baffle plates fitted to the front of the radiator ensure good contact of the air with the hot surfaces. There are a number of designs of this type of radiator, there being some indication of its being preferred to the radiator made expressly for ventilating requirements. The flow of

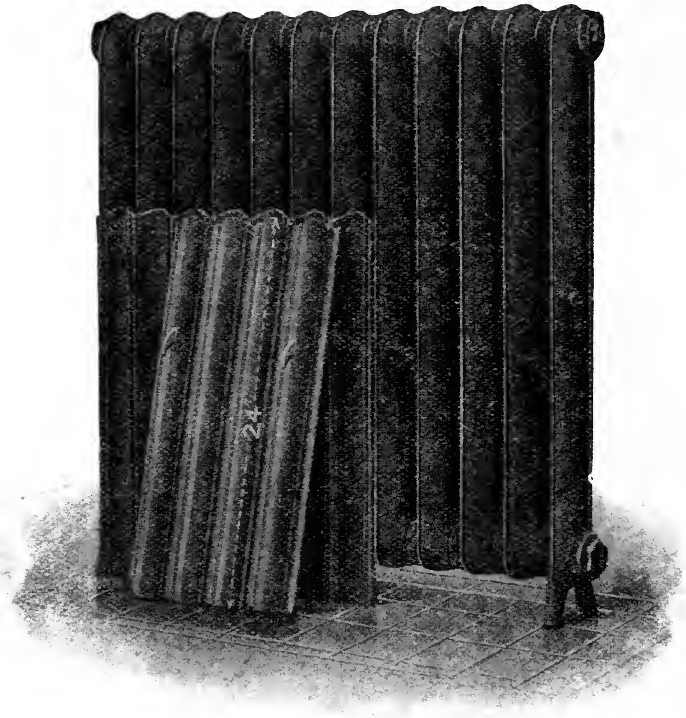

Fig. 159.—Ordinary radiator with baffle plates to obtain the effect of a ventilating radiator.

air is simply controlled by a small lever operating the adjustable air-inlet opening.

These different forms of ventilating radiators are connected up on any of the ordinary piping systems, and are furnished with stop-valves and air-cocks in the usual way.

As to calculating the amount of radiating surface required to afford certain temperatures by means of ventilating radiators (those visible in the rooms) there is a great element of uncertainty in the extent to which the air inlet will be opened or used. If always full open the radiator would be doing duty almost wholly like an indirect radiator, while if the air inlet is closed in cold weather, the radiator (for heating surface) could be considered as an ordinary direct heating radiator. As it is so difficult to decide this point with precision a common, and usually satisfactory, practice is to calculate as for ordinary direct radiation, then add 25 per cent. if it is known that the inlet ventilator will be used in moderation, or 50 per cent. if it is known that the intention is to have as full ventilation as is possible at all times.

The additional surface suggested is needed to allow for the room having more changes of air than rooms usually have when not specially ventilated, and the fact that the radiator receives the air first hand when it is at its coldest.

Outlet (i.e. extract) ventilation (usually a chimney) is as necessary for the efficient air-heating effect with these radiators as it is with indirect work.

The Institution of Heating and Ventilating Engineers.

Table of Symbols and Abbreviations, particularly useful in the Science and Practice of Heating and Ventilation, recommended by the Standardization Committee and adopted by the Institution at the Autumnal General Meeting, Oct. 10, 1916.

Notation	Signification
θ̶	"Therm." A synonym for the "British Thermal Unit." The Therm may be defined as the amount of heat absorbed by 1 lb. of water for a rise in temperature of 1 degree Fahr., the slight variation at normal temperatures being ignored for practical purposes under this term.
/	"Per." Ex:—5000θ̶/hr. (5000 therms per hour).
ft^2 or $\boxed{f}$	Square foot.
in^2 or $\boxed{''}$	Square inch.
ft^3 or ₵	Cubic foot.
in^3 or C''	Cubic inch.
°d	Degree difference.
T	Absolute Temperatures. Context indicating which scale.
t	Ordinary Temperatures. Context indicating which scale.
t_1 t_2	Initial and final temperatures.
ρ	Coefficient of friction for flow of fluids through conduits.
ζ	Coefficient of loss of energy in fluid streams due to passing single resistances.

The above table is supplementary to those symbols, etc., already generally adopted in Physics, Mathematics and Engineering.

APPENDIX

SYMBOLS FOR THE USE OF HEATING ENGINEERS

It had been felt that the time had arrived for Heating Engineers to have and use Symbols to represent and act as a means of shortening the many common terms and descriptions used in Heating work, particularly those employed in calculating or in expressing necessary sentences used in calculations. This has long been done on quite a perfected scale by the Electrical Engineer, but the Heating Engineer has but very few symbols indeed connected with his calling, practically the only important one being "*K*," which has been in regular use a few years and which will be seen in the following list.

Realizing this want the Institution of Heating and Ventilating Engineers arranged for the formation of a Committee to investigate this question—of which Committee the writer was a member—and the arrangement of symbols shown on the opposite page was arrived at. But, realizing that other technical and scientific bodies would be closely interested in so important a question, it was decided that the different Engineering Societies should be circularized to secure, if possible, their general agreement. This was as far as the matter had progressed at the time of going to press.

EXTRACTS FROM THE LONDON BUILDING ACT, 1894, RELATING TO WORK EXECUTED BY HEATING ENGINEERS.[1]

Fire-place Openings.—"The jambs of every fire-place opening shall be at least eight and a half inches wide on each side.

"The breast of every chimney and the brickwork surrounding a chimney shall be at least four inches in thickness.

"A party wall at the back of every fire-place opening from the hearth up to a height of twelve inches above the mantel shall be at least eight and a half inches thick." (*This is insufficient if a skirting board, or dresser, or other woodwork is on the other side. The heat from a bath-boiler flue will char it. One inch of silicate cotton should be inserted in such cases.*—F. D.)

Fire-place Hearths, (and see Stove Hearths, next page).—"There shall be laid level with the floor of every storey before the opening of every chimney a slab of stone, slate, or other incombustible substance, at the least six inches longer on each side than the width of such opening, and at the least eighteen inches wide in front of the breast thereof.

"On every floor except the lowest floor such slab shall be laid wholly upon stone or iron bearers or upon brick trimmers or other incombustible materials, but on the lowest floor it may be bedded on concrete covering the site or on solid materials placed on such concrete.

"The hearth . . . . shall be solid for a thickness of six inches at least beneath the upper surface of such hearth."

Cutting into Chimneys.—"A chimney breast or flue shall not be cut into except for the purpose of repair or during some one or more of the following things :—

(*a*) Letting in or removing or altering flue pipes or funnels for the conveyance of smoke, hot air, or steam, or letting in, removing, or altering smoke jacks.

(*b*) Forming openings for soot doors, such openings to be fitted with close iron door and frame.

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[1] *Note.*—These regulations have not been affected by the later amending Acts.

(*c*) Making openings for the insertion of ventilating valves subject to the restriction that an opening shall not be made nearer than twelve inches to any timber or combustible substance."

Distance of Flues, etc., from Woodwork.—" Timber or woodwork shall not be placed :—

(*a*) In any wall or chimney breast nearer than twelve inches to the inside of any flue or chimney opening.

(*b*) Under any chimney opening within ten inches from the upper surface of the hearth of such chimney opening.

(*c*) Within two inches from the face of the brickwork or stonework about any chimney or flue where the substance of such brickwork or stonework is less than eight and a half inches thick, unless the face of such brickwork or stonework is rendered.

" Wooden plugs shall not be driven nearer than six inches to the inside of any flue or chimney opening, nor any iron holdfast or other iron fastening nearer than two inches thereto."

Stove Hearths.—" The floor under every oven, copper, steam-boiler or stove, which is not heated by gas, and the floor around the same shall for a space of eighteen inches be formed of materials of an incombustible and non-conducting nature not less than six inches thick."

Flue Pipes, Steam Pipes and Hot-air Pipes.—" A pipe for conveying smoke or other products of combustion, heated air, steam, or hot water, shall not be fixed against any building on the face adjoining to any street or public way.

" A pipe for conveying smoke or other products of combustion shall not be fixed nearer than nine inches to any combustible materials. (*It is as well to exceed this distance when carrying sheet iron pipe beneath ceilings or near light woodwork, for should the pipe have its soot catch alight it may get red hot.*—F. D.)

" A pipe for conveying heated air or steam shall not be fixed nearer than six inches to any combustible materials " (*see below*).

Hot-water Pipes.—" A pipe for conveying hot water shall not be placed nearer than three inches to any combustible materials (*see below*).

" Provided that the restrictions imposed by this section with respect to the distance at which pipes for conveying hot water or steam may be placed from any combustible materials shall not apply in the case of pipes for conveying hot water or steam at low pressure."

Exemptions when a Heating Apparatus has a " free blow-off."—For the purposes of this section hot water or steam shall be deemed to be at low pressure when provided with a free blow-off." (*This qualifying clause gives liberty to run ordinary low pressure hot-water pipes close against woodwork, as is commonly done ; but with a low-pressure gravity steam apparatus working at* 5 *lb. to* 10 *lb. pressure, returning its own water to the boiler, and being therefore closed and having no free blow-off, a six-inch limit must be observed. This is not reasonable, as a low-pressure hot-water apparatus extending up say fifty feet, can have its water raised to a higher temperature than* 10 *lb. steam. Again, an exhaust steam apparatus with a free blow-off may oftentimes be served with steam at a much higher temperature than that in a low pressure closed gravity circulation. It will be seen that small-bore hot-water pipes (high-pressure or with valve) must be kept three inches from woodwork, which is three inches less than a steam pipe, though it is known that high-pressure pipes attain high temperatures, always far higher than low-pressure steam. It is a very awkward clause for the steam heating engineer, as a steam heating apparatus seldom has a free blow-off.*—F. D.)

Floors over Furnaces and Ovens.—" The floor over any room or enclosed space in which a furnace is fixed, or any floor within eighteen inches from the crown of an oven shall be constructed of fire-resisting materials."

TABLES

TABLE I.—TEMPERATURES THAT CAN BE ACQUIRED BY WATER (OR STEAM) AT CERTAIN PRESSURES (OR THE PRESSURE EXERTED BY WATER (OR STEAM) WHEN HEATED TO ABOVE 212° F. IN CONFINEMENT).—*Box.*

The pressures given are those which would appear on a pressure gauge. What is known as Total or Absolute Pressures are 14·7 lb. per square inch higher, which is the addition of Atmospheric pressure.

Gauge Pressure in lbs. per sq. in.	Temp. Fahr.	Gauge Pressure in lbs. per sq. in.	Temp. Fahr.	Gauge Pressure in lbs. per sq. in.	Temp. Fahr.
0 (atmospheric pressure)	212°	30	274°	90	331°
1	215	32	277	92	333
2	219	34	279	94	334
3	222	36	282	96	335
4	224	38	284	98	336
5	227	40	286	100	338
6	230	42	289	102	339
7	232	44	291	104	340
8	235	46	294	106	342
9	237	48	296	108	343
10	239	50	298	110	344
11	241	52	300	115	347
12	244	54	302	120	350
13	246	56	304	125	353
14	248	58	305	130	355
15	250	60	307	135	358
16	252	62	309	140	361
17	253	64	311	145	363
18	255	66	313	150	366
19	257	68	314		
20	259	70	316	160	370
21	260	72	318	170	375
22	262	74	319	180	380
23	264	76	321	190	384
24	265	78	322	200	388
25	267	80	324	220	396
26	268	82	325	250	406
27	270	84	327	270	413
28	271	86	328	300	422
29	272	88	330		

The above table shows the pressures accompanying the high temperatures of the water in a small-bore high-pressure hot-water apparatus when in use,

TABLE II.—HEIGHT OR CONTRACTION OF EQUIVALENT COLUMNS OF WATER AT DIFFERENT LOWER TEMPERATURES, THE HEIGHT AT 212° F. BEING ONE FOOT.—*Box.*

Temperature of Water, Fahr.	Height of Column in inches.	Difference from 212° in inches.	Temperature of Water, Fahr.	Height of Column in inches.	Difference from 212° in inches.
212°	12·000	·000	122°	11·647	·353
202	11·954	·046	112	11·611	·389
192	11·908	·092	102	11·599	·401
182	11·868	·132	92	11·570	·430
172	11·824	·174	82	11·550	·450
162	11·783	·217	72	11·532	·468
152	11·746	·254	62	11·518	·482
142	11·710	·290	52	11·508	·492
132	11·677	·323	42	11·502	·498

Amongst the uses this table may serve, is that of calculating the heights to which expansion pipes of hot-water apparatus should be carried above cold-water cisterns. It will be seen that water heated from 42 degrees to 212 degrees F. has its column increased ½ inch per foot.

TABLE III.—HYDRAULIC MEMORANDA.

A cubic foot of water weighs	62·32 lb.
A ,, ,, ,, contains	6·232 gals.
A ,, ,, ,, ,,	28·375 litres.
A ,, ,, ,, ,,	·0283 cub. metre.
A ,, inch ,, weighs	·03616 lb.
A cylindrical foot of water weighs	48·96 lb.
A ,, inch ,, ,,	·0284 lb.
An imperial gallon contains	277·274 cub. in.
An ,, ,, ,,	·16046 cub. ft.
An ,, ,, weighs	10 lb.
An ,, ,,	=1·2 U.S. gals.
An ,, ,,	=4·537 litres.
1 lb. of water	=27·72 cub. in.
,, ,,	=·1 imp. gal.
,, ,,	=·4537 kilo.
1 cwt. ,,	=11·2 imp. gals.
,, ,,	=1·8 cub. ft.
A ton of water contains	35·84 cub. ft.
A ,, ,, ,,	224 gals.
A column of water 12 in. high, 1 in. square weighs	·434 lb.

TABLE III.—*continued.*

A column of water 12 in. high, 1 in. square contains	·0434 gal.
A column of water 2·31 ft. high weighs	1 lb.
A ,, ,, 1 metre ,, ,,	1·43 lb.
Cubic feet × 6¼ (nearly exact)	= gals.
Gallons × ·16	= cub. ft.
Expansion of water heated from 39° (its point of greatest condensation) to 212°.	1 in 24
Expansion of water in freezing	1 in 12
1 litre of water	= ·22 imp. gals.
1 ,, ,,	= 61 cub. ins.
1 ,, ,,	= ·0353 cub. ft.
1 cubic metre of water	= 220 imp. gals.
1 ,, ,, ,,	= 1·308 cub. yd.
1 ,, ,, ,,	= 35·31 cub. ft.
1 ,, ,, ,,	= 61028 cub. ins.
1 ,, ,, ,,	= 1000 kilos.
1 ,, ,, ,,	= 1000 litres.
1 ,, ,, ,,	= 1 ton (about).
1 kilo of water	= 2·204 lbs.
Mercury column 1 in. high	= ·490 lb. per sq., in.
,, 2·04 ,,	= 1 lb. ,, ,,

TABLE IV.—QUANTITIES RELATING TO PIPES.

Size of Pipe.	Gallons per lineal foot.	Square feet of external surface to one lineal foot.	Size of Pipe.	Gallons per lineal foot.	Square feet of external surface to one lineal foot.
inches.	gallons.		inches.	gallons.	
½	·0084	—	3	·3056	·92
¾	·0191	·27	4	·5433	1·17
1	·0339	·34	5	·8490	—
1¼	·0529	·43	6	1·2226	—
1½	·0764	·50	8	2·1762	—
2	·1358	·62	10	3·4010	—
2½	·2122	·75	12	4·9	—

If the decimal point is removed one place to the right, the number will be per 10 feet; if point be removed two places to the right, the number will be per 100 feet.

A rough and ready method of estimating the contents of pipes is— square the diameter of the pipe and mark off one decimal point to give gallons in 1 yard: 4×4=1·6 gal., 6×6=3·6, 9×9=8·1 gals. per yard (3 ft.).

TABLE V.—RELATIVE AREAS OF WROUGHT IRON PIPES, FROM $\frac{1}{2}$ TO 6 INCHES INCLUSIVE.

(No Allowance for Friction if contents are in motion. This appears in the next table.)

Sizes.	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4	5	6
$\frac{1}{2}$	1	$2\frac{1}{4}$	4	$6\frac{1}{4}$	9	16	25	36	64	100	144
$\frac{3}{4}$	..	1	$1\frac{7}{9}$	$2\frac{7}{9}$	4	$7\frac{1}{9}$	$11\frac{1}{9}$	16	$28\frac{1}{9}$	$44\frac{4}{9}$	64
1	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$	4	$6\frac{1}{4}$	9	16	25	36
$1\frac{1}{4}$	..	..	..	1	$1\frac{11}{25}$	$2\frac{14}{25}$	4	$5\frac{19}{25}$	$10\frac{6}{25}$	16	$21\frac{11}{25}$
$1\frac{1}{2}$	..	..	..	..	1	$1\frac{7}{9}$	$2\frac{7}{9}$	4	$7\frac{1}{9}$	$11\frac{1}{9}$	16
2	..	..	..	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$	4	$6\frac{1}{4}$	9
$2\frac{1}{2}$	..	..	..	..	..	..	1	$1\frac{11}{25}$	$2\frac{14}{25}$	4	$5\frac{19}{25}$
3	..	..	..	..	..	..	..	1	$1\frac{7}{9}$	$2\frac{7}{9}$	4
4	..	..	..	..	..	..	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$
5	..	..	..	..	..	..	..	..	..	1	$1\frac{11}{25}$
6	..	..	..	..	..	..	..	..	..	..	1

This table shows at a glance the relative areas of different sized pipes. Thus, if it was required to be known how many $1\frac{1}{4}$-inch pipes have an aggregate area equal to one 3-inch pipe, it is only necessary to take the line from $1\frac{1}{4}$ inch in the left-hand column and follow it until beneath the larger size at the top of the table. The figure given, it will be seen, is nearly 6; in other words, a 3-inch pipe of a given length carries or holds nearly six times as much as a $1\frac{1}{4}$ inch pipe. By reversing the process, the number of small pipes that equal a large pipe can be found, the larger size being found in the top column and followed down until opposite the small size in the left-hand column. Allowance for friction appears in the next table.

TABLE VI.—NUMBER OF SMALL PIPES REQUIRED TO MAKE AN AREA EQUAL TO ONE LARGER PIPE—*R. C. Carpenter.*

(With Allowance for a moderate degree of Friction.)

Size of Pipe.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	4 in.	5 in.	6 in.
½ inch	1	2·5	4·7	7·6	11·3	19	37	55	108	188	290
¾ ,,	..	1	2·0	3·7	5·4	9·2	16·7	25·5	53	90	143
1 ,,	..	..	1	2·0	3·1	5·1	9·3	14·7	30	53	80
1¼ ,,	..	..	..	1	1·7	2·6	4·5	7·3	14·7	25	39
1½ ,,	..	..	..	..	1	2·0	3·1	4·7	9·8	16·8	26
2 ,,	..	..	..	..	..	1	2·0	2·9	5·8	9·9	16
2½ ,,	..	..	..	..	..	..	1	1·7	3·5	5·9	9·3
3 ,,	..	..	..	..	..	..	..	1	2·4	3·5	5·4
4 ,,	..	..	..	..	..	..	..	..	1	1·8	2·7
5 ,,	..	..	..	..	..	..	..	..	..	1	1·7
6 ,,	..	..	..	..	..	..	..	..	..	..	1

It has always to be recognized that when liquids or gases are flowing through pipes the resistance caused by friction increases (for a given area) as the pipes get smaller. Thus it will be seen in the above table that it requires practically 4¾ pipes of ½ in. diameter to allow of the same flow of liquid as one pipe of 1 in. diameter, although in actual area the 1 in. pipe is only equal to four of ½ in. diameter.

TABLE VII.—Pressure of Water in Cold-Water Pipes.

Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.
1	0·43	41	17·75	81	35·08
2	0·86	42	18·19	82	35·52
3	1·30	43	18·62	83	35·95
4	1·73	44	19·05	84	36·39
5	2·16	45	19·49	85	36·82
6	2·59	46	19·92	86	37·25
7	3·03	47	20·35	87	37·68
8	3·46	48	20·79	88	38·12
9	3·89	49	21·22	89	38·53
10	4·33	50	21·65	90	38·99
11	4·76	51	22·09	91	39·42
12	5·20	52	22·52	92	39·85
13	5·63	53	22·95	93	40·28
14	6·06	54	23·39	94	40·72
15	6·49	55	23·82	95	41·15
16	6·93	56	24·26	96	41·58
17	7·36	57	24·69	97	42·01
18	7·79	58	25·12	98	42·45
19	8·22	59	25·55	99	42·88
20	8·66	60	25·99	100	43·31
21	9·09	61	26·42	101	43·75
22	9·53	62	26·85	102	44·18
23	9·96	63	27·29	103	44·61
24	10·39	64	27·72	104	45·05
25	10·82	65	28·15	105	45·48
26	11·26	66	28·58	106	45·91
27	11·69	67	29·02	107	46·34
28	12·12	68	29·45	108	46·78
29	12·55	69	29·88	109	47·21
30	12·99	70	30·32	110	47·64
31	13·42	71	30·75	111	48·08
32	13·86	72	31·18	112	48·51
33	14·29	73	31·62	113	48·94
34	14·72	74	32·05	114	49·38
35	15·16	75	32·48	115	49·81
36	15·59	76	32·92	116	50·24
37	16·02	77	33·35	117	50·68
38	16·45	78	33·78	118	51·11
39	16·89	79	34·21	119	51·54
40	17·32	80	34·65	120	51·98

This table is of service when calculating pressures in closed tanks, pipes, or boilers. A pressure of 1 lb. per square inch is obtained by a head of water of 2·31 ft., or say 2 ft. 4 in. A common practice is to allow 1 lb. for every 2-ft. head, which admits of quick calculation, and what error is made is on the right side. Thus, a 30-ft. head would be said to afford a pressure of 15 lbs. to the square inch, but the correct pressure would be 13 lbs. only.

The size of pipe makes no difference to the pressure, nor does the size of the cistern which may be at the head of the pipe. In ascertaining pressure, the *perpendicular* measurement *only* is taken from the level of water in the cistern to the point where the pressure is to be experienced, and, as stated, 0·43 lb. pressure is allowed to each foot, or 2 ft. 4 in. to the pound.

TABLE VIII.—HEAT-CONDUCTING POWER OF MATERIALS (COMPARATIVE).

Copper	515	Gutta-percha	1·38
Iron	233	India-rubber	1·37
Zinc	225	Brick dust, fine	1·33
Lead	113	Coke dust	1·29
Marble, fine-grained	28	Cork	1·15
,, coarse-grained	22·4	Chalk, powdered	·869
Stone, fine	16·7	Straw, chopped	·563
,, ordinary	13·68	Coal dust	·547
Glass	6·6	Wood ashes	·531
Bricks	4·83	Sawdust, mahogany	·523
Plaster	3·86	Canvas, new	·418
Oak, across the grain	1·70	Calico ,,	·402
Walnut ,,	·83	White writing paper	·346
Fir ,,	·748	Cotton wool or sheep's wool, any density	·328
,, with the grain	1·37	Eider down	·314
Walnut ,,	1·40		

RESISTANCE TO CONDUCTIVITY.

Hair Felt	1·000	Gas-house carbon	·570
Silicate cotton	·832	Asbestos	·363
Sawdust	·686	Coal Ashes	·343
Pine wood	·553		

These tables are of use in showing the loss of heat that can occur from pipes and other surfaces, and the efficiency of the various materials used to prevent loss of heat.

TABLE IX.—TESTS OF VARIOUS PIPE COVERINGS, MADE AT SIBLEY COLLEGE, CORNELL UNIVERSITY, *by Professor R. C. Carpenter.*

Kind of Covering.	Relative Amount of Heat transmitted.
Naked pipe	100
Two layers asbestos paper, 1 inch hair felt and canvas cover	15·2
,, ,, 1 inch hair felt, canvas cover, wrapped with manilla paper	15·0

TABLE IX.—*continued.*

Kind of Covering.	Relative Amount of Heat transmitted.
Two layers asbestos paper, 1 inch hair felt	17·0
Hair felt sectional covering, asbestos lined	18·6
One thickness asbestos board	59·4
Four thicknesses asbestos paper	50·3
Two layers asbestos paper	77·7
Wool felt, asbestos lined	23·1
,, with air spaces, asbestos lined	19·7
,, plaster of Paris lined	25·9
Asbestos moulded, mixed with plaster of Paris	31·8
,, felted, pure long fibre	20·1
,, and sponge	18·8
,, and wool felt	20·8
Magnesia, moulded, applied as a plaster	22·4
,, sectional	18·8
Silicate cotton (slag wool) sectional	19·3
Rock wool, fibrous	20·3
,, felted	20·9
Fossil meal, ¾ inch thick	29·7
Pipe painted with black asphalt	105·5
,, ,, light drab lead paint	108·7
Glossy white paint	95·0

Much information is afforded by this series of tests. It shows conclusively that although we have distinctly good and bad conductors of heat, their efficiency in these respects depends very greatly on conditions. Materials applied loosely act as barriers of heat much better than the same substances tightly bound on, or ground up and plastered on. Hair felt, which the writer considers the most successful material in conserving heat, owes much to its being made up in a semi-loose state, much as nature puts the hair on the skins of animals. The felt consists more of air interstices than it does of hair, and were it ground up and plastered on the heated surface its effectiveness could not fail to be largely diminished.

These tests also show what has been referred to in this book when treating of the efficiency of radiators, that paint has practically no effect in reducing the heat-distributing power of the iron, but in some cases actually improves it. It may be considered that paints can be safely used on radiating surfaces, irrespective of the colours required.

TABLE X.—Showing the Saving effected by several Kinds of Coatings (*Beeston Foundry Co., Ltd.*).

Thickness of Coating.	Percentage saving on emission from bare pipe.			
	¾ in.	1 in.	1½ in.	2 in.
Soft brown felt	83·5	86	88·5	89·5
Silk waste over layer of Kieselguhr. .	77·5	80	82	83
Silk waste over air space enclosed in metal casing.	75	78	80	81
Kieselguhr (Fossil meal) with all organic matter burnt out	73	77·5	82	83
Kieselguhr (Fossil meal) and powdered cork	68·5	72	76	78
Fossil meal (ordinary)	68	72	76	78
Cork matting	63	71	82	88
Asbestos millboard with Kieselguhr filling	57	60·5	64	66
Asbestos string wrapped with asbestos fibre	43·5	46·5	50·5	52
Straw rope and clay	35	40	45	47

TABLE XI.—The Quantity of Water that Air is capable of Absorbing to become Saturated.

Deg. Fahr.	Grains per Cubic Foot	Deg. Fahr.	Grains per Cubic Foot.	Deg. Fahr.	Grains per Cubic Foot.	Deg. Fahr.	Grains per Cubic Foot.
10	1	45	3⅝	85	12½	141	58
15	1⅓	50	4¼	90	14⅓	157	85
20	1½	55	5	95	16⅝	170	112½
25	1⅞	60	5⅞	100	19⅛	179	138
30	2⅛	65	6⅞	105	22	188	166
32	2⅓	70	8	110	25½	195	194
35	2½	75	9¼	115	30	212	265
40	3	80	10¾	130	42½		

This table shows the necessity of affording moisture to air which is warmed to comparatively high temperatures. It also shows what a high degree of efficiency hot air has in drying-rooms, provided it is extracted and replaced with new as fast as it becomes saturated.

A convenient means of judging the humidity of the air is by the dry and wet bulb hygrometer, as it is called. This consists of a pair of thermometers, one of which acts in the usual way, this being the dry bulb, while the other has the bulb covered with muslin and kept wet by the muslin extending to a small vessel of water, the water travelling up by capillary attraction and keeping the whole saturated. The water in the muslin on the thermometer bulb is continually evaporating, and the degree of evaporation is according to the dryness of the air. As the water evaporates it has a cooling effect on the bulb, and the temperature recorded by the height of the mercury in the stem differs from that in the dry thermometer accordingly. The greater the difference the more dry the air must be, and in a case of extreme dryness a difference of 20 degrees might possibly be indicated. A healthful and proper degree of humidity is when the thermometers show a difference of 6 or 8 degrees, the wet bulb showing the lowest temperature, of course. A difference of 10 degrees indicates dryness, too dry in fact, though not excessively so, while a difference of 5 degrees shows excess of humidity.

It is now recognized that while air of too great a degree of dryness is objectionable, a greater ill-result is experienced when the air is allowed to get too humid or moist. The ill-effect on comfort and health, once wholly attributed to carbonic acid, human exhalations, etc., is now known to be more attributable to excessive moisture. Ventilation is now devoted largely to getting air-movement and decrease of humidity more than being wholly aimed at removing products of respiration, etc.

TABLE XII.—VITIATION OF AIR.

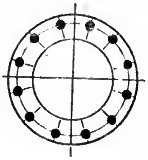
Cause of Vitiation.	Heat given off per hour, B.Th.U.	Carbonic acid given off per hour, cub. ft.
Man at rest	400	·65
Man at active work	500	·75
Woman occupied with duty	400	·65
Child (average)	200	·35
Gas burning (per cubic foot)	500 to 600	·57

TABLE XIII.—British Standard Pipe Flanges.

For Steam Pressures up to 55 lb. and for Water Pressures up to 200 lb. per Square Inch.

(This table does not apply to boiler feed pipes, or to other water pipes subject to exceptional shocks.)

Internal Diameter of Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	Number of Bolts.	Diameter of Bolts.	Thickness of Flanges.		
					Cast-Iron and Steel or Iron Welded-on.	Cast Steel and Bronze.	Stamped or Forged Wrought Iron or Steel.
In.	In.	In.		In.	In.	In.	In.
½	3¾	2⅝	4	½	½	⅜	3/16
¾	4	2⅞	4	½	½	⅜	3/16
1	4½	3¼	4	½	½	⅜	3/16
1¼	4¾	3 7/16	4	½	⅝	½	¼
1½	5¼	3⅞	4	½	⅝	½	¼
*1¾	5½	4⅛	4	½	⅝	½	¼
2	6	4½	4	⅝	¾	9/16	5/16
2½	6½	5	4	⅝	¾	9/16	5/16
3	7¼	5¾	4	⅝	¾	9/16	⅜
3½	8	6½	4	⅝	¾	9/16	⅜
4	8½	7	4	⅝	⅞	11/16	⅜
*4½	9	7½	8	⅝	⅞	11/16	7/16
5	10	8¼	8	⅝	⅞	11/16	½
6	11	9¼	8	⅝	⅞	11/16	½
7	12	10¼	8	⅝	1	¾	½
8	13¼	11½	8	⅝	1	¾	½
9	14½	12¾	8	⅝	1	¾	⅝
10	16	14	8	¾	1	¾	⅝
*11	17	15	8	¾	1⅛	⅞	⅝
12	18	16	12	¾	1⅛	⅞	⅝
*13	19¼	17¼	12	¾	1⅛	⅞	¾
14	20¾	18½	12	⅞	1¼	1	¾
15	21¾	19½	12	⅞	1¼	1	¾
16	22¾	20½	12	⅞	1¼	1	¾
*17	24	21¾	12	⅞	1⅜	1⅛	⅞
18	25¼	23	12	⅞	1⅜	1⅛	⅞
*19	26½	24	12	⅞	1⅜	1⅛	⅞
20	27¾	25¼	16	⅞	1½	1¼	1
21	29	26½	16	⅞	1½	1¼	1
*22	30	27½	16	1	1½	1¼	1
*23	31	28½	16	1	1⅝	1⅜	1⅛
24	32½	29¾	16	1	1⅝	1⅜	1⅛



* The Committee suggests that, for general use, these sizes be dispensed with.

Bolt-holes.—For ½-in. and ⅝-in. bolts the diameters of the holes to be 1/16-in. larger than the diameters of the bolts, and for larger sizes of bolts ⅛-in.. Bolt-holes to be drilled off centre lines, as illustraton.

TABLE XIV.—WEIGHT OF CAST-IRON PIPES PER LINEAL FOOT.

Internal Diameter.	Thickness of Metal.				
	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.
in.	lb.	lb.	lb.	lb.	lb.
1½	4·29	6·90	..	..	..
2	5·53	8·75	..	..	..
2½	6·74	10·58	14·72	..	..
3	7·98	12·43	17·18	..	..
3½	9·20	14·21	19·64	..	..
4	10·44	16·11	22·10	28·38	..
5	12·88	19·78	26·99	34·51	42·33
6	15·34	23·47	31·91	40·65	49·70
7	17·79	27·15	36·82	46·79	56·84
8	20·02	30·83	41·71	52·92	64·42

The weights given are for the pipe itself of the sizes stated. For socketed pipe add half a foot for each socket. For flanged pipe add half a foot for each flange.

TABLE XV.—APPROXIMATE COMPOSITION OF DIFFERENT KINDS OF FUEL.—(*Beeston Foundry Co., Ltd.*)

Kind of Fuel.	Weight of 1 cubic ft. broken.	Volume of 1 ton in cubic feet.	Approximate Composition Per Cent.				Total B.Th.U. from 1 lb.
			Carbon.	Total Hydrogen.	Sulphur.	Ashes and incombustible matter exclusive of water.	
Anthracite best	63	36	95	1·5	·5	3·0	14,700 (average)
„ ordinary			90	3·0	1·5	5·5	
„ poor			85	3·0	2·0	10·0	
Coal best	62	37	84	5·0	2·0	9·0	14,150
„ ordinary			80	5·0	1·0	14·0	12,500
„ poor			75	6·0	1 0	18·0	10,000
Coke best	30	75	97·5	—	0·8	1·7	14,000
„ ordinary			85	—	1·5	13·5	12,500
„ poor			65	—	1·5	33·5	9,000
Petroleum .	54	—	85	14·5	—	0·5	20,900
Peat undried	variable	variable	43	40·8	·2	16·0	7,100
„ dried			60	6·0 (largely water)	·3	33·7 including water)	9,900
Wood dried	variable	variable	50	6·0	—	44 (including water)	7,800
Coal Gas rich	28 to 35 Cub. ft. = 1 lb.	—	by weight 50·2 C	23	—	13	600 to 500 per cubic foot
„ ordinary		—	13·8 CO				

TABLE XVI.—Circumferences and Areas of Circles in Inches.

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
⅛	·3927	·012	8½	26·70	56·74	24½	76·96	471·43
¼	·7854	·049	9	28·27	63·61	25	78·54	490·87
⅜	1·178	·11	9½	29·84	70·88	25½	80·10	510·7
½	1·570	·196	10	31·41	78·54	26	81·68	530·93
⅝	1·963	·306	10½	32·98	86·59	26½	83·25	557·54
¾	2·356	·441	11	34·55	95·03	27	84·82	572·55
⅞	2·748	·601	11½	36·12	103·86	27½	86·39	593·95
1	3·142	·785	12	37·69	113·09	28	87·96	615·75
1⅛	3·534	·994	12½	39·27	122·71	28½	89·53	637·94
1¼	3·927	1·227	13	40·84	132·73	29	91·10	660·52
1⅜	4·319	1·484	13½	42·41	143·13	29½	92·67	683·49
1½	4·712	1·767	14	43·98	153·93	30	94·24	706·86
1⅝	5·105	2·073	14½	45·55	165·13	30½	95·81	730·61
1¾	5·497	2·405	15	47·12	176·71	31	97·38	754·79
1⅞	5·890	2·761	15½	48·69	188·69	31½	99·0	779·31
2	6·283	3·141	16	50·26	201·06	32	100·5	804·25
2¼	7·068	3·976	16½	51·83	213·82	33	103·6	855·3
2½	7·854	4·908	17	53·40	226·98	34	106·8	907·92
2¾	8·639	5·939	17½	54·97	240·52	35	109·9	962·11
3	9·424	7·068	18	56·54	254·57	36	113·0	1017·87
3¼	10·21	8·295	18½	58·11	268·8	37	116·2	1075·21
3½	10·99	9·621	19	59·69	283·52	38	119·3	1134·11
3¾	11·78	11·04	19½	61·26	298·64	39	122·5	1194·59
4	12·56	12·56	20	62·83	314·16	40	125·6	1256·64
4½	14·13	15·9	20½	64·40	330·06	41	128·8	1320·26
5	15·70	19·63	21	65·97	346·36	42	131·9	1385·45
5½	17·27	23·75	21½	67·54	363·05	43	135·0	1452·2
6	18·84	28·27	22	69·11	380·13	44	138·2	1520·53
6½	20·42	33·18	22½	70·68	397·6	45	141·3	1590·43
7	21·99	38·48	23	72·25	415·47	46	144·5	1661·91
7½	23·56	44·17	23½	73·82	433·73	47	147·6	1734·95
8	25·13	50·26	24	75·39	452·39	48	150·7	1809·56

The circumference of a circle is the diameter multiplied by 3·1416.

The diameter of a circle, if it cannot be measured across directly, can be found by dividing the circumference by ·31831.

The area of a circle is found by squaring the diameter and multiplying this by ·7854.

TABLE XVII.—Ventilating Gratings or Registers.

Table giving the average Clear Space through Gratings, i.e. the Area of the Grating minus the Iron Bars or Fretwork.

Size of Grated Area in square inches.	Clear Space in square inches.	Size of Grated Area in square inches.	Clear Space in square inches.	Size of Grated Area in square inches.	Clear Space in square inches.
4 × 6	16	8 × 15	80	12 × 24	192
4 × 8	21	8 × 18	96	14 × 14	130
4 × 10	26	9 × 9	54	14 × 16	149
4 × 13	34	9 × 12	72	14 × 18	168
4 × 15	40	9 × 13	78	14 × 20	186
4 × 18	48	9 × 14	84	14 × 33	205
6 × 6	24	10 × 10	66	15 × 25	250
6 × 8	32	10 × 12	80	16 × 16	170
6 × 9	36	10 × 14	93	16 × 20	213
6 × 10	40	10 × 16	107	16 × 24	256
6 × 14	56	10 × 18	120	18 × 24	288
6 × 16	64	10 × 20	132	20 × 20	267
6 × 18	72	12 × 12	96	20 × 24	320
6 × 24	96	12 × 14	112	20 × 26	347
7 × 7	32	12 × 15	120	24 × 24	384
7 × 10	52	12 × 16	128	24 × 32	512
8 × 8	42	12 × 17	136	27 × 27	486
8 × 10	53	12 × 18	144	30 × 30	600
8 × 12	64	12 × 20	160		

The solid flange, or margin, which all gratings have, is not included in any of the above measurements.

TABLE XVIII.—Equivalent Value of Units in English and Metrical Measurements.

One foot = 12 inches = 30·48 centimetres = 0·3048 metre.
One metre = 100 centimetres = 3·2808 feet = 1·0936 yard.
One mile = 5280 feet = 1760 yards = 1609·3 metres.
One square foot = 144 square inches = ⅑th square yard = 929 square centimetres = 0·0929 square metre.
One square metre = 10,000 square centimetres = 1·1960 square yards = 10·764 square feet.
One cubic foot = 1728 cubic inches = 2832 cubic centimetres = 0·02832 cubic metres.
One cubic metre = 35·314 cubic feet = 1·3079 cubic yard.
One pound = 16 ounces = 453·59 grams = 0·45359 kilogram.
One kilogram = 1000 grams = 2·2046 pounds = 35·27 ounces.
One B.Th.U. = 0·252 Calories.
One Calorie = 3·968 B.Th.U.

For Conversion of Metrical to English Measurement.

Millimetres	×	·03937	=	inches.
,,	÷	25·4	=	,,
Centimetres	×	·3937	=	,,
,,	÷	2·54	=	,,
Metre	=	39·37		inches.
,,	×	3·281	=	feet.
,,	×	1·094	=	yards.
Kilometres	×	·621	=	miles.
,,	÷	1·6093	=	,,
,,	×	3280·7	=	feet.
Square millimetres	×	·0155	=	square inches.
,, ,,	÷	645·1	=	,,
,, centimetres	×	·155	=	,,
,, ,,	÷	6·451	=	,,
,, metres	×	10·764	=	square feet.
,, kilometres	×	247·1	=	acres.
Hectares	×	2·471	=	,,
Cubic centimetres	÷	16·383	=	cubic inches.
[1] Calories	×	3·968	=	British Thermal Units.
,, per sq. metre	×	0·369	=	B.Th.U. per sq. foot.

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[1] For engineering and general industrial requirements the large Calorie is always employed and understood, this being spelt with a capital C. The small calorie, spelt with a small c, is a scientific unit and is only one-thousandth part of a Calorie.

Tables for the Conversion of Thermcmetric Degrees.

$$t^\circ\ \mathrm{C} = 0{\cdot}8\ t^\circ\ \mathrm{R.} = (1{\cdot}8t+32)^\circ\ \mathrm{F.}\ ;\ t^\circ\ \mathrm{F.} = \left(\frac{t-32}{1{\cdot}8}\right)\ {}^\circ\mathrm{C} = \left(\frac{t-32}{2{\cdot}25}\right)^\circ \mathrm{R.}\ ;\ t^\circ\ \mathrm{R.} = 1{\cdot}25.\ t^\circ\ \mathrm{C.} = (2{\cdot}25t+32)^\circ\ \mathrm{F.}$$

TABLE XIX.—Degrees Fahrenheit into Degrees Centigrade.

°F.	Units.									
	0	1	2	3	4	5	6	7	8	9
−3	*−34·44*	*−35·00*	*−35·55*	*−36·11*	*−36·67*	*−37·22*	*−37·78*	*−38·33*	*−38·89*	*−39·44*
−2	*−28·89*	*−29·44*	*−30·00*	*−30·55*	*−31·11*	*−31·67*	*−32·22*	*−32·78*	*−33·33*	*−33·39*
−1	*−23·33*	*−23·89*	*−24·44*	*−25·00*	*−25·55*	*−26·11*	*−26·67*	*−27·22*	*−27·78*	*−28·33*
−0	*−17·78*	*−18·33*	*−18·89*	*−19·44*	*−20·00*	*−20·55*	*−21·11*	*−21·67*	*−22·22*	*−22·78*
+0	*−17·78*	*−17·22*	*−16·67*	*−16·11*	*−15·55*	*−15·00*	*−14·44*	*−13·89*	*−13·33*	*−12·78*
+1	*−12·22*	*−11·67*	*−11·11*	*−10·55*	*−10·00*	*− 9·44*	*− 8·89*	*− 8·33*	*− 7·78*	*− 7·22*
2	*− 6·67*	*− 6·11*	*− 5·55*	*− 5·00*	*− 4·44*	*− 3·89*	*− 3·33*	*− 2·78*	*− 2·22*	*− 1·67*
3	*− 1·11*	*− 0·55*	0·00	+ 0·55	− 1·11	+ 1·67	+ 2·22	+ 2·78	+ 3·33	+ 3·89
4	+ 4·44	+ 5·00	+ 5·55	+ 6·11	+ 6·67	+ 7·22	+ 7·78	+ 8·33	+ 8·89	+ 9·44
5	10·00	10·55	11·11	11·67	12·22	12·78	13·33	13·89	14·44	15·00
6	15·56	16·11	16·67	17·22	17·78	18·33	18·89	19·44	20·00	20·55
7	21·11	21·67	22·22	22·78	23·33	23·89	24·44	25·00	25·55	26·11
8	26·67	27·22	27·78	28·33	28·89	29·44	30·00	30·55	31·11	31·67
9	32·22	32·78	33·33	33·89	34·44	35·00	35·55	36·11	36·67	37·22
10	37·78	38·33	38·89	39·44	40·00	40·55	41·11	41·67	42·22	42·78
11	43·33	43·89	44·44	45·00	45·55	46·11	46·67	47·22	47·78	48·33
12	48·89	49·44	50·00	50·55	51·11	51·67	52·22	52·78	53·33	53·89
13	54·44	55·00	55·55	56·11	56·67	57·22	57·78	58·33	58·89	59·44
14	60·00	60·55	61·11	61·67	62·22	62·78	63·33	63·89	64·44	65·00
15	65·55	66·11	66·67	67·22	67·78	68·33	68·89	69·44	70·00	70·55
16	71·11	71·67	72·22	72·78	73·33	73·89	74·44	75·00	75·55	76·11
17	76·67	77·22	77·78	78·33	78·89	79·44	80·00	80·55	81·11	81·67
18	82·22	82·78	83·33	83·89	84·44	85·00	85·55	86·11	86·67	87·22
19	87·78	88·33	88·89	89·44	90·00	90·55	91·11	91·67	92·22	92·78
20	93·33	93·89	94·44	95·00	95·55	96·11	96·67	97·22	97·78	98·33
21	98·89	99·44	100·00	100·55	101·11	101·67	102·22	102·78	103·33	103·89
22	104·44	105·00	105·55	106·11	106·67	107·22	107·78	108·33	108·89	109·44
23	110·00	110·55	111·11	111·67	112·22	112·78	113·33	113·89	114·44	115·00
24	115·55	116·11	116·67	117·22	117·78	118·33	118·89	119·44	120·00	120·56
25	121·11	121·67	122·22	122·78	123·33	123·89	124·44	125·00	125·55	126·11

TABLE XX.—Degrees Réaumur into Degrees Fahrenheit.

°F.	Units.									
	0	1	2	3	4	5	6	7	8	9
tens										
−3	*−35·50*	*−37·75*	*−40·00*	*−42·25*	*−44·50*	*−46·75*	*−49·00*	*−51·25*	*−53·50*	*−55·75*
−2	*−13·00*	*−15·25*	*−17·50*	*−19·75*	*−22·00*	*−24·25*	*−26·50*	*−28·75*	*−31·00*	*−33·25*
−1	+ 9·50	+ 7·25	+ 5·00	+ 2·75	+ 0·50	*− 1·75*	*− 4·00*	*− 6·25*	*− 8·50*	*−10·75*
−0	+32·00	+29·75	+27·50	+25·25	+23·00	+20·75	+18·50	+16·25	+14·00	+11·75
+0	+32·00	34·25	36·50	38·75	41·00	43·25	45·50	47·75	50·00	52·25
1	54·50	56·75	59·00	61·25	63·50	65·75	68·00	70·25	72·50	74·75
2	77·00	79·25	81·50	83·75	86·00	88·25	90·50	92·75	95·00	97·25
3	99·50	101·75	104·00	106·25	108·50	110·75	113·00	115·25	117·50	119·75
4	122·00	124·25	126·50	128·75	131·00	133·25	135·50	137·75	140·00	142·25
5	144·50	146·75	149·00	151·25	153·50	155·75	158·00	160·25	162·50	164·75
6	167·00	169·25	171·50	173·75	176·00	178·25	180·50	182·75	185·00	187·25
7	189·50	191·75	194·00	196·25	198·50	200·75	203·00	205·25	207·50	209·75

TABLE XXI.—Degrees Centigrade into Degrees Fahrenheit.

C.	Units.									
	0	1	2	3	4	5	6	7	8	9
Tens										
−3	*−22·0*	*−23·8*	*−25·6*	*−27·4*	*−29·2*	*−31·0*	*−32·8*	*−34·6*	*−36·4*	*−38·2*
−2	*− 4·0*	*− 5·8*	*− 7·6*	*− 9·4*	*−11·2*	*−13·0*	*−14·8*	*−16·6*	*−18·4*	*−20·2*
−1	+14·0	+12·2	+10·4	+ 8·6	+ 6·8	+ 5·0	+ 3·2	+ 1·4	*− 0·4*	*− 2·2*
−0	+32·0	+30·2	+28·4	+26·6	+24·8	+23·0	+21·2	+19·4	+17·6	+15·8
+0	+32·0	33·8	35·6	37·4	39·2	41·0	42·8	44·6	46·4	48·2
+1	50·0	51·8	53·6	55·4	57·2	59·0	60·8	62·6	64·4	66·2
2	68·0	69·8	71·6	73·4	75·2	77·0	78·8	80·6	82·4	84·2
3	86·0	87·8	89·6	91·4	93·2	95·0	96·8	98·6	100·4	102·2
4	104·0	105·8	107·6	109·4	111·2	113·0	114·8	116·6	118·4	120·2
5	122·0	123·8	125·6	127·4	129·2	131·0	132·8	134·6	136·4	138·2
6	140·0	141·8	143·6	145·4	147·2	149·0	150·8	152·6	154·4	156·2
7	158·0	159·8	161·6	163·4	165·2	167·0	168·8	170·6	172·4	174·2
8	176·0	177·8	179·6	181·4	183·2	185·0	186·8	188·6	190·4	192·2
9	194·0	195·8	197·6	199·4	201·2	203·0	204·8	206·6	208·4	210·2
10	212·0	213·8	215·6	217·4	219·2	221·0	222·8	224·6	226·4	228·2
11	230·0	231·8	233·6	235·4	237·2	239·0	240·8	242·6	244·4	246·2
12	248·0	249·8	251·6	253·4	255·2	257·0	258·8	260·6	262·4	264·2
13	266·0	267·8	269·6	271·4	273·2	275·0	276·8	278·6	280·4	282·2
14	284·0	285·8	287·6	289·4	291·2	293·0	294·8	296·6	298·4	300·2
15	302·0	303·8	305·6	307·4	309·2	311·0	312·8	314·6	316·4	318·2
16	320·0	321·8	323·6	325·4	327·2	329·0	330·8	332·6	334·4	336·2
17	338·0	339·8	341·6	343·4	345·2	347·0	348·8	350·6	352·4	354·2
18	356·0	357·8	359·6	361·4	363·2	365·0	366·8	368·6	370·4	372·2
19	374·0	375·8	377·6	379·4	381·2	383·0	384·8	386·6	388·4	390·2
20	392·0	393·8	395·6	397·4	399·2	401·0	402·8	404·6	406·4	408·2
21	410·0	411·8	413·6	415·4	417·2	419·0	420·8	422·6	424·4	426·2
22	428·0	429·8	431·6	433·4	435·2	437·0	438·8	440·6	442·4	444·2
23	446·0	447·8	449·6	451·4	453·2	455·0	456·8	458·6	460·4	462·2
24	464·0	465·8	467·6	469·4	471·2	473·0	474·8	476·6	478·4	480·2
25	482·0	483·8	485·6	487·4	489·2	491·0	492·8	494·6	496·4	498·2
26	500·0	501·8	503·6	505·4	507·2	509·0	510·8	512·6	514·4	516·2
27	518·0	519·8	521·6	523·4	525·2	527·0	528·8	530·6	532·4	534·2
28	536·0	537·8	539·6	541·4	543·2	545·0	546·8	548·6	550·4	552·2
29	554·0	555·8	557·6	559·4	561·2	563·0	564·8	566·6	568·4	570·2
30	572·0	573·8	575·6	577·4	579·2	581·0	582·8	584·6	586·4	588·2
31	590·0	591·8	593·6	595·4	597·2	599·0	600·8	602·6	604·4	606·2
32	608·0	609·8	611·6	613·4	615·2	617·0	618·8	620·6	622·4	624·2
33	626·0	627·8	629·6	631·4	633·2	635·0	636·8	638·6	640·4	642·2
34	644·0	645·8	647·6	649·4	651·2	653·0	654·8	656·6	658·4	660·2
35	662·0	663·8	665·6	667·4	669·2	671·0	672·8	674·6	676·4	678·2
36	680·0	681·8	683·6	685·4	687·2	689·0	690·8	692·6	694·4	696·2
37	698·0	699·8	701·6	703·4	705·2	707·0	708·8	710·6	712·4	714·2
38	716·0	717·8	719·6	721·4	723·2	725·0	726·8	728·6	730·4	732·2
39	734·0	735·8	737·6	739·4	741·2	743·0	744·8	746·6	748·4	750·2
40	752·0	753·8	755·6	757·4	759·2	761·0	762·8	764·6	766·4	768·2
41	770·0	771·8	773·6	775·4	777·2	779·0	780·8	782·6	784·4	786·2
42	788·0	789·8	791·6	793·4	795·2	797·0	798·8	800·6	802·4	804·2

°C	500	600	700	800	900	1000	1100	1200	1300	1400
°F.	932	1112	1292	1472	1652	1832	2012	2192	2372	2552

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(P.R. 1410).

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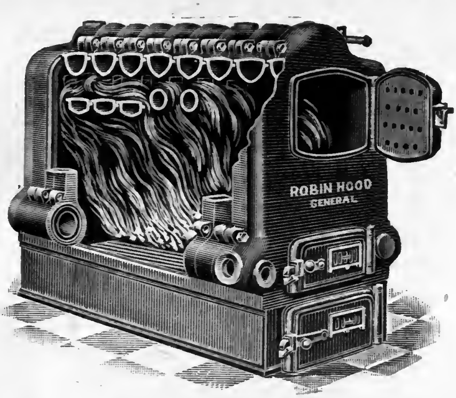

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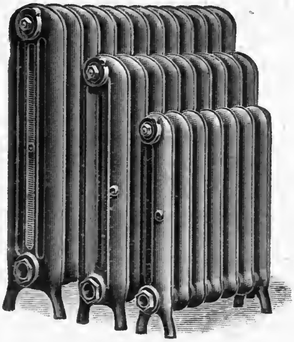

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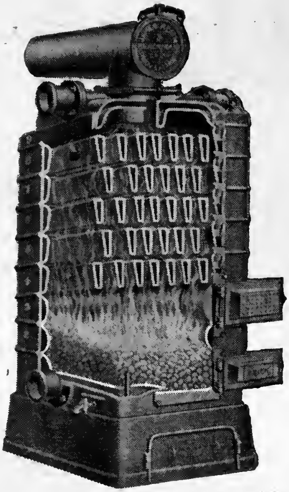

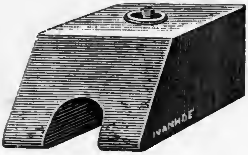
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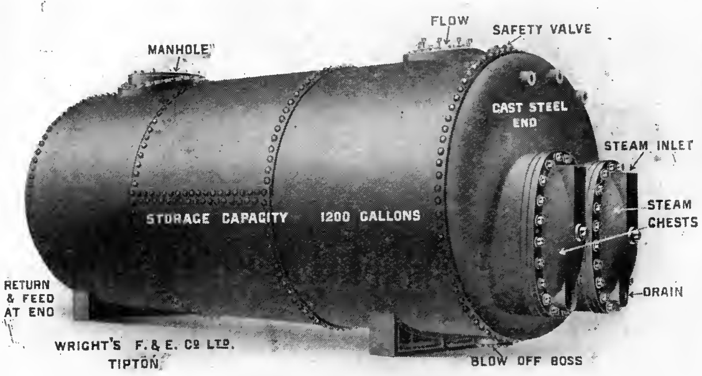

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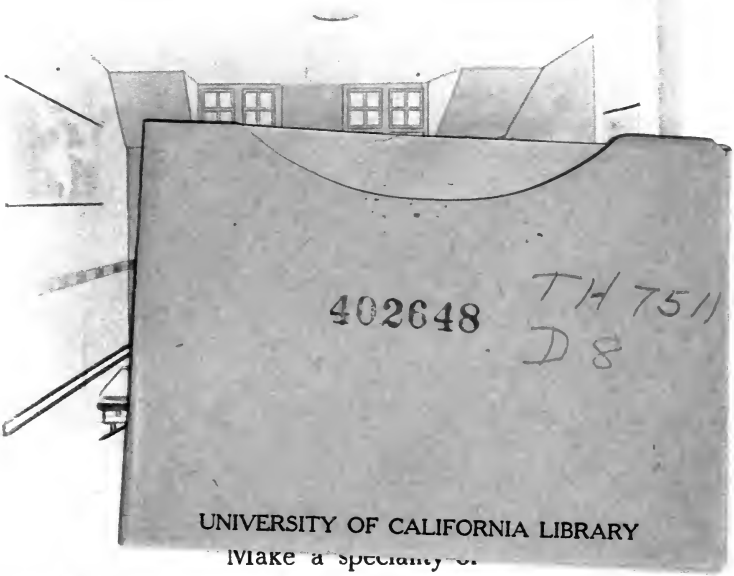

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